McLuhan's Theory and the Metaphorical Construction of the Body in the Life Sciences

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By

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Abstract

The Thesis of the Metaphoric Body

In this work I explore the interrelationships between metaphors, techno-cultural environments and theories in the life sciences. Essentially, the thesis of the *Metaphoric Body* deals with a multi-directional interactive metaphor. Technologies, according to the main theme of this thesis, are prostheses that are modeled on the body, and at the same time they redesign the body perceptually, conceptually, theoretically and physically (see fig. 0.1). Human perception depends on grand-metaphorical frameworks: on the one hand, techno-cultural environments are created by metaphorical thinking; on the other hand, the same techno-cultural environments reshape the metaphorical perception. Science is an integral part of this process, both as an important factor in the development of techno-culture and as a field of knowledge which is influenced by techno-culture.

The Reciprocal Interaction between the Two Domains of the *Body*↔*Machine* Metaphor

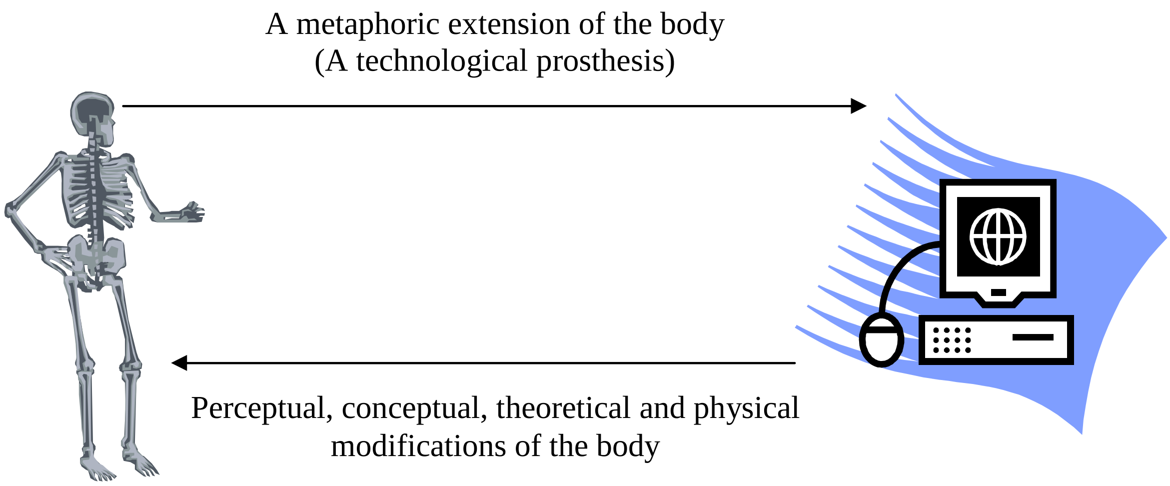

Fig 0.1: A schematic summary of the *metaphoric body* thesis

The thesis of the *Metaphoric Body* is based first and foremost on the ideas of Marshall McLuhan (1911-1980). In his work McLuhan focused on the study of media and technology and their impact on human perception and society. He identified the *Man*-made environment as an *extension* or prosthesis of the body. The extension idea was already discussed in the 19th century by intellectuals such as Ralph Emerson, Henri Bergson and Samuel Butler and by biologists such as Thomas Huxley. Yet McLuhan was the first intellectual who had begun to formulate an inclusive theory which defines the interaction between the two domains, the *body* and the *Man*-made environment, as a bidirectional metaphoric interaction.

The thesis of the *Metaphoric Body* expands and updates the theory of McLuhan and applies the McLuhanite approach to the history of life sciences. One of my goals is to develop a new approach that combines McLuhan's theory of media with new critical approaches to science and techno-culture. Inspired by one of the main themes in McLuhan's work, *the medium is the message*, I will try to identify historical patterns in the life sciences. My work combines sources from the following fields: the life sciences, history of sciences, philosophy, media studies, as well as studies in psychology and cognitive sciences concerning metaphorical thinking.

This work includes a detailed analysis of some of the main paradigms in the history of life sciences and a *low resolution* analysis of historical patterns and trends (1600-1900 A.D.). I will be using a *low resolution* analysis, instead of focusing on a limited period or a certain discipline, in order to identify long-term trends in the life sciences. Basically, I will show that the development of the mechanical environment, the *body↔machine* metaphor and industrial society, had led to the decline of the pre-modern *organic* perception and to the rise of the mechanistic perception in the life sciences. I will argue for the growing strength of the mechanistic approach throughout modern history and demonstrate that even the Vitalists, who seemingly rejected the mechanistic approach, took part in the construction of the mechanistic order in the life sciences. Although this work focuses on the shift from the organic order to the mechanistic order, I will also refer to the rise of the electronic order in the 20th century, which turned the tables on the industrial-mechanistic metaphor and created a new *body↔machine*. These historical changes, as we will see, did not occur through sharp *epistemic breaks* or *incommensurable paradigms*, but through what McLuhan defined as *hybrid energy* and *rear view mirrors*.

One of my main goals is to identify the hidden metaphorical ground of science, or in other words, the fertility and indispensability of metaphors in scientific thought. Contrary to modern objectivist views, I will contend that metaphors cannot be regarded as merely false assertions or verbal ornaments which can be reduced to literal assertions. Metaphorical frameworks produce *relative truths* depending on the experiential basis of the metaphor and on the techno-cultural context. Furthermore, in comparison with abstract modernist views (e.g. positivism or naïve realism), the postmodernist approaches (e.g. the thesis of the *Metaphoric Body*) recognize the significance of metaphors in human thought and they are able to better deal with two major aspects of scientific development: (a) the *extra-scientific* impact of techno-cultural environments on scientific theories and on the assumptions and expectations of scientists (b) the historical dynamics of science, that is, the relative success of contradicting theories in explaining a certain subject and the constant appearance of anomalies and deficiencies which undermine the validity of these theories until they collapse and are replaced by new theories.

Finally, the question arises, what is the techno-cultural environment or the grand-metaphorical framework that shapes my perception? As a disciple of McLuhan, my work is based on the *electronic* perception. In addition, my approach is *postmodernist*. The fundamental McLuhanite metaphors that shape my thesis include, among others, the *visual space*, *acoustic space*, *extensions*, *total field*, *implosion*, *hybrid energy* and *rear view mirrors*. My approach is based on the rejection of the objectivist view as well as on the rejection of a clear dichotomy between the *social* and the *natural*. Science is part of a total field in which social, cultural, scientific and technological factors influence one another. In other words, metaphors shape all forms of human knowledge and therefore we should recognize their importance. Nonetheless, we cannot ignore that metaphorical fertility has its price. The electronic, postmodern world developed from the modern world and thus one can identify the impact of critical modernist approaches on postmodernist approaches. In this respect, the thesis of the *Metaphoric Body* rather than adopting a naïve, uncritical approach to metaphors, recognizes the limitations and epistemic problems arising from the metaphorical thinking, which cannot be defined as *objective* and *literal*.

THE DISSERTATION IS COMPRISED OF TWO PARTS:

- ***Summary of Part I: Metaphors, Technologies and the Human Body***

In the first part of the work I will examine the metaphorical basis of human thought and the alternatives to the objectivist outlook. In addition, I will examine the interrelationship between technologies and metaphors. I will show that the *body*↔*machine* metaphor is an interactive metaphor in which both domains affect one another.

In this part I will discuss the following assertions and issues:

- Human thought is based on a metaphorical perception;
- The relations between the metaphoric domains (target and source domains) are reciprocal, bidirectional and asymmetric;
- Metaphors cannot be reduced to literal meanings;
- Metaphors have an experiential basis;
- Beyond the verbal aspect, metaphors also have corporeal and physical aspects;
- The extension idea, or the technological environment as a metaphoric prosthesis of the body;
- The dynamics of the *metaphorical* and the *literal*;
- McLuhan’s theory of media and metaphors;
- *Hybrid energy* and *rear view mirrors*;
- The mechanical vs. the electronic;
- Implosion: the electronic prosthesis, the cyborg and the physical reconstruction of the body; from analogical to metonymic and synecdochic relations;

- Prostheses and the simulacra of Baudrillard;
- Interspecies implosion;
- DNA and the metaphor of *information* – an example which demonstrates how the electronic-cybernetic environment reshapes the way in which the body is perceived and conceived.

❖ ***Summary of Part II: The Transformation from the Organic Perception of the Body to the Mechanistic Perception***

In the second part of the work I will examine how *the medium becomes the message* in the life sciences, or how techno-cultural environments and grand-metaphorical frameworks in different eras designed the body as a machine. We will follow the shift from the pre-modern world and the *organic order* to the industrial society and the *mechanistic order*. Although the theories of McLuhan and his colleagues are sometimes referred to as *great divide theories*, I interpret McLuhan in a different manner. Accordingly, I will argue that techno-cultural environments, as well as scientific traditions, develop in a hybrid manner. Furthermore, I will reveal the growing strength of the mechanistic approach and demonstrate that even vitalism had become more mechanistic.

Part II deals with different aspects of the mechanistic framework in the history of life sciences: the roots of the *body↔machine* metaphor, the physiology and organization of the *body↔machine*, the development of the industrial-chemical approaches, pathology, cell theory, adaptation, transformism and evolution (due to space constraints a chapter on the history of heredity and embryology was left out of the dissertation). Generally, I will identify and describe the differences between the *organic order,* the *first mechanistic phase* and the *second mechanistic phase*.

Among the prominent representatives of the first mechanistic phase were Rene Descartes, Herman Boerhaave, Albrecht von Haller, Julian Offray de La Mettrie, Lazzaro Spallanzani and Georges Buffon.

Among the prominent representatives of the second mechanistic phase were Hermann Von Helmholtz, Matthias Schleiden, Theodor Schwann, Rudolf Virchow, Charles Darwin and Ernst Haeckel.

In addition, I will show that the vitalistic approaches were closely related to the mechanistic program and contributed to its development. Among the prominent vitalists that appear in this work are John Hunter, Johann Blumenbach, Xavier Bichat, Jean Corvisart, Rene Laennec and Friedrich Tiedemann.

In this part I will discuss the following assertions and issues:

- The *body↔machine* metaphor and the growing strength of the mechanistic approach; from the organic order to the mechanistic order;
- The hybrid development of scientific traditions;
- The *first mechanistic phase* or the early mechanical approach;
- The *second mechanistic phase* or the industrial-chemical program;
- Vitalism as a collection of soft mechanistic views;
- Prominent Vitalists as pioneers of the mechanistic approach;
- The experiential failures of the *body↔machine* metaphor;
- The *design* of the *body↔machine*.

Contents

Part
I

Metaphors, Technologies and the Human Body

The main themes of this part are as follows. First, I will introduce a non-objectivist approach to metaphors, although, it should be noted, that one cannot find a fixed, unequivocal meaning or definition for the concept of *metaphor*. I'm using the phrase "non-objectivist", but I do not mean to side with the arbitrariness of *idealism*. I will, rather, argue that our own ideas about the world are always constructed, tested and modified via the interaction of sense and physical experiences with techno-cultural environments. As we will see, some scholars call it "an experientialist synthesis", while others call it "an interactionist approach". Secondly, I will examine the interactive aspects of metaphors, since the focus of this thesis is on the interaction of the human body with its *extensions* or *prostheses*. Surprisingly, the interactive aspect of metaphors was challenged by non-objectivist scholars who were directly or indirectly influenced by Max Black's interaction view. I will review their arguments, since the principle of reciprocal interaction stands at the core of the *Metaphoric Body* thesis. Thirdly, I will introduce McLuhan's ideas on the relations of metaphors and technologies. McLuhan's theory is not part of the different discourses on metaphors in philosophy, psychology or cognitive sciences (which are presented in chapter 1), but part of the discourse in media studies and it deals with the impact of technologies on human perception, society and culture. His approach will help me to extend the definition of the term *metaphor* from words to artifacts. Moreover, I will claim that both words and artifacts function as extensions/prostheses of the body. Fourthly, I will reexamine the relations of the *literal* and the *metaphorical* and argue that the metaphorical nature of knowledge is not static and fixed, thus metaphoric knowledge can become more *literal* and vice versa. Nonetheless, all literal meanings are relative and they depend on inclusive contexts and grand-metaphorical frameworks. Finally, we will see that the clear distinction between the domains of the *body↔machine* metaphor had disappeared. With the appearance of the cyborg, the analogical relations of the *body* and the *machine* were replaced by metonymic and synecdochic relations. Through the new electronic prostheses the body is being physically redesigned as a machine. Moreover, via the cloning technique the body becomes an imploded prosthesis of itself. As part of the reciprocal interaction between the *body* and the *machine*, one can identify the great impact of techno-cultural environments on the way the body is perceived in the life sciences. Although this work focuses on the development of the *body↔machine* metaphor in the mechanical age and in the industrial society, I will briefly refer to the connections between DNA theory, the electronic-cybernetic world and the metaphor of *information*.

1

Reciprocity, Experience and the Myth of Objectivity

The word *metaphor* consists of the Greek word *pherein* and the Greek prefix *meta*. The meaning of the expression is to carry across or to transport. Aristotle's classic definition identifies metaphors as calling one thing in the name of another:

> Metaphor consists in giving the thing a name that belongs to something else; the transference being either from genus to species, or from species to genus, or from species to species, or on grounds of analogy (Aristotle, *Poetics*, 1985, vol. 2: 1457b).

As Colin Turbayne notes (1970: 11 – 12), this wide definition includes several speech forms:

(1) Synecdoche - particular instead of general and general instead of particular. For example: “bread” instead of “food” or “ship” instead of “anchor” (“There lies my ship”).

(2) Metonymy - giving a thing a name that belongs to one of its attributes or to an adjunct. For example: “the crown” instead of “the king”.

(3) Catachresis - giving a thing a name that belongs to something else from another field, either because of missing “proper” terms in the lexicon or for another reason. For example: “With blade of bronze drew away the life”. According to Aristotle the verb, “to cleave”, describes more accurately the action of blade made of bronze than “to draw away”.

(4) Proportional/analogical relations between at least four dimensions or parts of two different domains. For example: “day” refers to “night” as “young” refers to “old”; thus we can say that “Old age is the evening of life.”

McLuhan considered only the fourth definition of Aristotle as a metaphor (McLuhan and McLuhan 1988: 229 – 238). He saw the other speech forms as variants or transformations of the fourth version. McLuhan also rejected the Aristotelian definition of the copular form (e.g. “He is a lion”), and the simile form (“He is like a lion”), as types of metaphors: he defined them as *connected* forms which are transformations of the metaphoric, discontinuous, resonant form (e.g. “The lion of Athens sprang on the foe”). Nevertheless, I will use the term *metaphor* in a broader sense, including the copular form and the simile form, with an emphasis placed on Aristotle's fourth definition, i.e. on the proportions, analogies and complex relations which are formed between *different* fields of knowledge or *different* domains. Metonymy and synecdoche are closer to the idea of *literal* meaning since the terms which are used in these speech forms belong to the same *domain*. But, as I would later claim, *literal* meanings themselves exist only temporarily and locally: they could be created only as abstractions in the dynamic web of the metaphoric knowledge.

In traditional modern philosophy, metaphor was considered as an incorrect, deceiving speech form. The objectivist program - from Thomas Hobbes and John Lock, through positivism of the 19th and 20th centuries, and to contemporary conservative intellectuals - tries to demonstrate that one should and could get rid of metaphors, especially when it comes to serious subjects, such as philosophy and science.[1] But today many scholars and researchers from humanities and the social sciences challenge this view which was named by Max Black: *a substitution view of metaphor* (Black 1962: 31 – 34). According to this view, there are two reasons for using a metaphor: (1) Metaphor is used when there is a need for filling a blank in a lexicon (Catachresis). The term *orange*, for example, was taken from the name of the fruit, to represent the color, and in our days it represents the color literally, directly and not metaphorically. In other words, it is a *dead metaphor*. (2) Metaphor is used as a verbal ornament in literature. Its aim is to create an intellectual enjoyment for the reader who has to decipher the code, solve the puzzle and find an equivalent literal expression. For example, the sentence “Richard is a lion” could be substituted with a more accurate sentence: “Richard is brave”. In addition, Black notes that there is a similar objectivist view, *a comparison view of metaphor*, which was, probably, derived from Aristotle's definition in the *Poetics*. According to the comparison view, one should and could get rid of metaphors indeed, but it also states that the metaphoric sentence is about Richard as well as about lions. Hence the metaphoric sentence will be translated to the "literal" sentence: "Richard is like a lion in being brave" (Black 1962: 35 – 36).

After a short review of the traditional approaches, Black introduces in his book a new non-objectivist approach (Black 1962: 38 – 47; Black 1998). He calls this view an *interaction view of metaphor*, and he based it on the ideas of I.A. Richards (1936). The new approach determines that it is impossible to reduce the idea behind any metaphor by two separate ideas or by two *purified* literal sentences. It seems that this basic idea characterizes all the new non-objectivist approaches to metaphors, despite all the differences between them. Moreover, the non-objectivist scholars would all accept the following assertion as well: metaphors do not merely represent existing similarities or objective similarities, but, rather, they actively create new meanings, new insights and similarities. Later I will review some evidence on the complex interaction between the two subjects which are fused together via the metaphor (e.g., the blending theory provides a systematic account of this phenomenon), but at this point we can recall the critique of Karl Popper on Hume's psychological explanation of the induction phenomenon and relate it to our discussion: similarity, claims Popper, cannot not be ascribed to objects or phenomena in themselves: since the comparison is between phenomena or objects that are not identical, the similarity depends on consciousness, on expectations and anticipation, on earlier points of view and on the active search of the mind for regularities (Popper 1963: 42 – 46). I find a support for this view in contemporary psychological research. Identifying similarities and differences is not a "hard-wired perceptual process" which is determined in a rigid manner, but it is rather a highly flexible process which is constrained by context and by the dynamic process of the *comparison* itself. For instance, psychological experiments confirm that: (a) similarity changes with context, e.g. the linguistic context, the dynamics of the interaction process etc.; thus when an object is being compared with different objects in different contexts it can be attributed with conflicting properties (b) the basis of similarity may vary across domains and with processing time and expertise (c) the notion of similarity also depends on the age of subjects (Medin et al. 1993; Honeck and Hoffman 1980).

A metaphor, then, is not *merely* giving one thing a name of another, but as George Lakoff and Mark Johnson put it:

The essence of metaphor is understanding and experiencing one kind of thing in terms of another (Lakoff and Johnson 1980: 5).

Before expanding on the interactionist view, I would like to add an exception, resulting from the fact that there is no fixed, unequivocal meaning for the term *metaphor*. For instance, in one of his articles Bipin Indurkhya, a non-objectivist researcher from the cognitive sciences, claims that the meaning of *metaphor*, as well as the meaning of *literal*, is ambiguous (Indurkhya 1994b). Hence Indurkhya recognizes three main usages of the term among his colleagues today: the "Lakoffian" usage, which the citation above loosely exhausted; Earl Mac Cormac's usage; and his own usage.[2] He defines his own version as "symbol in the making", e.g. "The check scandal has become a metaphor for all the problems of Congress" (Indurkhya 1994b: 64 – 65). Indurkhya demonstrates how his definition reflects a common use of the term *metaphor*. The examples he provides seem like cases of synecdoche and metonymy or as exemplars of models, that is, specific things that become symbols for general phenomena. Nonetheless, Indurkhya himself uses the term *metaphor* in the Lakoffian sense (with some objections of course), as appears from an extensive article summarizing his thesis on metaphor and cognition (Indurkhya 1994a). Even in the first article he admits that Lakoff's "interpretation of *metaphor* makes a lot of sense" (Indurkhya 1994b: 63). We can relate to the other two types of metaphor, synecdoche and metonymy (or Indurkhya's *symbol*), as derived forms of the analogical form of metaphor. Compared to the analogy form, synecdoche, metonymy and exemplars of a model are closer to the *literal*, and it could be argued that literal meanings themselves are not the given start point but a contingent result of a metaphoric process (see the discussion at the end of chapter 2).

Clearly there are great differences between the non-objectivists themselves, but in this article Indurkhya (1994b) do not emphasize their common ground, which could be traced to the interaction view (see Indurkhya's review - 1992: 65 – 91). Again, regardless of all differences, the basic idea underlying all the modified versions of Black's interaction view is this: it is impossible to reduce the idea behind any metaphor by two separate ideas, i.e., by two *purified* literal sentences. Moreover, all of the non-objectivist views are based on the assumption that our knowledge, concepts and theories about the *external* world are constructed metaphorically as a result of interplay between physical experiences, perceptions, mental creativity and cultural experiences. Our knowledge about the world, then, does not simply or neutrally reflect the *objective* structure of the world.

To understand the interaction theory, let us take, for example, a classic metaphor, *Man is a Wolf* (Black 1962: 39 – 41). This metaphor has two subjects: the *principal* subject- Man, and the *subsidiary* subject- Wolf. The subsidiary subject allows us to understand the principal subject in a new way. We experience the principal subject through the filtering "lenses" of the subsidiary subject. The subsidiary subject emphasizes some details, suppresses others, and organizes our view on the principal subject. The process of metaphorical understanding depends on the mapping of some relations in the subsidiary subject onto some relations in the principal subject. A new meaning of Man is formed by this interaction, and therefore one cannot separate these two subjects without distorting the meaning of the *original* sentence (the metaphor). When Man becomes Wolf he actually acquire traits associated with wolves, in other words, he becomes a vicious, fierce, hungry carnivore, which is engaged in a constant struggle. The interaction is reciprocal and Wolf, the subsidiary subject, becomes more humanlike through the *filtration* process.

Following Black, I would like to emphasize that the *Man is a Wolf* metaphor humanizes wolves and project our social world onto the life of wolves. This metaphor should be interpreted in the context of anthropomorphism and animal personification. In other words, we cannot simply project the Wolf on the Man without projecting the Man on the Wolf, and as the history of culture and the history of science show we constantly project ourselves on the animal world. Finally, any attempt to replace this metaphor with a specific list of *literal* descriptions of traits would fail to convey the meaning of the "animal-like" Man and all the myths and traditions associated with him (the word "wolf'", for example, evokes certain fears in different cultures): the *literal* replacement would be different in respect to the aspects that are emphasized and its mental and emotional content would be different as well. By melting together the principal and the subsidiary subjects, the popular myth of the *wolf-men* manifests the potential power of metaphoric interactivity. The psychological studies of Robert Verbrugge can shed light on this phenomenon of *condensation*. According to Verbrugge, the domains of the metaphor could appear in a single imaginary event and as a result transformations occur within the domains. This phenomenon was documented while participants were asked to describe their experiences in response to metaphorical statements. For instance, while thinking about a skyscraper as a giraffe and vice versa, people reported they imagine a building which "became very skinny and developed spots", or a giraffe with a building shape body running in the jungle (Verbrugge 1980: 110 – 120). This metaphoric interaction and fusion is clearly manifested by the *implosion* of Humans and Machines, as described in the following chapters.

❖ ***The Problem of Reciprocal Interaction***

Indurkhya, Lakoff and many others reject an important aspect of Black's interaction theory, namely the reciprocity of the two subjects. In the last decades many psychologists argued that only the principal subject of the metaphor is modified. Since reciprocal interaction is specifically important to the main themes of the *Metaphoric Body* thesis, I would like to address this issue. Basically, I will claim that Indurkhya, Lakoff and other researchers jump from the phenomenon of asymmetry in metaphors to an invalid conclusion concerning the absence of reciprocity in metaphors. In other words, they confuse symmetry with reciprocity. Additionally, I will use Indurkhya's own observations to find the reciprocity which was denied by him and by Lakoff and Turner. Then I will argue that to deny the reciprocal interaction of the metaphorical domains is to admit, implicitly, an objectivist view of metaphors, which Indurkhya, Lakoff and Turner explicitly reject. I will elaborate my specific objections in relation to their own examples. Generally, all the cases provided by Indurkhya, Lakoff and Turner are cases of asymmetry and not cases which prove the absence of reciprocity (a reciprocal influence is evident even in asymmetric interactions). In order to support my critique on Indurkhya, Lakoff and Turner I will review more evidence on metaphors, similarity, asymmetry and interaction. In this context, I will show that: (a) discerning *principal* from *subsidiary*, or *target* from *source*, is always relative or context depended, and therefore, in principle, modifying the source domain through the target domain does make sense (b) the condensation and transformation phenomena blend the source and the target (c) the reciprocal interaction of target and source domains are expressed by "subsidiary transfers", "value transfers" and "reverse transfers" (d) the reciprocal interaction of target and source domains is accounted by the blending theory. Turner is one of the originators of blending theory and therefore he changed his mind on the subject. A last remark before we begin. The following terms are basic equivalent terms used by the relevant literature: (1) principal subject / target domain / topic / tenor; (2) subsidiary subject / source domain / vehicle.

Let us begin with Indurkhya. If Black claims that as Man Becomes a Wolf, so Wolf becomes a Man, Indurkhya claims that the interaction doesn't have to be "symmetric" at all. But since Indurkhya means that the interaction doesn't have to affect the subsidiary subject at all, it would be more suitable to use the term "reciprocal" and not the term Indurkhya uses - "symmetric" (implying "the same effect" on both sides).

To explain his position, Indurkhya (1992: 70 – 72; 1994a: 105) provides an example which was taken from an article written by Black (Black 1998: 31 – 32). According to the example, the Star of David can be described in different ways: as a set of two triangles, as a hexagon with triangles or as a set of three parallelograms. Now, according to Indurkhya, in this interaction only the Star of David is described in a new way and reorganized. The interaction does not affect the figures of the subsidiary domain. At this point several questions arise. In the metaphorical process, as defined by Indurkhya himself (1994b), doesn't the Star of David become an exemplar of a model? When the Star of David is described as a set of two triangles it becomes an exemplar of triangles; when it is described as a hexagon with triangles the Star of David becomes an exemplar of hexagons (and triangles); and when the Star of David is described as a set of three parallelograms it becomes an exemplar of parallelograms. According to Indurkhya himself, metaphors cannot be reduced to separate subjects (the principal and the subsidiary), and therefore one may ask: doesn't the metaphorical interaction affect the understanding of the subsidiary subject? Doesn’t the way people think of the Star of David as a set of triangles affect the way they think about triangles? In other words, due to the metaphoric interaction triangles have new context, new meanings, new connotations and new associations, which are related to the cultural history of the Star of David. If people are getting used to think of the Star of David as a set of three parallelograms, wouldn't they, eventually, make it an exemplar of parallelograms? An example of this phenomenon is the DNA theory. For several decades the DNA is perceived as a computer or as a computer program. Eventually the DNA has become an exemplar of a computer program and even a practical model of molecular computers. In short, Indurkhya's own observations (whether we accept his definition of metaphors or not), helped us to locate the lost interaction.[3]

Indurkhya is not the only non-objectivist scholar who rejects the reciprocal aspect of metaphorical interactions. A similar point was raised by Lakoff and Turner. Lakoff, Turner and their colleges use the concept *target* domain as equivalent to Black's principal subject, and the concept *source* domain as equivalent to Black's subsidiary subject. Clearly the terms “target” and “source” are biased in favor of Lakoff and Turner's view. Like in Black's schema, the source domain *re-maps* and reorganizes the target domain (a systematic cross domain mapping). However Lakoff and Turner reject what they define as the “bidirectional” aspect of the interaction theory (Lakoff and Turner 1989: 131 – 133).

Lakoff and Turner's first example deals with the “life is a journey” metaphor. In this metaphor the target domain of life is restructured according to the source domain of a journey. Lakoff and Turner claim that the domain of journey is left untouched while it re–maps the domain of life. After all, we do not speak of journeys in terms of life. We do not say: “He was born” instead of saying “He started his trip”. Despite its metaphoric intelligibility, no one uses this phrase. Why? Probably because it sounds exaggerated, or as Lakoff and Turner put it: we can have only one life, but we can have many journeys. There is another important reason for this phenomenon: in these cases the target domain is unclear and ambiguous and the metaphor uses the less complicated and more obvious domain (i.e. the source domain) to explain the second domain (i.e. the target domain). Nevertheless, I would like to claim that these asymmetrical relationships do not prove that the metaphor has no effect, whatsoever, on the source domain. Lakoff and Turner's observations (like Indurkhya's observations) are not completely false: discerning the target domain from the source domain does make sense, because the effect on the target domain (the one which is explained and re-described) does not have to be identical to the effect on the source domain. In a similar way, Richards and Black distinguished the principal subject from the subsidiary subject. Thus even the interaction view does not maintain that the metaphoric interaction should be symmetric. Yet, we cannot claim that based on this observation the interaction leaves the journey domain untouched. The problem with Lakoff and Turner's account is their insistence on saying that the metaphoric interaction is not “bidirectional” and circular at all. There is a great difference between the claim that the interaction is not symmetric, namely having an identical effect on both sides, and the claim that the interaction is not bidirectional and reciprocal. Lakoff and Turner did not pay attention to difference between the two. They focused on the conceptual aspects of metaphors and did not relate to an important perceptual aspect: when the source domain *re-maps* the target domain, the two domains become similar and analogical to one another, and in certain respects they are fused together, and thus the interaction affects the source domain as well.

Therefore the same kind of arguments I’ve just used against Indurkhya could be used against Lakoff and Turner as well. First, we can use Indurkhya's account of metaphors. In this view, journeys become a symbol (exemplar/model) of the “course” of life and of life struggles. If a domain is made a symbol of another, then cognitively and associatively it changes. Hence “life” becomes part of “journeys” context. This line of argument takes us back to the semantic dispute over the definition of the term *metaphor* (Indurkhya 1994b), but as I’ve noted before, whether we accept Indurkhya's definition of the term, or not, it still helps us to locate the reciprocal interaction. Secondly, if the source domain is partially and momentarily made by the metaphor (as long as the metaphor exist) cognitively inseparable from the target domain (and this is the non–objectivist assumption regarding metaphors), then, perceptually speaking, the source domain has to be modified as well. Otherwise, we go back to the objectivist view, according to which, a metaphor is just a passive matching of inherent similarities and therefore it could be reduced to the literal meanings of its separate components. On the other hand, as I have already argued, creating similarities cannot be a one sided act. As non-objectivists, Lakoff and Turner themselves believe that similarities are actively created and they reject the objectivist assertion that the metaphor matches inherent similarities. Indeed, this kind of argument could be used against Black's “common places” as well, but this is another issue (Lakoff and Turner 1989: 132; Black 1962: 38 – 47).

In order to clarify the course of argument which appears in the paragraph above, I will use simple linear formulas, although I believe that the metaphoric process is much more complicated. The letter A indicates the source domain or the subsidiary subject; the letter B indicates the target domain or the principal subject; the letter B' indicates the change in B after the metaphoric interaction occurred. First, let us ignore the question of interaction. Under the non-objectivist view, the basic formula of the metaphoric process is of the following kind: $A \cap B \rightarrow A \cap B'$ (if A and B then B'). B' must include A as a gestalt or at least elements of A that express some characterizing relations of A (I support this claim below using empirical evidence, i.e., using the condensation and transformation phenomena and the blending theory, but for now let us accept this claim which is implied by the non-objectivist view). Otherwise we practically accept the objectivist view in regard to metaphors. Yet Lakoff and Turner are committed to the following non-objectivist assertion: some of the relations in B' are new; they were not inherently well defined in B before the interaction occurred; they were not merely and passively exposed; rather they were actively created by the interaction between the domains (A and B) in a certain context, and they cannot be reduced to separate sets of claims in each domain. Can this interaction be unidirectional? Elements of A, or A as a gestalt, have to be included in B' as long as the metaphor exist. Therefore, under the non objectivist view, A must interact with B, or elements from A must interact with elements from B, in order to change B and create B'. If elements from A, or A as a gestalt, becomes an integral part of B', then they transform A into A', since these elements, or A as a gestalt, are now part of B' ($A \cap B \rightarrow A' \cap B'$). Or else, we are assuming that the new aspects discovered in the B domain pre-exist in B objectively, and thus they are reducible to B in itself and independent of the metaphoric interaction. Therefore A could be detached from B; A remains A; and even B does not become B' ($A \cap B \rightarrow A \cap B$). Yet this is the objectivist view which Lakoff, Turner and Indurkhya reject.

- In the metaphoric process both domains are modified. The source domain, or the subsidiary subject, is perceptually modified at least in its context, connotations and associations.

Through the filtering process new connections are made, features are emphasized, suppressed and most importantly generated. In order to understand the abstract notion of *life* we attach it and materialize it in an imaginary event. Within this event a journey is taking place. Hence in the metaphor "life is a journey" the source domain of the journey is modified in its context, connotations and web of associations, just because the journey domain is partially fused with the domain of life. My point is that journey becomes a cliché symbol of life through the examples that Lakoff and Turner analyzed and through similar metaphors. The following example is taken from the pop song, *All Good Things (Come To An End)*, by Nelly Furtado:

Traveling I always stop at exits
Wondering if I'll stay
Young and restless

These lines demonstrate how journey (the source domain) is integrated into a scenario which is also part of life domain. Moreover, people actually take a journey in order "to find themselves in life". In this dynamic web of associations, journey is also mapped on other domains, such as the domain of love. As Lakoff points out, the domain of journey also serves as a source domain for experiencing, understanding and reasoning in the domain of love. The grand-metaphor of "love is a journey" fits into various situations, from "We're at crossroads" to a song that portrays love as an exciting and dangerous event: "We're driving in the fast lane on the freeway of love" (Lakoff 1998: 206 – 210). Notice how in these metaphoric expressions the domain of journey is partially fused with the domain of love. Now the domain of love has its own dynamic web of association and connotations. A flame, for example, is a symbol of life and of the soul, and it is also a symbol of love: "the flame of love", "the fire of love" etc. The symbol (i.e. the source domain of the metaphor) is used in the purpose of understanding and experiencing love, and so it is associated with other elements in the context of love: other romantic elements, the feelings associated with love, the mood of love etc. Hence the context of the *flame* symbol (the source domain), its associations and connotations, are modified due to its interaction with the target domain of love. Love and flame are jointly present and condensed in single imaginary events or in concrete movie scenes (e.g. romantic candlelight dinners). The expressions of this metaphor create condensed imaginary events, from *The Living Flame of Love* by Saint John of the Cross (1542-1591):

O living flame of love
that tenderly wounds my soul
(John of the Cross 1987 [circa 1584]: 293);

- To the simile in the pop song, *All Good Things (Come To An End)*, by Nelly Furtado:

Flames to dust
Lovers to friends
Why do all good things come to an end

Let us examine other cultural products of our age: (1) *eMule* (an electronic mule), a file sharing application for people who wants to share music, videos and other files via the internet; (2) the *Mule*, an all terrain vehicle. Both were popular among teenagers in the last few years. In these two metaphors the *eMule* application and the *Mule* vehicle serve as the target domain or the principal subject, while mule, the beast of burden, serves as the source domain or the subsidiary subject (in order to understand the metaphor, of course, you need to know what the meaning of the word *mule* in English is). Now think about teenagers spending hours to download and upload files on *eMule* or driving a *Mule* vehicle. Let us assume that by accident they see a mule, or listen to a talk about mules on television, on the internet, in their farm or on a visit to the countryside. The point is that the source domain will be modified at least in its context, connotations and associations via the metaphoric interaction with the principal subject. When these teenagers see the mule, or listen to a talk about the mule, they will recall *eMule* and they may visualize the logo of *eMule*. In the second example they will recall their beloved vehicle. Thus elements from the source domain of the beast and elements from the target domain of *eMule* or the *Mule* vehicle will be fused together in single imaginary events.

Changes of context and connotations, and changes in the web of association of the source domain, may also bring to a “transfer of values” back from the target to the source (the concept of “transfer of values” will be discussed later in this section). Consider a vulgar example from pop culture, Rabelais' style, which strongly demonstrates my point. The chorus of the song *Roses* by the hip-hop duo, *OutKast*, is about a girl (a “bitch”) named Caroline:

I know you'd like to thank your shit don't stank
But lean a little bit closer
See that roses really smell like boo-boo
Yeah, roses really smell like boo-boo

In our age roses are usually associated with good smell, love, friendship, purity etc. Roses in the metaphor of *OutKast* are the subsidiary subject or the source domain. The principal subject or the target domain is Caroline and her behavior. She is so *fed up* with herself that she perceives her own feces, which symbolize of course her attitude and behavior, as “roses”. Nonetheless, just as Caroline's association elevates the target so it modifies and degrades the source. The sellers of roses, I believe, would not be pleased by the reverse potential influence of this metaphor on the source domain of roses. Moreover, different types of modifications could be induced in the source domain when it is used in a metaphor. One type of modification, for example, could be induced in the source domain by a false assumption or by an action in an undesired or unaccepted direction. To explain my point I will use an incident related to another song by *OutKast*. Photographers used to shake photos in order to help the photos dry quickly. In their number one hit, *Hey Ya*, *OutKast* asks the “ladies” to “shake it like a Polaroid Picture”. In response, the Polaroid Company has informed the media and the public that in our days it is not necessary to shake the pictures and in fact it could actually damage the pictures. The company in the source domain was afraid that the metaphor of *OutKast* will bring about a modified action in the source domain. In other words, the reciprocal interaction of metaphors is easily exposed when someone is concerned with the negative influences of the interaction on the source domain. In the above mentioned incident there was also a positive reverse influence on the source domain: the company was pleased about the public relations.[4]

The argument I have developed in the last paragraphs, which was based on the partial fusion of metaphoric domains or elements from the metaphoric domains, is not just an abstract philosophical argument, and it is supported by: (a) the *condensation* phenomenon (b) the *blending* theory which Turner was one of its originators. First, the condensation phenomenon which I've mentioned earlier is very much relevant to this discussion. The study of Verbrugge demonstrates that the domains of the metaphor could appear in a single imaginary event which generates transformations. When the participants thought about skyscrapers as giraffes or vice versa, they visualized a building that "became very skinny and developed spots", a giraffe with a building shape body running in the jungle etc. In the study of Verbrugge the majority of responses to metaphoric statements (59.7%) were condensed responses (Verbrugge 1980: 119).

To illustrate the phenomena of condensation and transformation let us examine a pictorial example. Figure 1.1 shows an image which appeared in a comedy bit of *Late Night with Conan O'Brien*. This comedy bit, "New State Quarters", is aimed at ridiculing the states of the US. In this image the subject is the state of Oklahoma. However, the motivation to ridicule Oklahoma was crossed with the motivation to ridicule Sanjaya Malakar, a famous contestant in *American Idol*, known by his haircuts and bad singing. In this case it is impossible to discern the source domain from the target domain (unlike in most cases, but it is still as a good example of condensation and transformation). Both subjects serve equally, more or less, as source and target. The figure shows a condensed image of Sanjaya's haircut in the shape of Oklahoma. Actually Oklahoma is transformed into Sanjaya's haircut. Sanjaya and Oklahoma transform each other and they are fused together. Oklahoma is ridiculed by becoming the hair of Sanjaya, and Sanjaya is ridiculed because his hair was transformed into the state of Oklahoma.

Condensation and Transformation

Fig 1.1: The shape of Sanjaya's haircut as the state of Oklahoma. The context or the aim of this sketch was to ridicule both the contestant Sanjaya from *American Idol* and the state of Oklahoma. Notice that the metaphoric image is already condensed and it transforms the two subjects, i.e. the two domains are fused in a single imaginary event. Taken from: *Late Night with Conan O'Brien*, NBC, 26-4-07.

I think that there is a strong connection between the phenomena of condensation and transformation and the new blending theory (Fauconnier and Turner 2002; Coulson 2001; Coulson and Matlock 2001; Grady et al. 1999; Fauconnier and Turner 1998). Both theories, in my opinion, describe the metaphoric process as a surreal, dreamlike process. Blending theory emphasizes the fusion of elements from different domains within metaphorical situations. In the following explanation the metaphors - "This surgeon is a butcher" and "The ship of state" - are used as examples:

In a metaphorical blend, prominent counterparts from the input spaces [the source and the target] project to a single element in the blended space - they are 'fused'. A single element in the blend corresponds to an element in each of the input spaces. A ship in the blend is linked to a ship in the source space and a nation in the target, a surgeon is linked to both a surgeon and a butcher, and so forth (Grady et al. 1999: 114).

According to this view, the projections in the conceptual integration networks (an array of interrelated mental spaces wherein information from different domains is blended) are not necessarily unidirectional, as Turner himself admits:

The salient feature of such networks is the construction of a blended space which develops specific emergent structure and dynamics while remaining linked to the overall network. Projections in a network can occur in different ways and in different directions… Theories of metaphor and analogy have typically focused on the case where projection is one-way (from a "source" to "target") and they have overlooked the construction of blended spaces (Fauconnier and Turner 1998: 183).

I would like to return to the examples of Lakoff and Turner against reciprocity. One of their examples deals with the two sides of the "man–machine" metaphor: "machines are people", e.g. the computer "punishes" you; and "people are machines", e.g. the "human engine". Lakoff and Turner claim (1989: 132) that these are two different metaphors "because" (a) "the mappings go in opposite directions" (well, Lakoff and Johnson are begging the issue, if their goal is to prove that metaphors are not bidirectional); (b) "different things get mapped": in the first case will and desire are attributed to machines, and in the second case organs are mapped as mechanical parts. Indeed, in these two cases "different things get mapped", but it has nothing to do with the question of reciprocal interaction. Different things get mapped because the two metaphoric phrases deal with specific aspects of the man–machine interaction. According to Lakoff' himself, mapping one domain by another is always partial, and practically not all relations of the source domain are projected onto the target domain, even though in the future the metaphor could be extended to some other aspects (Lakoff 1998: 210). Still in each of these two cases the reciprocal aspect of metaphors is evident. When machines are attributed with will and desires they become a model for experiencing and understanding humane will and desire (even in science or especially in science). Thus the source domain is modified as a result of its interaction with the target domain. As for the second example of Lakoff and Turner, the historical roots of the "human engine" metaphor do not support their argument. Helmholtz and his colleagues, who developed this metaphor during the 19th century, argued that engines and respiratory systems are not only similar but equivalent (see chapter 6).

However, I have already agreed with Lakoff, Turner and Indurkhya that symmetry is not an essential component of metaphors, and it actually does not exist in most metaphors. In conclusion, what Lakoff and Turner did for the sake of their argument was to abstract particular cases of the grand-metaphor of the *body↔machine* from their cultural and historical context. As described in the following chapters, the grand technological metaphor has a long history of interaction and reciprocity. Moreover, in this section I will show that even specific cases of metaphors which were taken out of their cultural and historical context cannot be regarded as unidirectional, since reciprocity and feedback are needed for the understanding of any metaphor.

These examples of the grand-metaphor of the *body↔machine* bring us closer to the main issue of this work: the complex inter-relationships between technologies and the human body. The domains of *humans* and *technology* do not only serve as source and target for each other, but they are totally dependent on one another: technologies are designed as functional prostheses/extensions of the human body. I'm not arguing that this is an objective, non-metaphorical observation: as a representative of the non-objectivist approach, I recognize that my theory depends on metaphors, but, as I will demonstrate below, metaphors are not arbitrary and they depend on experience. Now, if the domain of technology is intentionally designed as a metaphorical prosthesis of the human domain, then we cannot relate to the idea that "people are machines" and the idea that "machines are people", as two separate, unidirectional, non-reciprocal metaphors. As McLuhan explained, whenever humans designed a technology, the same technology redesigned them. In conclusion, Lakoff and Turner did not choose a good example for their argument. In the age of cybernetics, cyborgs and feedback, the technological prostheses were practically integrated into the human body and the categorical distinctions between the two domains were erased.

- Asymmetrical relationships between metaphoric domains do not entail unidirectional relationships.

Let us review the relevant studies in psychology that deals with similarity and asymmetry in analogies and metaphors. This literature, I assume, was the source, or one of the sources, for the assertions of Lakoff, Turner and Indurkhya. Part of this literature refers to the principal subject or the target domain as the *topic* and to the subsidiary subject or the source domain as the *vehicle*. However I will continue to use the terms: principal subject/target and subsidiary subject/source. An influential work on the asymmetrical aspects of similarity is summarized in an article of Amos Tversky (1977). Tversky's model is based on stable representations of pre-existing features, and therefore it could be classified as a traditional comparison model (Verbrugge 1980: 101). Concerning the question of symmetry in metaphors Black's interaction view is recognized by this literature as supporting the position of asymmetry, because it is based upon the distinct roles played by the principal and the subsidiary subjects. In other words, the relations are asymmetric because the focus is on the principal subject (Verbrugge 1980: 100 – 104; Connor and Kogan 1980: 287). According to the metaphor of Black, we perceive and experience the principal subject through the "lenses" of the subsidiary subject and at the same time the filter itself (the subsidiary subject) is transformed via an asymmetric process. Verbrugge explains:

> The process is interactive, because the filter alters the identity of the topic, and the topic, in turn, influences the nature of the filter. For example, if we say *Highways in a rainstorm are snakes* or *Alpine highways are snakes*, the kind of snakelike properties that define the filter vary with the topic. We experience the identity of the snakes as more slippery, more sinuous, etc., depending on the context. The interaction is not symmetric, however, since the vehicle is usually the dominant transformer of identities (Verbrugge 1980: 102).

There are other aspects of asymmetry in analogies and metaphors. For instance, phrase "surgeons are like butchers" criticizes surgeons, while the phrase "butchers are like surgeons" elevates butchers (Medin et al. 1993: 259). Quantitative research of similarity and dissimilarity also show the presence of asymmetry in analogies. For instance, the similarity of North Korea to Red China is rated by subjects to be more than the similarity of Red China to North Korea (Tversky 1977; Tversky and Gati 1978). According to Tversky and Itamar Gati this kind of asymmetry is related to a general aspect of similarity:

> We tend to select the more salient stimulus, or the prototype, as a referent and the less salient stimulus, or the variant, as a subject. Thus we say "the portrait resembles the person" rather than "the person

resembles the portrait". We say "the son resembles the father" rather than "the father resembles the son"… (Tversky and Gati 1978: 84).

Since the number 100 is accepted as the prototype, people prefer to say "103 is virtually 100" rather than "100 is virtually 103". These cases are not exactly cases of metaphors, because the subjects are considered to be particular cases that belong to same domain. North Korea and Red China are countries; the father and the son both belong to the category of family; 100 and 103 are both numbers etc. Not surprisingly, then, the asymmetry in these cases is relatively small and the reciprocal interaction is evident. In these studies groups of subjects are been asked to rate pairs of words on a scale that measures the degree of similarity: the values range from 1 (not similar at all) to 20 (highly similar). One half of the group is asked to rate the similarity of X to Y. The other half is asked to rate the similarity of Y to X. In the study of Tversky and Gati only countries were compared (Tversky and Gati 1978: 86 – 87). Medin et al. compared countries and other pairs, such as cows and dogs (Medin et al. 1993: 265 – 266). The average difference in the rating of the pairs was 0.42 points in the study of Tversky and Gati and 0.96 points in the study of Medin et al. For instance, in the study of Medin et al. England was similar to the US by 12.84 points, while the US was similar to England by 11.40 points. Tversky and Gati (1993: 87 – 88) have performed a similar experiment in which the focus was on perceptual stimuli: instead of words they used pairs of figures. In this experiment the average difference in the rating of the pairs was 0.56 points. The asymmetrical aspect of similarity also depends on the way things are presented to the participants in the specific context: "Assess the degree to which a and b are similar to each other" is an instruction which is not biased towards one of the two subjects compared to "Assess the degree to which a is similar to b" which is biased towards the subject- "a" (Tversky and Gati 1978: 85). Additionally, Medin et al. point out that there are experimental manipulations "aimed at asymmetries", e.g. asking the participants to focus on the "base" term, i.e. on the subsidiary subject, before the comparison process begins (Medin et al. 1993: 266). To sum up, when Tversky and Gati claims that a toy train is more similar to a real train than vise versa because many of the features of the real train are not included in the toy train (Tversky and Gati 1978: 85), the emphasis is on the word "more" which indicates a reciprocal, asymmetric interaction. Otherwise, if X is not perceived as similar to its model, we could not have identified the model as a "model" of X.

Nonetheless, as I've already pointed out, these are unproblematic and obvious examples, since the compared subjects are considered to be cases that belong to the same domain.

The following studies focused on the issue of reciprocal interaction in metaphors. First, Robert Malgady and Michael Johnson have extended Tversky's study on asymmetry. They used pairs of words which were taken from literary metaphors: *neck -tower, living-fever, rain-tears* etc. As expected, according to Tversky's model, the more salient noun in each pair tends to become the subsidiary subject. Additionally, a preference was found towards the low in salience → high in salience presentation order. This order was preferred nearly 70% of the time (Malgady and Johnson 1980: 249 – 252). The study of Malgady and Johnson and many other studies demonstrate that the majority of the responses classify one side of a metaphor as the principal, while other responses classify the second subject as the principal and the remaining responses show no clear preference. Also, the direction and the degree of subjects' reactions are case dependent and person dependent. Therefore one cannot find a subject that can serve only as the principal subject (the target domain) in relation to another subject that can serve only as the subsidiary subject (the source domain).

An extensive research on the issue of metaphors and asymmetry was conducted by Kathleen Connor and Nathan Kogan (1980). Connor and Kogan have examined perceptual and conceptual aspects of metaphorical thinking using pictures and words. 126 Subjects were asked to watch pair of slides containing either pictures (e.g. an ancient tree vs. a grandfather) or phrases (e.g. messy hair vs. a mound of spaghetti). They were then asked to write metaphors or similes and it was recommended to them to write the sentences in the following (simile) form: "___ is like ___ because…" Additionally, participants were asked "not to be unduly influenced" by the left-right presentation of the pair. They were asked to think about both possible directions and to choose the preferred direction. The experimenter explained to them that a change in the direction of a comparison can be followed with a change in its meaning. Again, like in the previous study, asymmetry was found: 50% of the stimulus pairs have proven to be significantly asymmetric (19 pairs out of 40). In some cases no preference was found. A further analysis was performed on "significantly asymmetrical items". Connor and Kogan have analyzed the results of these significant pairs in order to find if the preferred direction of the metaphor is preserved even when the preferred topic (the principal subject) is presented on the right as the second term, and not on the left. The preferred topics preserved their status in only 9 of the 19 significant pairs. Thus even in “significantly asymmetrical items” the preference of “principal” and “subsidiary”, “source” and “target”, is neither clear nor absolute. As Connor and Kogan themselves point out, the context of the metaphor influences the decision of making one subject the principal and the second subject subsidiary (1980: 291, 298 – 300).

In the study of Verbrugge people were asked to write down a description of their thoughts and of the images that came into their mind after reading metaphoric sentences and similes (Verbrugge 1980: 108 – 120). Verbrugge, among many others, defines the metaphoric form as: “A is B”, e.g. “skyscrapers are giraffes”. Alternatively the simile form is defined as: “A is like B”, e.g. “skyscrapers are like giraffes”. According to Verbrugge’s study, 59.7% of the responses were condensed responses, namely responses which combined elements from both domains in a single imaginary event. Most of them were transformational responses (57.6%), which manifested partial fusion of the two domains, but some responses were defined as “metonymic” or “synecdochic”, since none of the subjects were transformed into the other subject. The other 40.3% were uncondensed responses and they were also divided into transformational and un-transformational responses. Additionally, condensed and uncondensed responses were also classified as asymmetric (the focus was on one of the two domains) and symmetric (the focus was on both domains). So, as in the studies I reviewed above, a majority of participants preferred to define one of the subjects as the principal subject, a large minority preferred to define the second subject as the principal subject, while others had no clear preference at all. 49% of all responses, including the responses to similes, exhibited transformational condensation. Another 22% percent exhibited transformation without condensation.

In the beginning of this chapter I’ve pointed out that the definition of the concept of metaphor is not clear at all. In addition, I’ve noted that metaphors are not static entities. McLuhan, for example, would not have agreed that the copular form (“A is B”) is the basic form of a metaphor. This form, he would say, is a transformation and abstraction of the metaphorical perception. Therefore a metaphorical phrase like, “The lion of Athens sprang on the foe" is transformed into a kind of a linear equation, like, "He is a lion". Suppose that instead of linear, abstract and general phrases, such as "skyscrapers are giraffes", Verbrugge would have used concrete metaphorical phrases in a certain context. For example, in the following case a person enters into the tower of Pisa, or the Empire state building, and goes up to its top. Now the subjects in the experiment have to comment on the following metaphorical statement: "I have entered the giraffe and went up to its head". This kind of metaphorical expressions is much more biased towards condensation. Let us take another example which was analyzed by Jerry Hobbs. In this example a democratic congressman complains about the veto policy of President Gerald Ford: "We insist on serving up these veto pitches that come over the plate the size of a pumpkin" (Hobbs 1990: 64 – 70). Congressmen in this example are described as baseball pitchers, the president as the batter and the bill as a ball. I assume that in the last two examples, which represent concrete metaphors given in a certain context, the percentage of condensed responses would be much higher, although one cannot ignore the copular form because people do use it in concrete situations. Additionally, Verbrugge notes that although condensed responses should include responses which do not contain explicit evidence of condensation, i.e. fusion of concrete elements of both domains, he nevertheless classified ambiguous cases as uncondensed. Finally, we should remember that the descriptions of participants cannot communicate all their experiences (Verbrugge 1980: 110, 112, 114).

Verbrugge showed that in most cases people respond to metaphors asymmetrically and they tend to focus on one subject, but, as I quoted him before, he would agree that in all cases the metaphoric interaction affects both subjects/domains. Some aspects of metaphoric asymmetry are related to the structural features of the sentence. The metaphoric form is more likely to produce asymmetries and condensed transformation than the simile form, while the simile form is more likely to produce metonymic condensation as giraffes walking around the city streets. According to Verbrugge, the roles of the two subjects in the simile form are more equivalent. Generally, when given the sentence "A is B" more people would tend to use A, the "first domain", as the principal subject, less people would use B as the principal subject and the other responses would tend to be symmetric (both A and B are in focus). Hence there are preferences which are not related to the order of words in the metaphoric sentence. In some pairs there is a clear conventional preference: schools are more likely to become the principal subject in the *school-prisons* pair, and highways are more likely to become the principal subject in the *highways-snakes* pair. Again, as I quoted Verbrugge before, the preference towards the transformation of highways does not mean the snakes' domain is left untouched by the interaction.

I have used the above mentioned psychological experiments in order to show that even experiments which are aimed at proving the asymmetric nature of metaphors are not suggesting that the two metaphorical domains have fixed roles, i.e. that one of them can serve only as the “target domain” while the other can serve only as the “source domain”. The experiment of Verbrugge, however, showed us something more: the condensation and transformation phenomena that partially fuse the two domains, and thus change both of them. Now I would like to discuss an article written by Charles Forceville (1995). Before discussing some interesting comments Forceville has made about these experiments, I begin with his interpretation of Black. Forceville's article is ambivalent and confusing, since he explicitly rejects the reciprocity of metaphors, but at the same time he identifies mechanisms of metaphoric reciprocity. At the end of his article he admits, to some extent, the reciprocal nature of metaphors. His article begins by accepting the view of Black while denying the conventional interpretation of Black. According to the conventional interpretation, Black argued that the interaction between the metaphorical domains is reciprocal. How could Forceville justify this assertion when Black explicitly wrote the reverse? Well, according to Forceville, “this is merely a slip of the pen” (Forceville 1995: 679). Unfortunately this “slip of the pen” did not occur to Black once or twice: Forceville himself provides three citations on this subject, two of them were taken from Black's Book (1962) and the third was taken from an article Black wrote more than a decade after (1998 [1979]). Surprisingly, Black never bothered to correct himself over the years. In any case, according to Forceville, while interpreting Black we should ignore the following statements written by Black: “…the two subjects 'interact' in the following ways… (c) [the interaction] reciprocally induces parallel changes in the secondary subject”, or “if to call a man a wolf is to put him in a special light, we must not forget that the metaphor makes the wolf seem more human than he otherwise would”. Instead of ignoring these statements, it would be simpler for Forceville, I think, to accept Black's view in general (as he does), and to reject his explicit believe in metaphoric reciprocity. Moreover, Forceville himself does not fully reject the bidirectional interaction of principal and subsidiary subjects, as explained below. In fact, he identifies an important process of reciprocity which appears in metaphoric comprehension.

If Black did not endorse the bidirectional view, as Forceville claims, then what did he mean in the statements cited above? According to Forceville, Black explained how the subsidiary subject reorganizes the principal subject, by emphasizing and suppressing its details and qualities. In this process the metaphor makes us ignore qualities which are ascribed to the wolf domain and are not adaptable to the *wolf-man* metaphor, while emphasizing other qualities and creating new ones. Forceville concludes: “It is in this sense that the wolf seems 'more human than he otherwise would” (Forceville 1995: 682). But this is exactly the reciprocal interaction that we were looking for. Verbruggue, whose interpretation I’ve quoted before, defines the reciprocal interaction in a similar way: the filter (i.e. the source domain of the snake) is modified by a specific asymmetric interaction with the target domain (i.e. different kinds of highways). Forceville seems to commit the same mistake Lakoff, Turner and Indurkhya have made: once they have identified the source and target domains, they defined the metaphor as unidirectional. In other words, Forceville identifies reciprocity and bidirectional influence with symmetrical influence.[5] Nevertheless, towards the end of the article he admits the existence of “subsidiary transfers” from target to source. Before I elaborate on this important process, let us see Forceville’s observations on some of the articles I reviewed above.

The main problem Forceville (1995) has found in the experiments of Malgady and Johnson (1980), Verbrugge (1980), Connor and Kogan (1980) - is that they ignore context levels beyond the isolated sentence. Forceville cites the authors of the articles who acknowledge this flaw. According to his argument, in most cases source and target could be discerned once the context is clear. Since normally metaphors appear in a context beyond the sentence, it can usually help us to identify the source and the target of the situation. In fact, claims Forceville, the context of the metaphoric sentence, imposes the focus of the metaphor more than all the mechanisms suggested by the above mentioned authors. Thus, in principle, both subjects can serve as source and target; it all depends on the situation and on the intensions of the speakers (see also Coulson and Matlock (2001) on the importance of context in generating and understanding the meanings of metaphors). Now, as a follower of Black, Forceville accepts Verbrugge's phenomena of condensation and transformation, but he does so because he thinks that when he can identify the “source” and the “target” he is disconfirming the reciprocity of the metaphoric interaction. Yet, actually, he only confirms the asymmetrical relationships between the metaphoric domains. Thus we can return to the arguments I have used against Lakoff, Turner and Indurkhya who, like Forceville, hold a non-objectivist view while rejecting the aspect of reciprocity. For example, it is not possible to locate the impact of the interaction in one domain because elements from both domains are fused together through the interaction.

I want to show how Forceville himself contributes to the position that reciprocal interactions occur and the source domain is modified even in a narrow context of a specific situation and even when the relationships between source and target are clear (Forceville 1995: 698 – 706). Forceville opens the discussion on *exceptional* cases with an analysis of two movie scenes. In one scene a dancing of a couple is portrayed as a sensual event and with erotic overtones. In the second continuous scene (the continuity of the scene is reinforced by the continuity of the music) the gestures of the couple, their movement and the entire context suggest that the act of lovemaking is like dancing. Forceville concludes that in the first scene dancing is the principal subject and lovemaking is the subsidiary subject, while in the second scene lovemaking is the principal subject and dancing is the subsidiary subject. Notice that Forceville used the second scene in order to decide that the subsidiary subject in the first scene was lovemaking. In addition, the scenes, as Forceville himself suggested, are not really separated. So I think it shows how much Forceville is willing to extend the context in order not to find the effects of reciprocity: even in a case of explicit reciprocity he tends to choose a narrow context as he can.

In the following example, Forceville examines a poem of William Blake. In the poem Mercy, Pity, Peace and Love are perceived as God and vice versa. In this case Forceville extends the context as much as he can in order to identify the source and the target, but he finds none since Blake, as Forceville observes, wanted both subjects to be principal and subsidiary. I will not elaborate on this case, but in a sense it resembles the example of Sanjaya I provided in fig. 1.1. Although Forceville gives this complicated, highbrow example from classic literature as an *exception*, these types of metaphors are not unusual and they demonstrate the shortcomings of the conceptual metaphor theory of Lakoff which is accepted by many scholars. In these cases the division of metaphor to source and target entirely collapse by a more symmetric interaction. Let me give another example from popular culture (for other "symmetric" examples see the discussion below on blending theory). *Faithless*' famous dance hit *God is a D.J.* is not only about the *formal* principal subject of the metaphor -"God", church and spiritualism, but it is more about the *formal* subsidiary subject - music and the club scene ("This is my Church, This is where I heal my hurts... between voice and drum... Respect, Love, Compassion... For tonight God is a D.J."). The dance club as a church is being elevated to the level of spiritual experiences and ceremonies. "God" and church are also modified and take the new shape of the D.J and the dance club. When God and church are identified with the club scene, the "value" transfers (as mentioned above and as discussed below) work in both directions.

Forceville can narrow the context of his analysis as much as he wants (the *love-dance* metaphor), still reciprocal interactions cannot be avoided, and Forceville finds "subsidiary transfers" from target to source in a type of advertisements which are very common and in a specific demonstration. He entitles the advertisement: "BMW Motorbike is Girlfriend" and the demonstration: "Pit Bulls are Jews". The BMW motorbike advertisement is addressed to men and the motorbike in the advertisement is compared to a date. The second case deals with a demonstration which was organized against new state regulations in Holland against pit bulls terriers. The decision was that all pit bull terriers should wear muzzles, should be kept on a leash, and were to be both officially registered and sterilized, and therefore they will gradually die out. In the demonstration some of the dogs owners made the dogs wear the yellow badge, i.e. the Jewish yellow star. At first sight these two cases are not problematic because we can identify the principal and subsidiary subjects or the target and source domains. In the first case the motorbike is the principal subject/the target domain, since the advertisement was designed to sell motorbikes. In the case of the demonstration, pit bulls are the principal subject/the target domain since the demonstration was about them. Unsurprisingly people resented the identification of the fate of the pit bulls with the persecution of Jews, and as we know many feminists resent advertisements which "objectify women" as the motorbike advertisement does. But if the source domain is not modified by the interaction, then why should people resent the usage of some subjects as source domains for other subjects? The danger, as Forceville observed, is exactly the modification of the source domain: the Holocaust and the persecution of Jews are *in danger* of being *diminished* by using them as a source domain for pit bulls, and in the motorbike case women are *in danger* of being *objectified*.[6] Therefore Forceville calls these transfers "subsidiary transfers", as opposed to the "dominant transfers" from source to target. In the final page of his article Forceville (1995: 706) asks: how standard subsidiary transfers are? My answer is: always, although the subsidiary transfers that Forceville describes become more evident in provocative incidents, such as the roses metaphor of *OutKast*, which I analyzed before. In other cases we are not as concerned with the process of subsidiary transfers as in provocative cases.

Following the work of Chaim Perelman and Lucie Olbrechts-Tyteca in the late 1960s, Seana Coulson discusses the issue of value transfers from target to source (Coulson 2001: 191 – 196). Coulson gives as an example an incident from the trial of the Hollywood madam, Heidi Fleiss, who was charged with tax evasion. A former convicted madam, Sydney Biddle Barrows, was asked to give a commentary on the trial. As a joke, and in order to legitimate her role as an "expert", she compared herself to a retired general giving an expert commentary during the Gulf War. A subsidiary outcome of this gag was the insulting of the generals in the source domain. Since the cultural framing of prostitution is negative, while the cultural framing of military command is considered to be more positive, the analogy humiliates the generals.

Before expanding our discussion on some other mechanisms of reciprocity and influences from target to source, I want to analyze the results of an article written by Sam Glucksman, Matthew McGlone and Deanna Manfredi. These researchers argue that, in general, most metaphors are not only asymmetrical, but "nonreversible" as well: unlike literal comparisons, metaphors often involve pairs of subjects in which one subject makes sense only as the source of the other subject, while the other subject only makes sense as the target of the first subject (Glucksman et al. 1997). In their experiment on the "nonreversibility" of metaphors forty students from Princeton were asked to rate statements on a scale from zero to seven. Zero meant that the "statement made no sense at all" and seven meant that the "statement made perfect sense". The participants valued metaphoric statements, metaphoric comparisons (similes), and literal similarity statements (e.g. "His PhD is like an M.D."). For Each statement the authors have produced a reversed copy by replacing the "original order" of the subjects (e.g. "My marriage was an icebox" was reversed to "My icebox was a marriage" and to "An icebox was my marriage"). Each participant received only one version of each combination for evaluation. Although the authors have chosen highly asymmetric metaphors in order to prove the irreversibility of metaphors, the quantitative results only confirmed that most metaphors are asymmetric, just as we saw in the experiments I've reviewed earlier. The "original order" of metaphors was rated 5.7 points in average, while the reversed order was rated 3.1 points in average. Similarly, the original order of metaphoric comparisons (similes) was rated 5.5 points in average, while the reversed order was rated 3.4 points in average. The original order of literal comparisons was rated 4.2 points in average, while the reversed was rated 4.9 points in average. Not surprisingly, then, the authors open the "result and discussion" section by pointing out that the results "may seriously underestimate the degree of nonreversibility of metaphors…" (Glucksman et al. 1997: 55).

However, Glucksman and his colleagues have also designed a qualitative analysis. In order to indicate what the statements communicate to the participant, each participant was asked to write down a paraphrase for the statements he rated between one and seven. Two judges were asked to analyze and classify the paraphrases according to the following rules. Paraphrases of the revered statements were classified as "acceptable" if they were jugged as "equivalent in meaning to the original-order statement" and if they were "within the 95% confidence interval of the original-order rating". "Unacceptable" reversal statements were defined as those which were rated zero, those which were rated as significantly less meaningful than the original order, those which were paraphrased as re-reversals (i.e. statements in the reversed order which were paraphrased back to the original order by the participants) and those which were paraphrased on a new ground (i.e. reversals which have produced a change in the meaning of the metaphor). Now the authors could conclude that, according to their interpretation, less than 4% of the metaphoric statements in the experiment were "acceptable" when reversed. I have several objections in regard to this experiment and to the interpretations given by the authors. First, it is not clear at all why “less meaningful” statements, and statements which produce different kinds of modifications in the opposite directions, are defined as “unacceptable” instead of “asymmetrical”. I will try to explain my point. The authors define irreversible metaphors as metaphors that change their meaning when reversed or become “meaningless” when reversed (pp. 52 – 54). They provide two examples for their double layer definition. The meaning of the metaphor “My surgeon is like a butcher” changes its meaning when reversed into: “My butcher is like a surgeon”. Yet Glucksman and his colleagues do not notice the value transfer from target to source which occurs if one uses the first order or the reversed order: as surgery elevates butchery so butchery diminishes surgery. Moreover, non-identical modifications do not imply the irreversibility of metaphors, but rather expresses the asymmetric relations within the metaphor.

The stronger claim of Glucksman and his colleagues is that the reversed order of many metaphors is “meaningless” and “uninterpretable”. Their prime example: “Alcohol is like a crutch” becomes meaningless when reversed into “A crutch is like alcohol”. But is it really “meaningless”? Meanings depend on contexts. The study of Glucksman and his colleagues, like the studies Forceville criticized, does not provide an extended context to the metaphoric statements beyond the statements themselves. However, metaphors outside the experiment room are encountered in a certain context of interpretation and this context defines the roles of source and target and their reciprocal interaction. “A crutch is like alcohol” makes perfect sense, for example, when a handicap replies to an alcoholic who laughs at his need for the crutch or when someone becomes *addicted* to a crutch he no longer needs. The absence of context is behind the shortcomings of (a) the experiment (b) the authors' interpretations to the results of the experiment. Since contexts were not given to the participants, they chose to interpret the metaphors in their conventional meanings. The re-reversal of metaphoric statements appeared not because one of the subjects made sense only as a source in relation to the other subject which made sense only as a target in relation to the first, but because when participants had to find a context for the interpretation they turned to some basic, relevant metaphors of their culture. Since no other context was given, the most familiar order could have served as a default for interpretation. “My marriage was an icebox”, for example, is based on a conventional, universal, cross-cultural metaphor: “Affection is Warmth” (e.g. “We have a *warm* relationship”). The students who have participated in this experiment were surely familiar with the “Affection is warmth” metaphor. If asked to paraphrase the statement, and when no other context is given, many people would just re-reverse “My icebox was a marriage” according to the familiar “Affection is Warmth” schema.[7] The result would be: “My marriage was an icebox”. Now give the participants a proper context and they will “make sense” even with the reversed order of a highly asymmetrical metaphor, such as the icebox-marriage metaphor or the crutch-alcohol metaphor. Just as I’ve demonstrated that the crutch-alcohol metaphor makes sense, one can demonstrate that the icebox-marriage metaphor makes sense. Let us examine the following context. A man, who is about to get a divorce, is talking with his friend about the divorce. At some point he goes to the refrigerator and lowers the temperature in the freezer in order to cool several beer cans. Afterwards he turns to his friend and tells him: “now this icebox is like my marriage”. The icebox in this statement is the target domain. Furthermore, the reciprocity in this situation is obvious because this statement is about the man's marriage and not just about his icebox: the icebox is cold like his marriage and his marriage is cold like the icebox. If the metaphor is not very convincing, it is not only due to an abstract asymmetry between the domains, but mainly due to the cultural contexts.

Moreover, the arguments I've used against Lakoff, Turner and Indurkhya could be applied here as well, since Glucksman and his colleagues claim that the meaning of metaphors is the result of the interaction between source elements and target elements. At this point they even rely on Black and claim that “topics and vehicles play interactive roles in metaphor comprehension” (Glucksman et al. 1997: 52). Therefore all the above mentioned arguments and evidence, and other arguments which are specified below, could be used against their claim that metaphors are unidirectional and irreversible. In conclusion, Glucksman and his colleagues mistakenly confine subjects to the fixed roles of “source” and “target” in any given situation, and they also ignore all the mechanisms of reverse transfers from target to source.

In order to expand our discussion on the reciprocal influences of target and source, I want to review (a) the work of John Barnden and his colleagues and (b) the Blending theory. According to John Barnden, Sheila Glasbey, Mark Lee and Alan Wallington (Barnden et al. 2004), a whole range of “reverse influences” is generally being ignored by the relevant literature in psychology. Barnden and his colleagues work in the field of cognitive sciences and artificial intelligence. Their study deals with the feedback between “source” (subsidiary) and “target” (principal) in metaphors. They demonstrate that reverse influences from target to source are needed in order to comprehend and generate metaphors. The inter-domain influences include reverse transfer of quarries, focus and expectations, reverse transfer of propositions and reverse influences on the certainty levels of propositions. Proposition transfers and focus transfers are aspects of metaphors which we have already discussed (e.g. *Hey Ya* of *OutKast*), but metaphors also include non-declarative types of expressions, such as questions and commands. “A man is a wolf”, for example, could be rephrased in a form of a question: “Is man a wolf?” In addition, besides the creation of new propositions from a scratch, certainty adjustments could be transferred between the domains. Metaphors can confirm or weaken the degree of certainty a person has in relation to a certain proposition. “Surgeons are butchers”, for example, can help strengthen the opinion of a person who believes that surgeons treat their patients callously. In the same way uncertainty could also be generated by metaphors. Now, according to Barnden and his colleagues, these processes do not occur only in one direction from source to target, since they are also needed in the opposite direction, from target to source. Metaphoric comprehension and the generation of metaphors rely on reciprocal interaction. The transference of queries from target to source in metaphorical processing is related to the context of the metaphor and to the prior knowledge of the person about the situation. Barnden et al. provide a simple example:

Most of my colleagues get dispirited when they're criticized, but John is a tank (Barnden et al. 2004: 9).

First the person can use a prior knowledge on a common conceptual metaphor-”Argument as war”. He also needs to identify the tank as a military object and not as a water tank etc. But how could the person find and map the relevant qualities of a military tank in a combat situation onto John? Following the first part of the statement, a query in the target domain arises: “Is John able to tolerate criticism well?” Now, in order to understand the metaphor in the given context the subject has to translate a query in terms of the target domain to a query in terms of the source domain: “Is John [now viewed as a tank] able to withstand military attack well?” To comprehend the metaphor is to be able to pose this reverse transferred query. Or consider another example which Barnden and his colleagues analyze. In the following passage Nick Hornby uses the metaphor of “ideas as living beings”:

> I tried not to run down Phil too much - I felt bad enough as it was, what with screwing his girlfriend and all. But it became unavoidable, because when Jackie expressed doubts about him, “*I had to nurture those doubts as if they were tiny, sickly kittens, until eventually they became sturdy, healthy grievances, with their own cat-flaps which allowed them to wonder in and out of our conversation at will.*” (in Barnden et al. 2004: 15).

Now, how are we to understand the metaphor of “sturdy, healthy grievances”? First we have to extend the scenario concerning the “tiny, sickly kittens”, but nothing in the source domain says anything about these kittens becoming healthy grown cats. This information is a reverse proposition from target to source. The kittens became grown cats which are identified as grievances.[8]

- Human knowledge is largely metaphorical, and thus theories that explain the *metaphorical* aspects of human knowledge are metaphorical themselves.

For example, the division of a metaphor into “source domain” and “target domain”, by the conceptual metaphor theory (CMT was originated in: Lakoff and Johnson 1980), is conventional and metaphorical and it suffers from anomalies and disadvantages. We have already seen that these categories are biased towards a unidirectional view of metaphoric relationships. Metaphoric relationships could be perceived by alternative views. The blending theory (BT) provides such an alternative, although it shares many aspects with the conceptual theory of metaphors (Fauconnier and Turner 2002; Coulson 2001; Coulson and Matlock 2001; Grady et al. 1999; Fauconnier and Turner 1998). The blending theory follows the basic assertion of the conceptual theory, according to which metaphors involve a systematic, constrained mapping of ideas, language, relations and inferential structure between conceptual domains. Yet some important differences clearly distinguish between the two theories:

> CMT posits relationships between pairs of mental representations, while blending theory (BT) allows for more than two; CMT has defined metaphor as a strictly directional phenomenon, while BT has not; and, whereas CMT analyses are typically concerned with entrenched conceptual relationships (and the ways in which thy may be elaborated), BT research often focuses on novel conceptualizations which may be short-lived (Grady et al. 1999: 101).

As Joseph Grady, Todd Oakley and Seana Coulson explain, the domains of conceptual theory are more stable and they are characterized by systematic relationships, while in blending theory the basic unit of cognitive organization is the mental space which is "a partial and temporary representational structure which speakers construct when thinking or talking about a perceived, imagined, past, present, or future situation" (Grady et al. 1999: 102). Spaces and domains are related but not equivalent: spaces represent particular scenarios of given domains. Instead of two domains, i.e. the source and target domains, blending theory defines a network of four different mental spaces. The first two spaces, the *input* spaces, are related to the source and the target domains, although there could be more than two input spaces. The third space is the *generic* space which includes the shared concepts of both input domains. The fourth space is the *blend* space which fuses information, structures and scenarios from the two input spaces. In other words, the blend space allows the input spaces to interact.

The analysis of concrete examples demonstrates the advantages of blending theory over the conceptual theory. Let us take, for instance, the metaphor "This surgeon is a butcher" (Grady et al. 1999: 103 – 107). We can define butchery as the source domain and surgery as the target domain, and then we can describe how butchery is mapped onto surgery (butcher is mapped onto surgeon, animal onto patient etc). However, if the metaphor was designed to diminish the value of the surgeon, and to portray him as incompetent practitioner, then we cannot account the incompetence of the surgeon by projecting this quality from source to target, because butchers may be less prestigious than surgeon, but they are not considered to be incompetent at the art of butchery and cutting. Blending theory deals with this issue more efficiently than conceptual theory.

The generic space represents the shared structure of both input spaces (the space which is related to the domain of butchery and the space which is related to the domain of surgery): in this space there is a person who performs a procedure on another being using a sharp instrument. The blend space receives elements and structures from both input spaces. From the source input space it receives the butcher and his job related activities. From the target input space it receives the identity of the patient (the speaker), the identity of the surgeon, and elements which are related to the operating room. The new properties created by the metaphoric interaction appear in the blend space. Now, the blend space receives from the two input spaces incompatible information regarding (a) the means of butchery which were designed to cut animal flesh, i.e. food (b) the aim of surgery which is to heal the body of the patient. The person who performs the operation in the blend space uses the incongruous tools of butchery in order to heal the patient. Hence the means of butchery are blended with the goal and context of surgery, although the butcher with his tools is incompetent to perform the surgical procedure.[9] Coulson analyzes similar examples, such as the “Digging your own grave” metaphor, in which the act of digging cannot be mapped directly from the source domain of digging onto the target domain of being responsible for your own troubles (Coulson 2001: 168 – 172). Another interesting metaphor she analyzes deal with a guy who was “born on third base”. This metaphor blends frameworks and elements from the baseball domain with frameworks and elements from the domain of success (pp. 172 – 178).

The limitations of the conceptual theory of metaphor are revealed in cases, such as the *Sanjaya-Oklahoma* caricature, Blake's metaphor, the *dance-love* metaphor and the *DJ-God* metaphor. In these cases the “source” and the “target” of the metaphor cannot be discerned. Many of theses cases are related to social criticism and especially to jokes and satire, for example the joke of “The Menendez brothers virus”. As Coulson demonstrates, the rhetorical aim of this joke is to project inferences back to the source domain (Coulson 2001: 179 – 185). The virus in the joke eliminates files, takes their disk space, and then it claims that it was physically and sexually abused by the erased files. The source domain in this case is the trial of the Menendez brothers and the target is the domain of computer viruses, but at the same time the aim of this joke is to ridicule the legal and public defense chosen by the young men (the source), who had been charged with killing their parents. In their defense the brothers claimed that they killed their parents because the parents had abused them. On the other hand, the prosecution and many Americans believed that the Menendez brothers had killed their parents for the millions of dollars they inherited and started spending after the death of their parents. In the virus joke the absurd claim of the virus, which was anthropomorphized and acquired humanlike characteristics, is transferred back to the source domain in order to generate a similar response towards the brothers.

In conclusion, reciprocal interaction in metaphors and reverse transfers from target to source are evident on the following, partially overlapping levels:

1. As I explained in the beginning of this section, when metaphoric interactions take place the source domain is modified, at least on three basic levels: context, associations and connotations. Additionally, asymmetric relationships are not equivalent to the absence of reciprocity.
2. A non-objectivist view of metaphors cannot be reconciled with a unidirectional view of metaphors. This philosophical argument is empirically supported by the condensation and transformation phenomena and by the blending theory.
3. As Black and Verbrugge explained, the “filter”, i.e. the source domain, is modified due to the characteristics of the interaction between the source and target domains.
4. Metaphoric interactions involve transfer of values from source to target and from target to source. The transfer of values from target to source is easily exposed when someone is concerned with negative influences or undesirable effects of the interaction (e.g., the *OutKast-Polaroid* incident, the song *Roses* of *OutKast*, the *Pit Bulls-Jews* demonstration, the *BMW Motorbike-Girlfriend* advertisement and the *surgeon-butcher* metaphor).
5. There are many metaphorical cases which could be defined as more “symmetric”. In these cases the division of metaphor to source and target entirely collapses (e.g. the *Sanjaya-Oklahoma* caricature, *The Menendez brothers virus*, Blake's metaphor of God, Faithless' metaphor of God and the *body↔machine* grand-metaphor).
6. As Barnden and his colleagues demonstrate, feedback transfers are needed in the process of metaphoric comprehension.

7. Finally, I have also reviewed the criticism of blending theory on the shortcomings of conceptual metaphor theory.

Although I think I've clarified the advantages of the reciprocal interaction approach over the unidirectional approach of the conceptual metaphor theory, there is another aspect which may clarify the fundamental difference between the two approaches. In my opinion, the debate over the reciprocal interaction of metaphoric domains largely corresponds to the differences between the modernist *mechanistic* approach and the postmodernist *electronic* approach, or between what McLuhan called *visual space* and *acoustic space*. The mechanistic approach is characterized by linearity, abstraction and fragmentation, while the electronic approach is characterized by feedback, simultaneousness and totality (holism). I do not intend to explain the differences in this chapter, but in the following chapters we will see the deep impact of technology on thought, culture and science: in chapter 2, I will discuss the differences between the mechanistic and electronic orders; in chapter 3, I will discuss some other aspects of the electronic order and its impact on society; in the second part of the work, I will demonstrate how the historical developments in biology corresponded to the rise of the mechanistic order and to the characteristics of industrial society. An interesting connection between all these issues is Gestalt psychology, that developed under the influence of the new electronic environment (e.g. under the influence of field theory and experiments on perception and films). Gestalt psychology rejects the reductionist-mechanistic approach and in this context it even influenced the development of the post-mechanistic approach in embryology through the *field* metaphor. Now, like many other scientific approaches, the conceptual metaphor theory is still modernistic and in some respects it expresses the characteristics of the mechanistic order: according to this approach, the metaphoric process, or metaphoric mapping, is linear and unidirectional. On the other hand, the interaction view, and especially the new versions of this approach, is more *electronic*: according to this approach, the metaphoric process, or metaphoric mapping, is based on reciprocity, feedback and even holistic responses. According to Joseph Glicksohn and Chanita Goodblatt (1993), the interaction theories of Richards, Black and their followers are closely related to gestalt psychology and actually they should be embedded within the framework of gestalt psychology for two main reasons: (a) in the interaction theories the metaphor is considered to be “a whole (gestalt), created by an interaction between its primary and secondary subjects” (b) any metaphoric phrase should be understood and analyzed in the broad context in which it was uttered, e.g. the text, the poem, the dialogue etc. Glicksohn and Goodblatt further note that Gestalt psychology had an indirect influence on the Anglo-American New Criticism of Richards and his colleagues (Glicksohn and Goodblatt 1993: 83, 85 – 86). To support this claim I will note that McLuhan was directly influenced both by Richards and Gestalt psychology. Needles to say, McLuhan explicitly argued that his ideas belong to the electronic world. The work of Barnden and his colleagues is another example of a theory of reciprocal interaction that is clearly based on the electronic order, i.e., on feedback systems, computers and artificial intelligence.

❖ *More Problems of the Traditional Objectivist View*

In the discussion above I’ve rejected the objectivist view for two main reasons: (a) metaphors do not simply represent inherent or objective similarities, but rather similarities and new insights are generated and discovered through the metaphoric interaction (b) metaphors cannot be reduced to *literal* meanings without a change in their meaning and without loosing mental and emotional content. In the last decades a vast amount of evidence accumulated against the objectivist view, and as we saw in the previous section, researchers from different fields developed alternative, non-objectivist approaches. The work of Lakoff and Johnson summarizes some of the new evidence (Lakoff and Johnson 1980; Lakoff 1998; Lakoff and Johnson 1999; see also: Kövecses 2005). According to Lakoff, the following objectivist assertions do not coincide with the new evidence:

All everyday conventional language is literal, and none is metaphorical.
All subject matter can be comprehended literally, without metaphor.
Only literal language can be contingently true or false.
All definitions given in the lexicon of a language are literal, not metaphorical.

The concepts used in the grammar of a language are all literal; none are metaphorical (Lakoff 1998: 204).

Lakoff and Johnson's work demonstrates that metaphors shape all forms of human language, from ordinary language, through poetics, to the language of philosophy. We usually do not pay attention to metaphors, although we create and use them when we think, act, talk, argue, or when we try to comprehend a subject matter (for instance, my attempt to explain "what is a metaphor"). *Metaphors*,[10] such as "argument is war", "time is money", and "love is a journey" - are taken for granted because they are already conceptually rooted in our language and in the way we think about the relevant subjects. Therefore when one thinks of time, it is very likely he would use relations from the *source* domain of experiencing money to *map* relations from the *target* domain of experiencing time: "You're *wasting* my time"; "How do you *spend* your time these days"; "That flat tire *cost* me an hour" (Lakoff and Johnson 1980: 7 – 9). Yet, in practice not all the relations from the source domain will be practically mapped and translated into the target domain, and furthermore, it is not uncommon to find simultaneous mapping, i.e. more than one metaphor in one sentence or a phrase. For instance, the phrase "within the coming weeks" (Lakoff 1998: 210, 219), gives us the possibility to experience time as a stationary landscape which has extension and bounded regions ("within"), and, at the same time, it gives us the possibility to experience time as a moving object ("coming"). This example, among many others, serves Lakoff to demonstrate how even the most basic concepts in human language, such as time, category, causation, etc. – are metaphorically constructed. Thus, every field of knowledge is organized by metaphorical thinking.

It is well known that while trying to stick to the literal, the objectivist view itself is based on metaphorical thinking and metaphorical conceptualization. Following Michael Reddy, Lakoff and Johnson demonstrate how the objectivist view relies on a prevalent metaphor in English (Lakoff and Johnson: chaps. 25 – 27). The objectivists perceive and conceptualize language and meaning under the spell of the Conduit metaphor. According to this metaphor, the speaker puts ideas and meanings (objects) into words (containers), and sends them, along a channel, to the listener who takes them out of the containers: "I *gave* you that idea", "It's hard to *get* that idea across to him", "The meaning is right there *in* the words" (Lakoff and Johnson 1980: 11). Thus the Conduit metaphor maps ideas/meanings as objects, linguistic expressions as containers, and communication as “sending” (Lakoff and Johnson 1980: 10). The Conduit metaphor characterizes the objectivist theory of meaning and communication. The objectivist view asserts that it is possible, and even necessary, to find an objective and fixed meaning “right there” *in* the words and phrases themselves. This fixed meaning is determind by the conditions under which a sentence would be objectivley true or false, and it could easily be sent to any listener using words and sentences as containers. If the meanings are “right there” *in* the words, then, as the philosopher Donald Davidson argue, “Literal meaning and literal truth conditions can be assigned to words and sentences apart from particular contexts of use” (Lakoff and Johnson 1980: 202; Davidson 1978: 33). But what about the following sentence: “please sit in the apple-juice seat” (Lakoff and Johnson 1980: 12)? Without the context in which it was said, this sentence has no “objective” and “fixed” meaning of “itself” whatsoever. Here the specific context of use is undeniably relevant for determining the meaning of the sentence, for instance a guest arriving for breakfast, where he found himself in front of four place settings (three with orange juice and one with apple juice).[11]

Davidson denies the existence of metaphorical meanings. According to his view, there are only literal meanings, i.e., no one speaks *metaphorically*. It seems that Davidson has created his own version of the “comparison view of metaphor” (see for example, Davidson 1978: 39 – 41), as Black called it, except for one aspect: Davidson does not argue that metaphors are illegitimate devices in science and philosophy. The following citations from his article demonstrate that Davidson has adopted the comparison view:

> Metaphor and simile are merely two among endless devices that serve to alert us to aspects of the world by inviting us to make comparisons… We say Mr. S. is like a pig because we know he isn't one. If we had used a metaphor and said he was a pig, this would not be because we changed our minds about the facts but because we chose to get the idea across a different way (Davidson 1978: 40 – 41).

In his reply to Davidson, Black noticed these passages (see Black 1979: 139). McLuhan's assertion, that *the medium is the message*, was explicitly directed against the idea that the medium is a neutral container of content and abstract messages (see chapter 2). In Davidson's case the neutral container is the medium of metaphors. Note that the Conduit metaphor, as any other metaphor, suppresses some aspects of the target domain (in this case human communication). This phenomenon is not surprising at all because metaphoric constructions are always partial and never complete, or else the source domain and the target domain would have to be identical. The Conduit metaphor makes us believe that words and sentences have meanings in themselves, meanings which have nothing to do with the speaker, the listener, and the situation. In short, the Conduit metaphor suppresses context. Since the Conduit theory is a metaphor, it can be replaced by other metaphors which do not ignore the human aspects and the social context of the word. A very good example of that is the approach of Mikhail Bakhtin and his colleagues, who emphasize the problems arising from the usage of the formalist–objectivist metaphor. Alternatively, they suggest the *Bridge* metaphor that emphasizes words as part of a transformative addressed process, i.e., a two–sided, dynamic dialogue with an indeterminate meaning (Todorov 1984: 55 – 56; Voloshinov 1973: 86).

Now, the objectivists do not deny that in specific contexts a certain speaker would like to convey an indirect meaning instead of the literal (direct) meaning of the word or sentence. For example, according to the objectivist view, a metaphor like "The theory is made of cheap stucco" has two meanings: the literal meaning, which is blatantly false, and the speaker's indirect meaning which is also literal ("the theory is weak"; note that this is just another metaphor). Therefore the objectivists relate to metaphors as cases of indirect meaning. In the objectivist view, metaphors are merely passive linguistic tools, if at all. In other words, metaphors make us see objective similarities already found in the target and source domains: these similarities are based only on inherent properties which things and objects have in themselves (Lakoff and Johnson 1980: 206 – 209). Nevertheless, we have already seen that one cannot simply attribute the similarities "found" in the two domains of a metaphor to the domains "themselves", because they depend on a creative process of reciprocal interaction. Moreover, the domains in "themselves" were already structured metaphorically, before the new metaphor appeared. Not surprisingly, then, one can find metaphors behind the similarities of other metaphors. This phenomenon was documented by Lakoff and Johnson. For example, a metaphor like "Ideas are Food" is primarily based on other conceptual metaphors, such as: "The Mind is a Container", "Ideas are Objects" and the Conduit metaphor. There are even cases which are much more problematic, e.g. "Love is a journey". "In itself" the concept of love is "not inherently well defined". There are no non-metaphorical ways to define and talk about love; we can only compare "Love is a Journey" to "Love is a Physical Force" or to other metaphors (Lakoff and Johnson 1980: 214 – 215).

- ***Metaphors and Experience***

It is very important to emphasize that Lakoff and Johnson do not deny the relevance of the *world outside* to the knowledge and beliefs that we develop. They do not go from one extreme to another, namely from objectivism towards an ideal subjectivism, and they agree that our own ideas about the world are always constructed, tested and modified via the interaction of sense experience and physical environments with our socio-cultural environment. Lakoff and Johnson call this approach: an *experientialist synthesis*. In general, the *experientialist* approaches assert that it is very problematic, or impossible, to distinguish between physical and cultural contribution to concepts, theories and metaphors, since the way we use, choose and interpret physical experiences, is dependent on different cultural frameworks (see, for example, the expression of this approach in the sociology of science: Barnes et al. 1996: chap.3). In some cultures, for example, the future is ahead of us, whereas in others it is in the back of us. Also, not all cultures emphasize the up–down orientation: as opposed to some widespread western conceptual metaphors which are presented below, these cultures emphasize balance and centrality. In conclusion, metaphors are always dependent on both physical and cultural elements and therefore different cultures can construct alternative metaphors (Lakoff and Johnson 1980: 14, 19 – 24, 192 – 194; see also: Johnson 1987; Lakoff 1987; Lakoff and Johnson 1999; Kövecses 2005; Gibbs 2003a; Gibbs 2006).[12]

The cognitive psychologist Raymond Gibbs explains how he and many of his colleagues detached themselves from the traditional approaches to meaning construction and understanding (Gibbs 2003a; Gibbs 2003b; Gibbs 2006: chap. 6). Instead of analyzing meanings as abstract, disembodied symbols, the new approaches suggest that meanings are created contextually and they are grounded in ordinary embodied experiences. Embodied experiences are involved in many aspects of knowledge construction. According to the "perspective-taking" approach, speakers and listeners create, adopt and shift perspectives in the process of comprehension. Additionally, according to the "indexical hypothesis", in the process of understanding people derive the possible actions for each object in the situation. Therefore, it is easier for people to understand, and it takes them less time to process, a sentence like "Art used the chair to defend himself against the snarling lion" than the sentence "Art used the chair to propel himself across the room". Gibbs also reviews psychological studies that analyze some possible ways in which embodied experiences may influence the metaphorical construction of abstract concepts. Researchers study the intuitions which participants have regarding physical experiences and regarding their own embodied experiences. Their aim is to analyze experiences which appear to serve as source domains in metaphoric constructions and to demonstrate how these experiences relate to their target domains. For example, heat in a pressurized container serves as a source domain for understanding and experiencing anger, e.g. "He *exploded*", "The *smoke coming out* of his ears". In the same way hunger serves as a source domain for desire, e.g., "I wanted *to eat him alive*! He was *yummy*!" The act of standing serves as a source domain for a variety of target domains, e.g., "The law still *stands*", "The part *stands* for the whole" (Gibbs 2003a)

Similar to Gibbs, Zoltán Kövecses explains how contemporary researchers conduct psychological experiments and collect neurobiological evidence, in order to characterize physical and bodily factors which are involved in the construction of metaphors (Kövecses 2005: chap. 2). On the psychological level researchers try to show, for example, how an experience of riding on a moving train may bias the way we think and talk about the category of time: when on a moving train more people may perceive time as a moving observer (e.g. "We're coming up on Christmas"). On the neurobiological level researchers try to confirm that metaphors involve a simultaneous activation of two groups of neurons in the brain: the group associated with the *source* domain and the group associated with the *target* domain. The metaphorical mapping is associated with the pattern of the neural circuitry. For example, since infancy the emotion domain expressed by loving embraces is simultaneously activated with the temperature domain. This universal, embodied and cross-cultural experience may give rise to the "Affection is Warmth" metaphor (e.g. "We have a *warm* relationship"). Another interesting example is a research conducted by Frank Boers who speculated that as a domain becomes more salient in certain circumstances it is more likely to serve people as a source domain for metaphors (Kövecses 2005: 239 – 241). I would say that this hypothesis corresponds to the famous dictum of McLuhan: "The medium is the message". In part II, I will use McLuhan's approach in order to examine if and how the history of biology corresponds to the changes that occurred in the techno-cultural environment. In any case, Boers has analyzed the prevalence of *Health* as a source domain for *Economy* (e.g. "*healthy* companies", "economic *remedy*" etc.) throughout the year. Generally, people tend to get sick during winter. In this season they are more aware of the health condition of their bodies. Therefore, issues of heath and sickness are more salient during the winter. Boers reviewed issues of *The Economist* magazine over a period of 10 years. He showed a systematic pattern, according to which the use of health related metaphors in economic issues was higher from December till March in comparison with the other seasons. Additionally, Boers did not find an increase in the use of other major source domains for metaphors in economy during the winter. Nevertheless, one should emphasize again that physical conditions and embodied experiences are variable and they are interrelated with a variety of social, cultural, historical and personal factors. For example, anger is physiologically characterized by an increase of blood pressure and skin temperature. In English, and in other languages, these phenomena serve as an experiential basis for the "Anger is Heat" metaphor, but the Chinese metaphors for anger tend to focus on pressure and much less on heat (Kövecses 2005: 246 – 252).

Do all metaphors have an experiential basis? Grady (1997) suggest that metaphors can be classified according to their experiential basis. Primary metaphors are constructed in accordance with our daily embodied experiences, and they constitute the basic level of our thought. Examples are: "Affection is Warmth" as we have seen above, and "More is Up; Less is Down" as described in Lakoff and Johnson (see below). Primary metaphors could be used to construct a higher level of compound metaphors which are more detached from direct experiences. We cannot claim, for example, that

“Theories are Buildings” (e.g. “the *foundation* of the theory”, “Your facts are not *solid* enough to *support* your hypothesis”) have a direct experiential basis. However, we can argue that “Theories are Buildings” is a compound metaphor composed of the following primary metaphors: (a) “Organization is physical structure”; in these cases buildings, textiles and artworks are used in order to comprehend abstract organizations by mapping physical parts onto abstract constituents and logical relations of constituents onto physical arrangements of parts (b) “Persisting is remaining erect”; in these cases we map an erect object, which is viable or functioning in a vertical position, onto the persistence or acceptance of an abstract entity. Now (a) and (b) have more direct experiential basis than “Theories are Buildings” which is more abstract. On a daily basis we encounter organized physical objects, such as artifacts, and we also encounter objects in a functioning vertical state, such as trees, active people, poles and buildings. “Theories are Buildings” combines both (a) and (b), and thus we may say: “the conclusion is *supported* by the evidence” or “the theory has *collapsed*”. But these two primary metaphors are not necessarily bound: we can use (a) without using (b) and vice versa. For example “The *fabric* of society” involves (a), but not (b). Grady further claims that (a) and (b) are primary in the “most fundamental sort”: they are “nondecomposable” and “self contained” (Grady 1997: 285 – 286).

Although I find Grady's analysis valuable, I disagree with his atomistic view, i.e. with his definition of “independent”, “self contained” conceptualizations which are constructed on their own, in response to specific types of physical experiences and with no relation to a whole system of meanings and beliefs. For instance, Grady defines “Organization is physical structure” as a primary metaphor, but in order to identify the *organization* of different objects that surround us, we have to be equipped with a suitable set of data, beliefs, expectations and theories that define the concept of *organization*. As Wittgenstein claimed, “To understand a sentence means to understand a language. To understand a language means to be master of a technique” (Wittgenstein 1953: §199). In chapter 2, I will demonstrate that even simple sentences, dealing with direct and immediate physical experiences, depend on an entire system of knowledge and beliefs. Once the context is revealed, it is easier to detect the metaphorical frameworks that are hidden behind the simple sentence.

Following William Nagy, Lakoff and Johnson summarize some possible ways in which physical and embodied experiences, coincident of course with cultural experiences, influence the construction of metaphors. Spatial metaphors, they suggest, are not constructed arbitrarily. I shall briefly review some examples (Lakoff and Johnson 1980: 14 – 21):

1. Happy is *up;* sad is *down* (I'm feeling *up*; my spirit *rose*). A possible physical basis: sadness and depression usually involve drooping posture, while being happy or feeling good usually involve erect posture (a subject studied by Charles Pierce).
2. Conscious is *up*; unconscious is *down* (Wake *up*; he *fell* asleep). A possible physical basis: human beings like most mammals sleep lying down and stand up when they awaken.

The following examples depend on the Container metaphor and they are relevant to our discussion on the body:

3. More is *up*; less is *down* (The numbers of books printed each year keeps *going up*). A possible physical basis: when one adds a material or physical objects to a container the level goes up (Lakoff and Johnson 1980: 16).
4. Classical logic was shaped through the Container metaphor, as can be seen in the structure of *modus ponens* (the issue of formal logic as the logic of containers was studied by I. A. Bochenski):

Socrates is a man
All men are mortal
Therefore, Socrates is mortal

Note that the Venn diagrams actually represent arguments through circle containers. In classical logic each category is a clear-cut bounded container. Thus, if Socrates is in the category/container of Human beings and the category/container of Human beings is in the category/container of mortals, then Socrates is in the category/container of mortals (Lakoff 1998: 212 – 213). Lakoff and Johnson argue that the logic of containers stems from the basic experience of our body:

> We are physical beings, bounded and set off from the rest of the world by the surface of our skins, and we experience the rest of the world as outside of us. Each of us is a container, with a bounding surface and an in-out orientation. We project our own in-out orientation onto other physical objects that are bounded by surfaces. Thus we also view them as containers with an inside and an outside. Rooms and houses are obvious containers. Moving from room to room is moving from one container to another, that is, moving *out of* one room and *into* another (Lakoff and Johnson 1980: 29).

> Container schemas, for example, arise out of our bodily experience, and they have the basic logic of the syllogism. The syllogism can be viewed as arising out of our bodily experience and our capacity for metaphorical projection, rather than having some transcendental existence (Lakoff 1987: 354).

I do not believe that the explanation of Lakoff and Johnson is a sufficient explanation, because the way we think and the way we experience the body largely depend on the techno-cultural environment *in* which we live. In the next chapter I will present a more radical approach on the issue of the *Metaphoric Body*, which is based on the ideas of Marshall McLuhan.

2

Technological Extensions and their Impact on Society

In this chapter, and in the following chapters, I will use McLuhan’s grand-narrative and ideas, which serve as the foundation for the thesis of the *Metaphoric Body*.

Richard Coyne (1995: 280 – 286), defines four levels of relationships between technology and metaphors:

1. Technologies function as a source of metaphors, while they are comprehended metaphorically. For example, since the development of mechanics, during the Renaissance, biological structures and processes were described and explained using mechanical concepts. Today the mind and the brain are described as computers, and computers are described as brains. Note that this is the interactive characteristic of metaphors. Furthermore, we design technologies and artifacts so they would fit the basic metaphors of our cultures (Lakoff 1998: 241): graphs and thermometers, for example, follow the “More is up” metaphor.
2. There is a complex circular connection between technologies, metaphors and problems. Metaphors create problems. Some of these problems could be solved using technologies, which create a bias towards certain metaphors, which create new problems... Today, for example, information processing technology is dominant, and as a result, other domains, like design, are perceived through the domain of information processing. Therefore new problems arise in these domains, e.g. transferring information accurately. The solution to the problems is technological, and the spiral movement continues...

3. Metaphorical relationships between technologies. Any new technology is perceived and designed in the light of our experience with other technologies. The computer screen, for example, is perceived as a desk with objects that we can "touch" and "point" them.
4. Awareness of the problems that arise from metaphorical thinking, metaphorical design and metaphorical relationships between technologies (level 2 and level 3), can create a basis for evaluation of technologies in relation to the needs of the users. For example, if a screen "pencil" is not adequate for a certain task (when different line thickness is needed), then one could perceive the task through another metaphor, like a "brush".

Coyne adds to the first level the claim that technologies could influence cultures in a hidden way, as McLuhan and Walter Ong suggest. Indeed, the Toronto School of Communication (McLuhan, Ong, H. Innis, E. Havelock, E. Carpenter and their followers) greatly contributed to the study of the impact of media on society, culture and human thought. Let us examine, then, how McLuhan analyzed the relationships between technologies, metaphors and embodied experiences.

❖ ***Experience and Metaphorical Extensions of the Body***

Similar to Black, McLuhan was influenced by I. A. Richards' theory of metaphor. According to McLuhan, a metaphor is a complex of analogical relations, or a translation and a transformation of experience that enable one to see one set of relations through another (McLuhan 1964: 59 – 60). Similar to Lakoff and Johnson, McLuhan attaches great importance to the role of metaphors in shaping human thought. Yet McLuhan emphasizes the role of metaphorical *perception*, while Lakoff and Johnson emphasize the role of metaphorical *conception*. According to McLuhan, "metaphor is a means of *perceiving* one thing in terms of another. The concepts come after, often long after, the percepts" (McLuhan and McLuhan 1988: 230; see also pp. 121 – 128, 225). Lakoff and Johnson, on the other hand, focus on the "Concepts We Live By" (Lakoff and Johnson 1980). However, I think that it is very problematic to separate the perceptual aspect from the conceptual aspect because they are interrelated: we perceive under a certain conceptual system and we construct, change and update our conceptual system according to percepts.[13]

Lakoff and Johnson, as we saw in the previous chapter, claim that metaphors depend on an experiential–corporeal basis and on different cultural frameworks. They admit that it is hard to distinguish between the physical and the cultural influences on the formation of metaphors. There seems to be an agreement between McLuhan, Havelock and Ong on the one hand, and Lakoff and Johnson on the other, regarding the experiential basis of objectivism. In general, both schools reject the *myth of objectivity* and they argue that writing and the printing press are the ground on which the word was transformed from an oral event into a static object and the objectivist approach and the *conduit* metaphor developed.[14]

However, when Lakoff and Johnson analyze the *container* metaphor, they ignore the cultural frameworks that shaped the metaphor. As we have seen, they suggest that the general experiences of embodiment serve as an experiential basis for the *container* metaphor and classical logic ("Container schemas, for example, arise out of our bodily experience, and they have the basic logic of the syllogism"; "Each of us is a container"). One cannot deny that artificial containers are connected to embodied experiences. Otherwise we would not have designed them, as I will explain below (the *extension* idea). Nevertheless, we do not think through the *container* metaphor simply because we *own* a body. First, as McLuhan argued, in the name of Henry Bergson, without language we would have, probably, been totally involved with the objects surrounding us (McLuhan 1964: 79).[15] Moreover, the *container* metaphor has developed on a certain techno-cultural ground. For the preliterate it is not at all obvious that space is a container:

> Professor E.S. Carpenter, the anthropologist, tells of native wood craftsmen who contrived most elaborate structures. When asked to box them for shipment, they were at a loss. The idea of putting the complex spaces of their carvings inside a plain cubic container was an entire novelty to them. Putting one space inside another space seemed to them as if making a parody of their own work. The idea of enclosed space is alien to the complex sensuous spaces of nonliterate men. Sigfried Giedion explains in *The Beginnings of Architecture* that the Romans were the first and only people ever to enclose space in the ancient world - by putting the arch inside a rectangle (McLuhan and Watson 1970: 170).[16]

In chapter 4 we will see that the body in oral cultures is perceived through the *macrocosm↔microcosm* metaphor, according to which the whole universe resonates within the body. The idea that the body is a *closed container* belongs to literate cultures and especially to the modern age. People living in oral cultures do not experience themselves as closed containers. The oral *self* is polyphonic and polymorphic. For instance, according to Havelock, even in the 5^{th} century BC the majority of Greeks did not understand the idea of autonomous personality. The oral technique of mimesis was not based on detachment, but on great involvement, emotional identification and the merging of *knower* and *known*. In other words, through mimesis the person was transformed into what he perceived. Havelock shows that with the development of the phonetic alphabet and script culture, the *knower* was separated from the *known* and the Greeks, led by Plato, were able to create the solid *psyche* or the autonomous *rational* personality (Havelock 1963: 45 – 47, 197 – 214; McLuhan and McLuhan 1988: 16 – 21). Thus, contrary to the explanation of Lakoff and Johnson, the linear logic of containers does not arise from the general experiences of embodiment in themselves and it depends on techno-cultural conditions. Preliterate ways of thinking are not characterized by abstract syllogism and classical logic, but rather by contextual-situational thinking. In *Orality and Literacy* Ong summarizes some of the evidence on this subject. For instance, when people from an oral culture are asked what color are the bears in Novaya Zembla (when the premises are: in the Far North, where there is snow, all bears are white; Novaya Zembla is in the Far North), they relate to contextual-situational aspects, instead of *following* the abstract, linear argumentation and the logic of containers. Thus a typical answer to this question would be: “I don't know. I've seen a black bear. I've never seen any other… Each locality has its own animals” (Ong 1982: 49 – 57).

The impact of embodied experiences depends on techno-cultural environments. When Lakoff suggests an experiential basis for the common *knowing is seeing/ seeing is believing* metaphor, once again he projects the characteristics of western and literate cultures on all human cultures in all times. He relies on a false assumption, according to which: “…most of what we know comes through vision” (Lakoff 1998: 240). Indeed:

The rational man in our Western culture is a visual man. The fact that most conscious experience has little "visuality" in it is lost on him (McLuhan and Fiore 1967: 45).

The senses, as McLuhan explained, are not unbiased mediators: in each culture, they operate under the *stress* of different means of communication. What seems to people from the Western culture as a universal common sense does not necessarily reflect the state of affairs in oral cultures. Lakoff is biased towards "visuality", which McLuhan identified with the effects of phonetic writing and especially with Western print culture: "Before the invention of the phonetic alphabet, man lived in a world where all the senses were balanced and simultaneous". The Chinese ideogram, for example, "affords none of the separation and specialization of sense, none of the breaking apart of sight and sound and meaning which is the key to phonetic alphabet"(McLuhan 1996: 241; McLuhan and Fiore 1967: 117; McLuhan 1962: 34 – 35; McLuhan 1964; McLuhan and McLuhan 1988).[17] McLuhan's ideas on the balance of the senses and the varieties of sensory experience in different techno-cultural environments have anticipated and influenced new studies in cultural-history and anthropology of the senses (see for example: Howes 2005a; Howes 1991; Foster 1988).[18]

As we saw at the end of the previous chapter and the beginning of this chapter, metaphors have physical aspects. Artifacts, for example, are designed according to the basic metaphors of our cultures, e.g. the graphs and thermometers that reflect the "More is up" metaphor. However, the discussion on metaphors and embodied experiences can be further extended. Following McLuhan, I would like to claim that a metaphor is not only the perception of one domain according to another, but also the design and construction of one domain according to another. The human environment is modeled on the human body and at the same time it modifies the body perceptually, conceptually, theoretically and even physically, as I will explain in the following chapters. Thus the interaction is reciprocal. But what is the experiential basis for the assertion that the human environment is modeled on the human body? Well, this experiential basis depends on the function and essence of artificial products with respect to the people who design and use them. Technologies function as *prostheses/extensions/amplifications/metaphors* of the human body, i.e. they are extensions of organs, senses, bodily functions or processes. As verbal metaphors translate certain relations from one domain to another, artificial products materialize certain aspects of the human body in the environment: clothes are extensions of the skin and in general they assist the mechanism of thermoregulation; forks are extensions of palm and fingers; books and libraries are extensions of memory; refrigerators extend the capacity and the ability of the body to store food or energy (in the body food and energy are stored on different levels, e.g. fat tissues); telescopes, microscopes and lenses are extensions of sight; weapons are extensions of fists, legs, teeth, nails, and any other aspect or function of the body which is used in fighting; wheels are extensions of legs in motion; and so forth (McLuhan 1964; McLuhan and McLuhan 1988).[19] Generally, one can define simple tools as motionless extensions of organs, and machines as extensions of bodily functions or processes:

> As contrasted with the mere tool, the machine is an extension or outering of a process. The tool extends the fist, the nails, the teeth, the arm. The wheel extends the feet in rotation or sequential movement. Printing, the first complete mechanization of a handicraft, breaks up the movement of the hand into a series of discrete steps that are as repeatable as the wheel is rotary (McLuhan1964: 152).

Occasionally, the *outering* of bodily processes, which McLuhan also defines as pushing “archetypal forms of the unconscious out into social consciousness” (McLuhan and Parker 1969: 31; cited by Kroker 1984: 56), is been done consciously and intentionally. The Phone, for example, is a product of the attempt to imitate the human body (McLuhan 1964: 270 – 271). Chairs are also a very good example of this, since each part of the chair is called under the name of the organ it extends / the organ for which the part serves as a prosthesis: feet, legs, seat, back, arms (McLuhan and McLuhan 1988: 117). The best examples are direct prostheses which are physically connected to the body (this issue is discussed in chapter 3).

McLuhan adopted the idea of *extension* from the work of the anthropologist Edward T. Hall. Hall himself got the idea from the architect and engineer Buckminster Fuller (McLuhan 1987: 287, 308, 515). Yet the origins of this idea can be traced back to the insights of 19th century intellectuals and scientists, such as Samuel Butler, Thomas Huxley, Ralph Emerson and Henri Bergson. For instance, in chapter 8 we will see that following the publication of Darwin’s work, Butler began to write about the interrelationships between humans and machines and their joint evolution. According to Butler, machines are “mechanical limbs” that enhance human abilities and modify the evolution of mankind, while the propagation and evolution of these machines depend on humans (Butler 1921 [1863; 1865]: 42 – 53; Butler 1968 [1872]: 189 – 219). Butler's view echoes in *Understanding Media*, especially in the following passage: "Man becomes, as it were, the sex organs of the machine world, as the bee of the plant world, enabling it to fecundate and to evolve ever new forms" (McLuhan 1964: 46). Later McLuhan related to the thoughts of Emerson on the interrelationships between humans and machines (McLuhan and McLuhan 1988: 94 – 96). Emerson summarized the idea that the design of artificial environments depends on the anthropomorphic perception:

> Our nineteenth century is the age of tools. They grew out of our structure. "Man is the meter of all things," said Aristotle; "the hand is the instrument of instruments, and the mind is the form of forms." The human body is the magazine of inventions, the patent office, where are the models from which every hint was taken. All the tools and engines on earth are only extensions of its limbs and senses. One definition of man is "an intelligence served by organs." Machines can only second, not supply, his unaided senses. The body is a meter (Emerson 1968 [1870], vol. 7: 157).

Additionally, Emerson was aware of the reciprocal interaction between humans and machines:

> Machinery is aggressive. The weaver becomes a web, the mechinist a machine (Emerson 1968 [1870], vol. 7: 164).

- My interpretation of the extension idea is as follows:

The *body* is the source domain and the *environment* is the target domain, If I may use the terms of the conceptual metaphor theory: we design the environment according to the functions of the body, thus creating the artificial environment. The *target* domain in this case is designed to serve the *source* domain as an extension/prosthesis. We should notice that the body is only the fundamental source domain for its extensions. In order to create the extensions we use other source domains. First, when we design a technology we use basic cultural metaphors, e.g. the *more is up* metaphor. Secondly, we physically and conceptually use the bodies of animals and other organisms to design artifacts and technologies. For instance, skin of animals is used in the production of clothing, i.e. we produce tanned leather as an extension of the human skin. Viruses are used in the production of vaccines that strengthen the immune system. Organisms also serve as models of extensions, for instance wings of birds and insects serve as models of aircraft wings (airplanes enhance the movement of the body and some aircrafts are also used as extensions of fighting abilities and the senses, e.g. surveillance aircrafts). Thirdly, we design technologies using other technologies as metaphorical sources, e.g. the computer screen as a desk. Finally, we should remember that the interaction between the source and target domains is reciprocal. Technologies are not passive extensions of the body: as I will explain in the following chapters, through the interaction the source domain, i.e. the body, is modified perceptually, conceptually, theoretically and even physically (a schematic representation of the thesis appears in fig. 0.1, in the Abstract).

- Is the idea of *extension* metaphorical?

In the previous chapter I've already argued that theories which explain the *metaphorical* aspects of human knowledge are metaphorical themselves. As a non-objectivist it would be ridiculous if I would argue otherwise. The conceptual theory of metaphor and its basic concepts (*source* and *target domains*) are metaphorical. Blending theory and its basic concepts (*input*, *generic*, and *blended spaces*) are metaphorical. The *extensions* theory, as well, is not based only on *simple* observations: as the explanations and citations above show, the idea that technologies are *prostheses* of the body depends on metaphorical perception and theoretical interpretation. Nonetheless, metaphors are not arbitrary: the experiential basis of metaphors consists of empirical data and social-cultural-technological conditions. The question is how does the metaphor deal with empirical data and what are the insights and advantages of one metaphorical framework in comparison to alternative metaphorical frameworks?

Let us return to McLuhan. One of McLuhan's assertions is that all utterings or outerings of the human body share some basic metaphorical characteristics. In this sense he does not distinguish between verbal/ideal metaphors and physical metaphors: "For just as a metaphor transforms and transmits experience, so do the media" (McLuhan 1964: 59). In fact, he rejects the clear distinctions between *software* and *hardware* extensions, and proclaims that "words are things and things are words". This assertion retrieves an archaic oral perception: in ancient Greece logos meant both an idea and an object (McLuhan and McLuhan 1988: ix, 217; McLuhan and Powers 1989: 181 – 182). Similarly, in Hebrew *word* ("Dibur") and *object* ("Davar") share the same root which also means an event.[20] The spoken word exists only as an event, and any attempt to freeze the spoken word will cause it to disappear. One can freeze words only by visual means, such as writing and print (Ong 1982: 32). Correspondingly, McLuhan did not define the *medium* as a closed container, but as a dynamic environment or process that develops in a certain society via the appearance of a technological innovation. In this context McLuhan developed the *Tetrads* in order to demonstrate that all words and artifacts are characterized by the same dynamic structure that comprises four basic processes.[21]

According to McLuhan, language is metaphorical because it *saves* and *translates* one experience into another. Media or technological environments also translate one experience into another. Money, for instance, saves and translates different kinds of work and skills. Moreover, language and technology are interrelated. We design and develop technologies using language which is itself a social technique that (a) enhances and extends mental/cognitive abilities and (b) amplifies the mind into the outer-social world and enables to pass ideas from person to person:

> That technologies are ways of translating one kind of knowledge into another mode has been expressed by Lyman Bryson in the phrase "technology is explicitness." Translation is thus a "spelling out" of forms of knowing. What we call "mechanization" is a translation of nature, and of our own natures, into amplified and specialized forms... All media are active metaphors in their power to translate experience into new forms. The spoken word was the first technology by which man was able to let go of his environment in order to grasp it in a new way. Words are a kind of information retrieval that can range over the total environment and experience at high speed. Words are complex systems of metaphors and symbols that translate experience into our uttered or outered senses. They are a technology of explicitness. By means of translation of immediate sense experience into vocal symbols the entire world can be evoked and retrieved at any instant (McLuhan 1964: 56 – 57).

As an amplifier of cognition language does not only express the senses, but it also translates them into one another through synesthesia: “loud color”, for example, translates the visual sense into the acoustic sense, and “bright sounds” translates the acoustic sense into the visual sense (McLuhan and Powers: 5; see also Marks 1996, on synesthesia as a perceptual metaphor). In conclusion, according to McLuhan’s view, language and words are not passive, arbitrary and abstract signs: words and things are in a mutual, dynamic relationship that depends on a common ground of experience, i.e. on active speakers and actors, who experience and translate things into words and words into things (E. McLuhan 1989: 85). Thus any medium is a metaphor that “translates and transforms, the sender, the receiver, and the message” (McLuhan 1964: 90).

❖ *Implosion and McLuhan’s Grand-Narrative*

In the following pages I will discuss some of McLuhan's main ideas which are relevant to the thesis of the *Metaphoric Body*. The basic meaning of McLuhan’s famous aphorism, “The medium is the message” (McLuhan 1964: chapter 1), is that technologies are not passive extensions of the body, since the characteristics of technological environments transform society and human perception. In the beginning of *Understanding Media* McLuhan asserts that:

> After three thousand years of explosion, by means of fragmentary and mechanical technologies, the Western world is imploding. During the mechanical ages we had extended our bodies in space. Today, after more than a century of electric technology, we have extended our central nervous system itself in a global embrace, abolishing both space and time as far as our planet is concerned (McLuhan 1964: 3).

McLuhan borrowed the term *implosion* from Lewis Mumford who had discussed the immigration of different ethnic groups to the US (Lash 2002: 187). In McLuhan’s grand-narrative, *implosion* is the historical process of overturning the characteristics of the mechanical age and industrial society via the new electronic environment (see esp. McLuhan 1964; 1962). As I will explain below, the mechanistic-industrial order is based on the principle of fragmentation. Although the trends of fragmentation had already appeared in ancient times (through mechanical inventions and the development of the phonetic alphabet), they became dominant only in the last centuries. Following McLuhan, I use the term *fragmentation* in a broad sense that includes specialization, division of labor, atomism and reductionist-analytic approaches that break complex problems/processes into fragments/special functions and then reassemble the fragments in a linear fashion. These approaches define the whole "as the sum of its parts" and they apply one of the maxims that characterized the mechanical age: "a place for everything and everything in its place". Nonetheless the new electronic environment had begun to reverse the mechanistic trends that dominated the industrial society, or as McLuhan's metaphor determines, the fragments *implode* and totality reemerges in society and in human perception. McLuhan's most familiar idea in this context is the shrinking of the world to a *global village* (or, as he later called it, the *global theater*), in which everyone could be immediately involved in remote events and in the life and deeds of everyone else, thanks to the new electronic media which is accessible from almost anywhere on the planet. We can identify the electronic implosion on the following levels:

- *Technological implosion*

McLuhan observed that through a gradual and hybrid process the new electronic environment reverses the trend of mechanical fragmentation and specialization (see especially McLuhan 1964: chap. 5 and chap. 33; McLuhan and McLuhan 1988: 101). The electronic world and the cybernetic program promote a new order which contrasts with the industrial-mechanistic order. The characteristics of the new order are the systemic approach, the total field, totality/holism, circularity, feedback loops, flexibility and simultaneous operations. In the last decades the electronic flexibility is manifested by multimedia, computers and the World Wide Web, that implode old technological functions through a total system. The new electronic systems merge the functions of the book, the typewriter, the mail, the newspaper, television, music, telephone, commerce and trade, medical exams etc. (see, for example, Levinson 1999). Despite the existence of some technical problems, the new trend is to integrate and implode different devices and functions in a single electronic gadget: the integration of numerous tiny transistors into small electronic chips enables the design of electronic gadgets like the cellular phone which is also a calendar, a camera, a calculator, a word processor, a radio, an interface to the internet, etc. Technological implosion is also manifested by the miniaturization of gadgets. Although their physical size and volume decreased over the years, the storage capacity of electronic devices increased. As Wikipedia defines the trend, "higher density is more desirable, for it allows greater volumes of data to be stored in the same physical space."[22] Books, libraries, archives, records, and hardware media in general, are squeezed into virtual databases and the cyberspace. As a result many people can simultaneously share and download information from the same sources in cyberspace. Nanotechnology is the future of miniaturization. Additionally, as Paul Virilio observed (Genosko 1999: 95 – 96), the implosion principle is also manifested by flight simulators and the new workout equipment (e.g. exercise bikes and exercise treadmills) that implode space. I think that the technology of Virtual Reality is the ultimate expression of space implosion. This technology is still in its infancy, but the electronic culture, science fiction movies and TV series, like *Star Trek*, envision VR technology that provides the user the experience of being in different environments and in a large space. In principle, entire worlds could be imploded into a small space through VR technology. To a large degree, VR technology and especially professional simulators already do that.

- *Social implosion*

The electronic speed and the global electronic matrix have shrunk the world to a *global village*. They create immediate involvement of people from all over the world and thus they implode social space and time. In addition, McLuhan's aphorism, "The medium is the message", expresses the implosion of *media* and *content* (according to McLuhan, the content of each medium are other media). Jean Baudrillard continued to analyze this subject ("The implosion of meaning in the media"). In his work he described the *hyperreal*, or the self-referential signs of electronic media matrix, as imploding *contents* and *meanings* and as swallowing the *social* and the *real* (see chapter 3 and Baudrillard 1983; 1994). The role of television in breaking of boundaries and in social implosion was also analyzed by Joshua Meyrowitz (1985), who described the implosion of social situations, implosion of crowds (different ethnic groups, age groups, genders), implosion of content, implosion of the public and private, and implosion of *high* and *low* cultures (compared to the trends of book culture and industrial society). Globalization and implosion appear through radio, telephones, television, satellites, internet and airplanes. Note that the impact of social implosion is much stronger at the age of the internet. The new electronic environment and the new electronic mentality create and enhance many types of implosion, from *fusion* cuisine to *MMA* (an alternative to separate competitions of boxing, jujitsu wrestling, judo, kickboxing, karate etc.: Mixed Martial Arts developed as a televised implosion of all martial arts in one arena. Each MMA fighter combines different striking and grappling techniques from different martial arts).

- *Mental implosion*

Mental implosion stands in contrast to the mechanistic approach. In the electronic perception totality/holism, feedback/circularity and flexibility replace fragmentation/reductionism/specialization, linearity and standardization. The new electronic approaches include field theories, systems theory, Gestalt psychology (which was influenced by field theory and by experiments on perception and films), the cybernetic program and Artificial Intelligence. The impact of the new approaches is felt in different fields, from developmental biology to models in social sciences. Similarly, postmodern critiques of the sciences are "transgressing disciplinary boundaries… between the natural sciences and the humanities" (Greenberg 1990: 1; cited in Sokal 1996). The sciences in the industrial society went through an extensive process of specialization. On the other hand, the postmodern approaches merge the *natural* and the *social* and they examine the natural sciences in an inclusive context. For example, the thesis of the *Metaphoric Body* examines the techno-cultural ground of life sciences.

- *Implosion of the body*

As I will explain in chapter 3, in the electronic age the technological extensions imploded into the body via the cyborg and the cloning technique. I will show that genetic engineering and tissue transplanting techniques also lead to an inter-species implosion.

➢ *Visual Space vs. Acoustic Space*

Generally, McLuhan divides the history of the West into four main periods: (1) preliterate/ tribal culture (2) literate- phonetic alphabet/ script culture (3) print/ industrial culture (4) electronic / postindustrial culture. McLuhan was highly influenced by James Joyce and in one of his books he identified ten major periods in the history of Western culture (from the Paleolithic age to the age of television), which correspond to the ten thunders in *Finnegans Wake* (McLuhan and Fiore 1968: 46 – 48). Although McLuhan focused on cultural and historical revolutions, he did not argue that the techno-cultural modifications occur through sharp *epistemic breaks* or as revolutions between *incommensurable paradigms*. As I will explain below, the techno-cultural revolutions which McLuhan described were formed through hybrid processes (*hybrid energy* and *rear view mirror*). This aspect in the work of McLuhan is often ignored.

McLuhan's grand-narrative is based on two major categories: *acoustic space* (or *audile-tactile space*) and *visual space*. The concept of acoustic space refers to the perception, thought and social organization in preliterate cultures, which are characterized by mimesis, contextual thought, tribalism, lack of individualism and holism. Fragmentation and specialization appear in these cultures only on a small scale. Neo-acoustic space retrieves in a new form some of the main characteristics of preliterate acoustic space through the electronic implosion. Basically, acoustic space indicates the existence of interplay between all the senses without dominance, although McLuhan sometimes claims that in preliterate cultures the ear can dominate the eye. According to McLuhan, the phonetic alphabet had shifted the balance of senses: the characteristics of the phonetic alphabet and the bias towards the visual sense created the visual space (visual space should not be confused with the visual sense *per se*). Visual space is the world of the literate people. Finally, McLuhan distinguishes script culture from print culture: visual space was formed with the development of the phonetic alphabet, but it was modified and became much more dominant with the development of print culture and industrial society (Carpenter and McLuhan 1960b, McLuhan 1962; McLuhan 1964; McLuhan and McLuhan 1988).

McLuhan's grand-narrative can be summarized as follows. The phonetic alphabet was the hidden ground on which the Greeks *exploded* the closed tribal society and created the *individual* and *rational* thought. With the development of script culture, the meaning of *rationality* was transformed from a ratio and a meeting place of the senses (the *common sense*), into a linear, abstract thought which is based on formal logic, detachment and objectivity. Unlike other scripts, the phonetic alphabet decomposes language through semantically meaningless letters that correspond to semantically meaningless sounds: the complex gestalts of sounds, sights and meanings were reduced to meaningless visual fragments that become meaningful again by putting them together in a linear fashion, step-by-step. The consonant became an abstraction of the mind and "…the alphabet became a universal, abstract, static container of meaningless sounds" (McLuhan and McLuhan 1988: 15). Although the Greeks had assimilated the phonetic alphabet through the oral technique of mimesis, they eventually abandoned mimesis because it conflicted with the characteristics of the new script: abstraction, detachment, objectivity, fragmentation, linearity and the logic of containers.

Print culture diffused, enhanced, extended and modified the social and psychological effects of the phonetic alphabet. Visual space was modified and became dominant. Similar to the phonetic alphabet, the printing press is based on the fragmentation of a complex operation. The standard fragments of print (the movable types) are reassembled by means of a standard, linear process. In fact, the printing press was the first assembly line that enabled the mass production of uniform products, and thus it was the prototype of the industrial world. Print culture and the industrial world were the ground on which standardization, uniformity and the division of labor appeared. They promoted the standardization of national languages and the decline of local dialectics, the standardization of laws and regulations, the standardization of time (by mechanical clocks), the standardization of measuring systems and the appearance of the modern nation-state (locality, dialectics and ethnic loyalty were pushed aside by centralization and homogenous citizenship of individuals).

The fourth period began to take shape in the mid 19th century with the appearance of the commercial telegraph. The development of 20th century electronic environment created the neo-acoustic space. According to McLuhan, the characteristics of the electronic environment (implosion, totality etc.) translate the Western culture back into the acoustic space. The neo-acoustic space reverses the historical trends that had become dominant in print culture and industrial society: see the table below which summarizes some of the characteristics of visual space vs. the characteristics of audile-tactile space (acoustic space). Despite the differences between the acoustic space of the ancient world and the neo-acoustic space of the postmodern world, both appear on the right column. I would like to emphasize again that the shifts from acoustic space to visual space and from visual space to neo-acoustic space are gradual.

TABLE 2.1: *Visual Space* vs. *Audile-Tactile Space*

Visual Space	***Audile-Tactile Space (ancient and postmodern)***
Homogenous, continuous, static space, an infinite container	Inhomogeneous, finite, spherical space, resonance-interval, metamorphic flux, a total field
Centralization, center and margins, explosion and expansion	Decentralization, many centers with no margins, implosion, contraction
Phonetic alphabet Print Typographic Hotter Tables	Oral, face to face dialogue Electronic media Graphic, Iconic Cooler Aphorisms, McLuhan's *probes*
Fragmentation, reductionism, atomism, linearity, sequential order	Total, holistic, non-linear, non-sequential, feedback, simultaneous, analogical
Deduction, classical logic, abstraction, dialectics, method, objectivity	Situational-contextual thought, mimesis, dialogue, fuzzy logic

Visual Space	***Audile-Tactile Space***
Linear perspective, fixed point of view or *neutral* point of view (e.g. in arts: Renaissance painting, tonality in music, classical music)	Multiple perspective, the reversed perspective of TV screens and monitors (light through) (e.g. in arts: pre-modern painting, 20th century painting, tribal music, atonal music, avant-garde music, electronic pop and rock [esp.: hip-hop – rap, punk, metal, post-punk, hardcore, industrial, noise ,alternative …]
National	Tribal
Privacy, individualism	The tribal world is characterized by deep involvement. In the electronic culture: McLuhan's "global village" and "brothel without walls" (i.e. the camera) and Baudrillard's "obscene" of the real
Systematic classification which is based on fragmentation "A place for everything and everything in its place"	Pattern recognition, corporate awareness In pre-literate cultures everything is related to everything else
Specialization, standardization, job, division of labor, separation of powers	Totality, roles, flexibility, implosion of situations
Isolated, abstract figures,	Gestalt, complex interplay of figure and ground

Visual Space	***Audile -Tactile Space***
Proteus bound, An autonomous, solid personality, the Cartesian mind, Becoming	Proteus unbound, Polyphony, Being
Euclid	Heraclites
Mechanistic	Organic, animistic, electronic
Newtonian and Cartesian spaces	Relativity and Quantum mechanics

In addition to the books of McLuhan, discussions on many of these issues can be found in books that were written by his colleagues, for instance: Harold Innis (1951), Eric Havelock (1963), Walter Ong (1982; 1958) and Edmund Carpenter (1959).
Representing works that were written by disciples: Howes (2005a), Levinson (1999), Baudrillard (1994; 1983), Postman (1985; 1982), Meyrowitz (1985), Eisenstein (1979), Schwartz (1973).
The Biographies of McLuhan: Marchand (1990), Gordon (1997).
A discussion on the artistic sources that influenced McLuhan can be found in: Theall (2001; 1997), Eric McLuhan (1997).

❖ *Electro-Cybernetics and the Mechanistic Approach*

The term *cybernetics*, which is now associated with electronic engineering, was derived from the Greek term *kybernetics*, i.e. a steersman. Throughout history the term was borrowed by scholars, such as Plato and Ampère, to describe the function of governments. The term governor itself, which was derived from Greek and Latin, has two meaning in English: a public steersman and a mechanism that regulate the operation of machines (Dechert 1966: 11 – 12). It can be claimed that the technological roots of 20th century electro-cybernetics existed for centuries, and even thousands of years: already in the ancient world there were "feedback mechanisms" (a term that belongs to the 20th century), which were designed to regulate, to some extent, the operation of machines, e.g. the float regulators used in water clocks. Another prominent example of this is the steam engine governor which was designed by James Watt in 1788.[23] According to Otto Mayr (1970), Watt's governor was the first self-regulating mechanism in the modern age which had been accepted by the engineering community and attracted worldwide attention. It was also the first regulating mechanism which was mathematically analyzed (in 1868 by James Clerk Maxwell). However, as will be mentioned below, the old regulating mechanisms are very different from electronic feedback mechanisms.

➢ *Hybrid energy*

Cybernetic regulation depends on the transference of *information* between parts of the system and also between the system and its environment (the standard definition of the term *information* was given by Claude Shannon in the late 1940's). All cybernetic technologies are characterized by the *feedback loop*, which generates circular reactions and flexibility.[24] As a concept and as a principle, the feedback loop was developed at the end of 1920's by researchers from the field of radio-communication. The feedback principle, as Mayr explains (1970), does not depend on a certain physical medium and it could be implemented in various systems: gaseous, mechanical, hydraulic, electronic, biological and social.

Hybridization does not characterize only the feedback technology. In linguistics and literature there is a similar phenomenon: *heteroglossia* or the "multiplicity of social voices and a wide variety of their links and interrelationships (always more or less dialogized)" (Bakhtin 1981: 263). According to the Russian linguist, Michael Bakhtin, languages are always "heteroglot", i.e. they always combine contradicting voices and genres of present and past, of different social and ideological groups, different cultural groups, different age groups, different schools, different circles, etc. Bakhtin adds: "These 'languages' of heteroglossia intersect each other in a variety of ways, forming new socially typifying 'languages'" (p. 291). He defines the formation of "hybrid constructions" in language as a fruitful, insightful and productive poetic technique, that sheds new light on objects, subjects, and their context, for example in parody (pp. 301 – 331; esp. 312 – 313). Indeed, in parodies and satires new insights are always produced when certain characters are placed in untypical and even bizarre situations. As we have seen before, McLuhan argues that words are artifacts and artifacts are part of the human language. Unsurprisingly, then, the heteroglossic advantages appear in *Understanding Media* (1964), as characters of verbal language as well as of technological language. In the course of the book, and especially in chapter 1, McLuhan observes that new media always interact with existing patterns (old media) and transform them. He defines it as ***hybrid energy***. In practice, hybridization is a creative, fruitful technique in engineering as well as in arts:

> The electric light ended the regime of night and day. But it is when the light encounters already existing patterns of human organization that the hybrid energy is released. Cars can travel all night, ball players can play all night... [Chaplin] had adapted the pianoforte to the style of the ballet, hit upon the wondrous media mix of ballet and film in developing his pavlova like alternation of ecstasy and waddle. He adapted the classical steps of ballet to a movie mime that converged exactly the right blend of the lyric and the ironic… Artists in various fields are always the first to discover how to enable one medium to use or to release the power of another… When wheels were put in tandem form, the wheel principle combined with the lineal typographic principle to create aerodynamic balance. The wheel crossed with industrial, lineal form released the new form of the airplane. The hybrid or the meeting of two media is a moment of truth and a revelation from which new form is born… the moment of the meeting of media is a moment of freedom and release from the ordinary trance and numbness imposed by them on our senses (McLuhan 1964: 52 – 55).

The new electronic technology "reverse[s] the mechanical dynamic" (McLuhan 1964: 38). Yet 20th century automation developed from the intersection of the electric medium and the feedback principle, which acted upon the mechanical medium. The characteristics of the electro-cybernetic order, i.e. circularity, flexibility and implosion, transformed the old mechanical medium. Many forms were created by this intersection: electric engines, the modern newspaper (print + telegraph), the cinema, the phonograph, weapons and other mechanical technologies that were formed or transformed by electricity (McLuhan 1964: 194, 256, 348 – 349). Although the electronic world gradually pushes aside and replaces the mechanical world, it developed from the mechanical world. Electricity itself was initially produced (and is still produced) by converting kinetic energy of rotating mechanical devices into an electric current using electromagnetic induction (e.g. the dynamo). Thus, as McLuhan himself writes:

> The age of the mechanical has had to overlap with the electric… (McLuhan 1964: 194).

Mayr agrees that the new electric medium was essential to the proliferation and success of feedback mechanisms in the 20th century:

> The predominance of mechanical methods, both theoretical and practical, over control engineering came to an end with the rise of electrical technology. New electrical solutions were proposed for traditional control problems, such as electrical speed, level and temperature regulators; the principle of feedback proved particularly useful in the technologies of communication... Practical control engineering made great progress during the Second World War, when each belligerent made efforts to gain superiority in this field. When after the war the secrecy was lifted, there suddenly became available (1) a mature technology of automatic control which had proven itself in dealing with the problems of radar, fire control, autopilots, guided missiles, and so on; (2) a theory that was universal and easy to manipulate; and (3) a stuff of scientists and engineers who quickly spread this new knowledge, thus introducing the era of automation and cybernetics (Mayr 1970: 131 – 132).

Before the 20th century the *feedback* did not exist as an abstract idea that binds together all circular regulating mechanisms (Mayr 1970: 129 – 131). In principle limited and unsophisticated kinds of feedback mechanisms could be integrated into mechanical instruments without the usage of electricity. Float-level regulators, which were installed in water clocks and other devices, appeared already in the Hellenistic science and in the Islamic medieval science. Yet, in medieval Europe, around the 14th century, new mechanical developments, and especially the development of the mechanical clock, led to the neglect and rejection of ancient "feedback" mechanisms.[25] The mechanical clock and other mechanical technologies became dominant and they also became an important source of metaphors that influenced cultural views and social thought in Europe (Mayr 1986). According to Mayr, the old "feedback" mechanisms did not coincide with the mechanical trend: the purpose of the subtle "feedback" mechanisms was to maintain equilibrium, while mechanical instruments of the early modern age were based on monumental structures, dramatic action and the use of great force, e.g. wind and water wheels, church organs, pumps, cranes and hoists, three-masted sailing ships and siege cannons (Mayr 1986: XVI – XVII). However, it should be noted that the applied knowledge in the mechanical age also included subtle mechanisms, such as small lenses, watches and compasses. In any case, according to Mayr, "feedback" mechanisms reappeared during the 19th century, but they had little success and they were found only in unknown books and few stores. Watt's governor was the only self-regulating mechanism that became an international success (Mayr 1970: p. 31; chap. X). Nonetheless, the regulatory capabilities of mechanical automata are very limited, unless they are integrated with the electric medium.

- Mechanical fragmentation vs. electronic implosion

I would like to emphasize that there is considerable disagreement between the historical accounts of Mayr and McLuhan. The disagreement is over the differences between the electronic implosion and the characteristics of the industrial-mechanistic order. In 18th century Britain liberalism was expressed by theories that emphasize autonomy achieved by self regulation or equilibrium, e.g. the economic theory of Adam Smith (1981 [1776]). Mayr claims that in some respects the liberal ideas correspond to the feedback principle, although they are not directly connected to it. Furthermore, according to Mayr, the liberal order is reflected in Watt's regulating mechanism. Mayr believes that the connection between these two dimensions of "feedback", as he calls it, stems from the following complementary aspects: on the one hand, technology is a force that promotes social changes and changes in social values; on the other hand, technology is a social product that reflects needs, values and social views (Mayr 1986: XVI – XVII; part II).

It seems that Mayr makes a mistake which McLuhan warned against (McLuhan 1964: 349): he relates to the feedback principle of electronic engineering as an extension of the principles of the mechanical age. Indeed, liberal authors and economic thinkers in 18th century Britain focused on the principles of balance and equilibrium (McLuhan and Watson 1970: 103), but their theories expressed and extended the principles of the industrial-mechanistic order: **fragmentation, specialization and division of labor**. The free market theory of Adam Smith is a prime example of that. As I will immediately explain, the industrial-mechanistic program is based on the decomposition of complex problems into fragments and the reintegration of the fragments in a linear-sequential order through a standard process. For this reason, McLuhan referred to Newton and Adam Smith in the same breath as "great experts and advocates of the fragmentary and the specialist approaches" (McLuhan 1964: 64). The electronic order, on the other hand, is based on **totality and implosion** (McLuhan 1964: passim). As I have already explained, during the 20th century the electronic implosion began to reverse the trends of fragmentation that characterized the industrial-mechanical world.

I will try to clarify the relationship between the mechanistic order and the industrial theory of Smith. Social and economic theories of the industrial age were based on the mechanistic approach. Society, according to these views, is a combination of fragments / atoms / individuals / distinct parts of the machine. The industrial-mechanistic metaphor defined the needs, efforts, interests and deeds of each individual as the basic units of society. Thus, in contrast to holistic or systemic approaches, the whole in the industrial theories is the sum of its parts. 17th century scholars already applied the mechanistic approach in social thought. For example, Thomas Hobbes identified the organic body and the body politic as mechanical automata. He believed that in the *state of nature* society did not exist and it was eventually formed due to the interests of the individuals. Similarly, William Petty perceived the body politic through the mechanical filter and analyzed it as a quantifiable mass (Hobbes 1904 [1651]: especially pages xviii, 83 – 86; Keller 2000: 324).

The division of labor in society, which Smith praises, corresponds to and derives from the industrial mode of production. Actually, the industrial mode of production is based on mechanical fragmentation: in the linear, standard process of production each worker specializes in one fragment of the assembly line. The industrial-mechanistic order and the prototypes of the assembly line are well illustrated in Denis Diderot's *Pictorial Encyclopedia of Trades and Industry* (Diderot 1959 [1763]). Following the *Encyclopedia*, Smith's famous book, *An Inquiry into the Nature and Causes of the Wealth of Nations* (1981 [1776]), opens with an explanation of the importance and the advantages of the division of labor in industry. According to Smith, the division of labor is the “greatest improvement in the productive powers of labour”, which yields an increase in productivity, efficiency and wealth. In the following passage Smith uses the production of pins as an example:

> … a workman not educated to this business (which the division of labour has rendered a distinct trade), nor acquainted with the use of the machinery employed in it (to the invention of which the same division of labour has probably given occasion), could scarce, perhaps, with his utmost industry, make one pin in a day, and certainly could not make twenty. But in the way in which this business is now carried on, not only the whole work is a peculiar trade, but it is divided into a number of branches, of which the greater part are likewise peculiar trades. One man draws out the wire, another straights it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving, the head; to make the head requires two or three distinct operations; to put it on is a peculiar business, to whiten the pins is another; it is even a trade by itself to put them into the paper; and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which, in some factories, are all performed by distinct hands, though in others the same man will sometimes perform two or three of them. I have seen a small manufactory of this kind where ten men only were employed, and where some of them consequently performed two or three distinct operations. But though they were very poor… (Smith 1981 [1776], vol. 1: 14 – 15)

The human-mechanical interaction is reciprocal: on the one hand the mechanical technology extends human abilities, but on the other hand the worker becomes a fragmented, specialized and standardized part in the industrial assembly line. Liberal economic theories, then, expressed and promoted the industrial-mechanistic order. The mechanical paradigm of Newton served as a model for the economic balance in Smith’s theory. Instead of equilibrium between the movements of atoms, the equilibrium in Smith’s model is between the actions of individuals, according to general empirical laws, i.e. the laws of supply and demand. The Newtonian philosophy was very popular in the 18th century, and the model of mechanical equilibrium inspired the life sciences, social thought and prose. Smith, Hume and the Scottish Enlightenment were distinguished representative of the Newtonian *movement*.[26] The economic system, as Smith described it, is not a holistic system, but a system which is based on (a) the actions of individuals who are motivated by self interests (b) the division of labor. The balance of the system is achieved by the *invisible hand*. This ambiguous metaphor appears three times in the work of Smith. In the *Wealth of Nations* Smith argued that "By preferring the support of domestick to that of foreign industry, [the individual] intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention" (Smith 1981 [1776], vol. 1: 456). In *The Theory of Moral Sentiments* Smith wrote that the rich "are led by an invisible hand to make nearly the same distribution of the necessaries of life, which would have been made, had the earth been divided into equal portions among all its inhabitants, and thus without intending it, without knowing it, advance the interest of the society, and afford means to the multiplication of the species. When providence divided the earth among a few lordly masters, it neither forgot, nor abandoned those who seemed to have bee left out in the partition" (Smith 1761: 273 – 274). In the *History of Astronomy* the concept of the *invisible hand* appears in relation to the ancient beliefs that ascribed irregular events of nature, such as lightning and thunders, to invisible gods, demons, fairies or "the invisible hand of Jupiter" (Smith 1795: 25). Hence the equilibrium of the economic system which Smith describes is the product of the sum of all the rational activities of self-centered individuals who work within a social framework, and probably it is also the product of a more traditional force - the invisible hand of the Protestant God.

The dictum "A place for everything and everything in its place" best describes the trends of fragmentation, specialization, division of labor and standardization that characterized industrial society. According to McLuhan, even Montesquieu's theory of separation of powers, i.e. the system of "checks and balances" that characterizes the modern nation-state, appeared in the same industrial-mechanistic context (McLuhan 1964: 272 – 273).[27] Indeed, as Mark Waddicor explains, Montesquieu's scientific method and his analysis of human society were inspired by the mechanical sciences. Montesquieu was a Cartesian thinker, but he was also influenced by the work of Newton and he defined him as the successor of Descartes (Waddicor 1970: chapter 2).

In this context one can identify another fundamental difference between the historical accounts of McLuhan and Mayr. McLuhan perceives the printing press as the hidden ground on which the industrial society and the nation-state developed (on the impact of print see, for example: McLuhan 1962; McLuhan 1964; Ong 1958; Ong 1982: 115 – 135; Eisenstein 1979; Anderson 1991). Mayr, on the other hand, does not refer to print and he mostly emphasizes the impact of the mechanical clock (Mayr 1986). The mechanical clock was developed during the 13th century and it had a great influence on modern thought and culture, for instance modern science transformed the universe and the body into mechanical clocks. Print has had a long history in Europe: already the Romans developed print techniques in order to replicate pictures in a uniform and repeatable fashion. The movable type was invented by Johannes Gutenberg around the mid 15th century and it laid the foundation of the industrial age. McLuhan and his school identify the printing press of Gutenberg as the first assembly line for mass production of uniform products. Through the movable type the word became a commodity. The printers were among the prominent early capitalists and they had an important role in the development of capitalism. In addition, the social-economic organization around the new invention of the movable type corresponded to the mode of mechanical production (fragmentation, specialism and standardization): as a uniform product for mass consumption the book promoted a division of labor which involved authors, editors, typesetters, distributors and sellers. Finally, it should be noted again that McLuhan emphasized the role of the phonetic alphabet in the creation of Western mechanistic mentality. For example, when McLuhan referred to Lewis Mumford and to the assertion that the mechanical clock “preceded the printing press in order of influence on the mechanization of society”, he claimed that Mumford ignores the role of the phonetic alphabet as the source of visual space and “Western mechanism” (McLuhan: 1964: 147).

The movable type not only diffused the impact of the phonetic alphabet, but it was also the prototype of the industrial world. Before the invention of the movable type, the unique sentences of each text were carved into a woodblock (the woodcut technique / xylography). Following the phonetic alphabet, the movable type solved this complex problem using the principles of fragmentation, standardization and linear arrangement. Gutenberg prepared a set of separate metal letters which could be rearranged and pressed on papers. This method enabled Gutenberg to copy different texts using only a limited number of standard fragments. Consequently, the holistic and unique pattern of the text was reduced to a uniform set of units which can be rearranged in a linear fashion while producing endless copies of uniform and standard products. Note that the Chinese and the Koreans invented movable type printing before Gutenberg, but they did not use the abstract and reductionist technique of the phonetic alphabet (although the Koreans unsuccessfully tried to develop a similar writing system): their ideograms comprise tens of thousands of holistic signs, and therefore the movable type printing that they invented was not effective at all compared to the combined efficiency of the phonetic alphabet and the movable type. The formula of the mechanistic order replicated itself in many social and scientific aspects, from the division of labor and separation of powers in industrial society to the mechanistic approach in the sciences. Industrialization peaked in the 20th century, but at the same time the new electronic technology began to modify the industrial world. Fragmentation, division of labor and linear operation were replaced by implosion, totality and feedback.

Mechanization, then, was achieved by breaking complex processes into fragments which can be integrated in a linear fashion, step by steep. Accordingly, mechanical automata are composed of distinct movable parts, each having a special function: the mechanical clock is composed of springs, cog-wheels, and a pendulum (every part of the clock has a distinct function in the linear chain of causes); the movable type breaks the operation of the writing hand into a sequence of linear, repeatable actions; the factory and the assembly line operate in the same manner. Mechanical automata operate in a linear, deterministic and standard manner. Each one of them can perform only a specific procedure. Hence they are specialized extensions of bodily functions. On the other hand, computerized systems operate through feedback mechanisms and data processing and thus they can react in a flexible manner to different conditions and tasks. In addition, as I have noted before, the integration of numerous tiny transistors into small electronic chips enables each computerized system to perform a variety of different functions. Finally, as McLuhan explained, the new electronic technologies are non-specialized because their source of energy can be applied to different types of operations:

It is the fact that, in any automatic machine, or galaxy of machines and functions, the generation and transmission of power is quite separate from the work operation that uses the power. The same is true in all servomechanist structures that involve feedback. The source of energy is separate from the process of translation of information, or the applying of knowledge. This is obvious in the telegraph, where the energy and channel are quite independent of whether the written code is French or German. The same is separation of power and process obtains in automated industry, or in "cybernation." The electric energy can be applied indifferently and quickly to many kinds of tasks.

Such was never the case in the mechanical systems. The power and the work done were always in direct relation, whether it was hand and hammer, water and wheel, horse and cart, or steam and piston. Electricity brought a strange elasticity in this matter, much as light itself illuminates a total field and does not dictate what shall be done. The same light can make possible a multiplicity of tasks, just as with electric power. Light is a nonspecialist kind of energy or power that is identical with information and knowledge. Such is also the relation of electricity to automation, since both energy and information can be applied in a great variety of ways (McLuhan 1964: 350).

- **Cybernetic feedback**, then, can be defined as an extension of **the mental-manual control** over different tasks and different machines (these machines also serve as extensions of the user's body).

Automata are extensions of bodily functions and in this respect the cybernetic feedback is no exception. Thanks to the cybernetic principle the user can perform different tasks simultaneously and leave the machines without any physical supervision of his body. The tasks are controlled by an extension of a remote body or a remote user who can perform other activities. Thus, if the cybernetic feedback is an extension and amplification of the mental-manual control, and if the electronic medium can extend and amplify the nervous system (see chapter 3), then the electro-cybernetic technology creates very efficient extensions of bodily functions that integrate the neural and the manual.

❖ *The Power of Media*

The studies of McLuhan, the Toronto School and their disciples deal with the socio-cultural and psychological influences of technologies and media. The main theme of this school is that new technological environments can (a) create new realities, new situations and new social patterns, while pushing aside or eliminating old patterns (b) modify the balance of the senses, transform the experience of space and time, transform perception and mind, create new ways of thinking and transform the *self*. In the following chapters, I will use the ideas of McLuhan and his colleagues to study the impact of techno-cultural environments on the life sciences and on the metaphorical frameworks that shape the biological theories. McLuhan's most celebrated aphorism, “The medium is the message”, was directed against the communication studies of his time (McLuhan 1964: chap.1). First, McLuhan rejected the approach of researchers who focused on abstract *content* and ascribed to media superficial and short term effects. This approach was represented by the noted American sociologists Robert Merton and Paul Lazarsfeld (see, for example, McLuhan 1964: 297 – 298). Secondly, McLuhan rejected abstract, formalist and objectivist approaches, e.g. the cybernetic theory of communication. In the Shannon-Weaver model of communication the medium is defined as a passive linear channel which is used to transfer information: according to McLuhan, their model is based on the metaphor of “transportation” in which “information”, the “message” or the “content” are abstract and they do not depend on any social, psychological or techno-cultural ground. McLuhan, on the other hand, suggested a theory of “transformation”: he perceived the medium as something that *translates* and *transforms* the sender, the receiver, and the message (Shannon and Weaver 1949; McLuhan and McLuhan 1988: 85 – 87; McLuhan 1964: 90). Thirdly, McLuhan went against modernists and moralists who reacted to the new electronic culture (or postmodern culture) with arrogance and contempt. He realized that the moralists replace observation and understanding with worthless panic and rage: instead of studying the new form, the new environment, the media, the hidden ground of the new culture – the moralists are hypnotized by abstract and banal “content” and they fight a losing battle. For McLuhan the content of a medium “is like the juicy piece of meat carried by the burglar to distract the watchdog of the mind" (McLuhan 1964: 18, 314), or to cite his metaphorical paraphrase: "The medium is the massage" (McLuhan and Fiore 1967).

McLuhan observed that any "content" is actually another form, i.e. an older medium: the content of speech is thought; the content of writing is speech; the written word is the content of print; print is the content of telegraph; novel is the content of movies, etc. (McLuhan 1964: 8, 305). One should note that the satirical writing of McLuhan was intended to provoke the reader. He had no intension to deny the importance of "content" altogether. *Content* is important for three main reasons. First, content itself in an older medium. Secondly, the impact of media can only be studied through their effects and their contents. Thirdly, the impact of the medium is not homogenous and it depends on an existing ground, i.e. it depends on the hybrid fusion of the new medium with older media, culture and social structure.

When McLuhan wrote that "the medium is the message", he meant that cultures are changed in their form and not just in their abstract content. The approach of McLuhan emphasizes the power of technological environments to promote psychological, social and cultural changes through their characteristics. Technologies are not neutral and passive objects that depend only on the way people use them. Therefore, instead of asking what should be done with the medium and what kind of content should we put in this *container*, we must first ask: What is happening? What is the medium doing to us? The medium, according to McLuhan, is not an isolated figure, but an interface of culture and technology, i.e. a hidden environment of *services* (new patterns and new situations) and *disservices* (old patterns and old situations that are pushed aside). McLuhan describes the medium as a dynamic process that transforms society through a new invention:

> When I say the medium is the message, I'm saying that the motor car is not a medium. The medium is the highway, the factories, and the oil companies. That is the medium. In other words, the medium of the car is the effects of the car. When you pull the effects away, the medium of the car is gone. The car as an engineering object has nothing to do with these effects. The car is a figure in a ground of services… It really means a hidden environment of services created by an innovation (McLuhan 1970: 6 – 7).

McLuhan adopted the idea of dynamic relationship between *figure* and *ground* from Edgar Rubin and Gestalt psychology. The figure is the small area of attention, while the ground is the large area of inattention (McLuhan and McLuhan 1988: 5). In another place McLuhan describes "…extensions as creating new service/disservice environments which alter modes of private and corporate perception" (McLuhan 1987: 402). Since McLuhan was aware that the metaphor of "The medium is the message" emphasizes the importance of technology and diminishes the importance of the human agent, he suggested an additional metaphor - "the user is the content": "When I say 'the medium is the message', I suppress the fact that the user or audience or cognitive agent is both the 'content' and maker of the experience, in order to highlight the *effects* of the medium, or the hidden environment or ground of the experience" (McLuhan and Nevitt 1972: 231; McLuhan 1987: 443, 448). Hence the interaction of technology and its users is reciprocal. Additionally, I think that we can define the user as the content in light of the extension idea, since technology is modeled on the user's body and it serves as an extension of him.

- In the following part I will argue that scientific paradigms largely depend on techno-cultural environments. In this context I will show that the medium becomes the message through *hybrid energy* and *rear view mirrors*.

Human perception, techno-cultural environments and science do not develop through the incommensurable paradigms of Thomas Kuhn (1970) or the sharp epistemic breaks of Michel Foucault (1970). I think that one can identify in the work of McLuhan an alternative approach which is based on the metaphors of *hybrid energy* and *rear view mirror*. In *Understanding Media* McLuhan argued that the "peculiar drama" of the 20th century was living in an environment which is both mechanical and electronic. As we saw in the previous section, McLuhan uses the metaphor of hybrid energy to describe the interaction of new and old media as a creative and fruitful encounter (McLuhan 1964: 52 – 55, 342). The idea of hybrid development appears in McLuhan's work also in relation to other periods. For example, when McLuhan describes the transition from acoustic space to visual space, he argues that "paradoxically" the phonetic alphabet was assimilated through the oral technique of mimesis, which was eventually abandoned because it conflicted with the values of script culture. Furthermore, he notes that "The alphabetic revolution took centuries" (McLuhan and McLuhan 1988: 16 – 17, 32 – 33). Similarly, McLuhan describes the transition from script culture to print culture as a hybrid process: "The interface of the Renaissance was the meeting of medieval pluralism and modern homogeneity and mechanism – a formula for blitz and metamorphosis", or "Francis Bacon, PR voice for moderni, had both his feet in the Middle Ages" (McLuhan 1962: 141, 183, 186). McLuhan noticed that the content of any medium is an older medium. Not surprisingly, then, each new medium is initially experienced and explored in terms of its predecessor: early scripts (e.g. the bible, the *Iliad* and the *Odyssey*) conveyed an oral, mimetic form of reciting; early copies of print conveyed the semi-oral, dialogistic form of scripts; early television shows were inspired by the radio (filmed radio: people standing still and reciting their parts).

Rear view mirror is a metaphor that belongs to the same family of the *hybrid energy* metaphor. McLuhan uses this metaphor to describe our lack of awareness of the characteristics and impact of new technological environments, which stems from anachronistic ways of thinking. According to McLuhan, we tend to experience and comprehend the new environment in terms of the recent past, namely through the patterns of the old environment. As McLuhan puts it, "We look at the present through a rear-view mirror. We march backwards into the future" (see fig. 2.1; taken from McLuhan and Fiore 1967: 74 – 75). Unawareness, denial and even fear are involved with the tendency to focus on figures and abstract "content" (i.e. old media): changes in the hidden ground are overlooked, while the present is perceived and experienced with the help of familiar concepts and conventional views.[28] For example, the scientific discussion on the "bending" of space by a body or by its gravitational field is a rear view mirror. According to McLuhan, scientists attempt to fit and to squeeze the theory of relativity into the *visual space*, that is, into the old Euclidian container or the absolute space that *contains* objects (McLuhan and McLuhan 1988: 40 – 43).

Here are some other examples of the rear view mirror effect. "Suburbia lives imaginatively in Bonanza-land" (McLuhan and Fiore 1967: 72 – 75). The *official culture* and the establishment are "striving to force the new media to do the work of the old" (McLuhan and Fiore 1967: 81, 94; McLuhan 1966: 107). The social theory of

Marx, as McLuhan described it, can be defined as a rear view mirror: Marx focused on industrial production and he did not notice that the telegraph, i.e. the precursor of the new electronic environment, promoted the formation of a new society (McLuhan and Fiore 1968: 4 – 5; McLuhan and Nevitt 1972: 67; McLuhan 1964: 38, 49). Cultural products, for instance science fiction movies like *Star Wars*, also project old patterns on the future (see, for example, McLuhan and Powers 1989: 134). According to Neil Postman, the rear view mirror is a way of thinking that is characterized by statements, such as “the car is just a fast horse” and “electric light is just like a powerful candle” (Postman 1985: 83 – 84). The design and operation of the computer interface as a *desktop* can also be considered as a rear view mirror that enables us to comprehend and experience the new activity in familiar terms. Disneyland, as Baudrillard analyzes it, can also be considered as a good example of the rear view mirror phenomenon (Baudrillard 1983: 23 – 26; see chapter 3).

The Rear View Mirror Effect

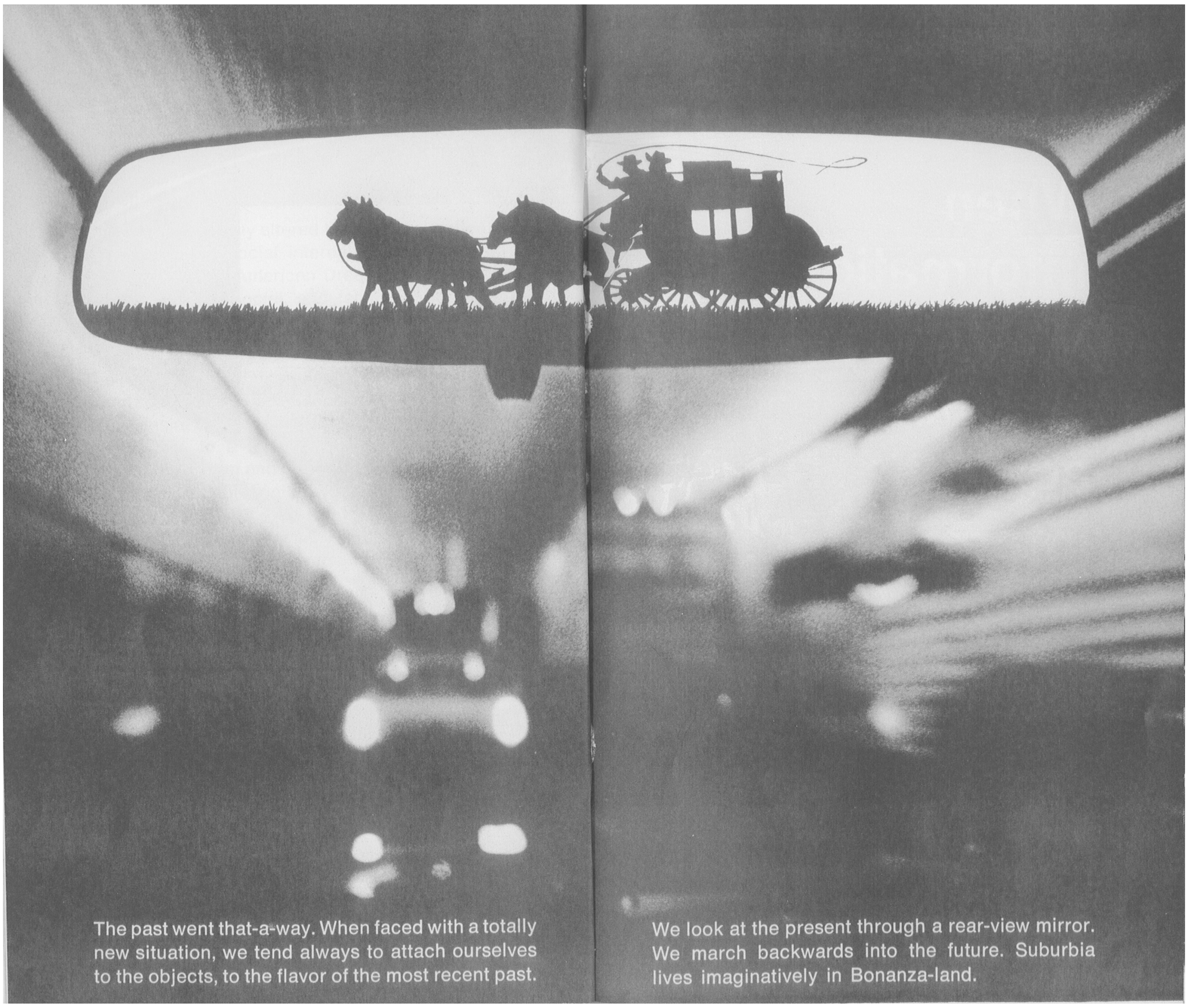

Fig 2.1: According to this metaphorical image, the driver focuses on the rear view mirror (the recent past), while the sights from the front window in the direction of movement (the present) are blurred. We tend to experience the present in terms of the past and we try to fit new technologies to the standards of the old environment. Thus, we tend to ignore the hidden ground/the new environment that comes with the new technology (Taken from McLuhan and Fiore 1967: 74 – 75).

❖ *The Metaphorical and the Literal*

To conclude the first two chapters let us examine again the debate over the *metaphorical* and the *literal*. Is human knowledge entirely metaphorical? Can we draw the line between the *metaphorical* and the *literal*? My answer is that *fixed* and *absolute literal meanings* do not exist, but only *relative literal meanings* which appear in a dynamic, holistic web of the metaphorical thought. The status of literal meanings depends on the context of use: in a narrow context one can hide the grand metaphorical frameworks on which the literal statements depend, but when we examine these statements in a broad context the metaphorical frameworks are revealed.

According to Lakoff, the traditional distinction between the metaphorical and the non-metaphorical is obsolete. This distinction no longer exists because studies from the past decades have shown that everyday language, the basic concepts of our language and abstract concepts, e.g. time and causality – are all constructed metaphorically. Nevertheless, Lakoff claims that statements, such as "the balloon went up", or "the cat is on the mat", are not metaphorical. Thus, sentences that describe concrete physical experiences might be defined as literal sentences (Lakoff 1998: 204 – 205). I agree with Lakoff that sentences that describe *immediate*, *direct* experiences are more "literal", but only in a relative sense, as I will explain below.

Similarly, when McLuhan claims that "All words, in every language, are metaphors", he immediately adds:

> However, all words are metaphors (except, in a special sense, the word 'word' itself): the non metaphorical word is a feature only of a primitive tribal thought and experience about words. The native hunter or Inuit says, 'of course "stone" is stone, else how could I known stone?' (McLuhan and McLuhan 1988: 121; McLuhan and Powers 1989: 30)

McLuhan further notes that for "archaic man language is an immediate evoker of reality, a magical form" (McLuhan and Watson 1970: 117; see also: Gordon 1997: 344, note 14). According to the archaic oral perception, as we have seen before, there is a clear and natural connection between words and things: "words are things and things are words". I do not think that we should adopt the naïve, uncritical approach of ancient oral cultures which tend to accept metaphorical assertions as the *plain* truth, but we should neither adopt the modernist-objectivist approaches which ignore the importance of the metaphorical thinking and even try to reduce metaphorical assertions to *literal* assertions.

In the beginning of chapter 1, I pointed out that McLuhan considered only the fourth definition of Aristotle as a metaphor. Under this definition, metaphors translate one situation into another, while creating analogical ratios between the two situations. According to McLuhan, metaphors are "discontinuous" since "a leap has to be made, across the interval between the two situations, each composed of a figure and ground". The other figures of speech which Aristotle defined as metaphors are variants or transformations of the discontinuous, resonant metaphorical form. The copular form (e.g., "He is a lion") and the simile form (e.g., "He is like a lion") transform the discontinuous resonant metaphor into a connected, linear form. They create an abstraction of the metaphorical perception and imagination. The copular "is" matches and connects figures, while suppressing the metaphorical ground of the situation. Thus, for example, the copular form transforms a metaphor like "The lion of Athens sprang on the foe" into a kind of a linear equation: "He is a lion". Similarly, Aristotle defined synecdoche and metonymy as metaphors. However, in synecdoche and metonymy the interactions appear *within* the same domain. Hence we can argue that these figures of speech are closer to the idea of *literal* knowledge. Synecdoche (the part for the whole or vice versa) transforms a metaphor into a connected form: a thing is perceived, more or less, *in its own terms,* i.e. "in some greater or lesser aspect of itself". For example in the synecdoche "All hands on deck" the whole (people on duty/ people who perform a certain task) is perceived as one of its parts (hands) (McLuhan and McLuhan 1988: 229 – 238).

The differences between the *metaphorical* and the *literal* depend, of course, on the definition of these terms. Indurkhya (1994b) defines metaphors as "symbols in the making", e.g. "The check scandal has become a metaphor for all the problems of Congress". Therefore we can say that he identifies metaphors as cases of synecdoche and metonymy. Under this definition, conceptual knowledge is always metaphorical, since we construct and experience it as a dynamic exemplar or as an ever-evolving model. In response to the claim that the meaning of a metaphor should be decomposed and explained in terms of its constituent literal meanings (otherwise a problem of infinite regression arises), Indurkhya turns the problem upside down. He argues that literal meanings are not primary and metaphorical meanings are not secondary. On the contrary, "conventional-literal meanings are merely metaphors that we have gotten used to" (Indurkhya 1994b: 70). This process is documented in the work of Lakoff and Johnson (1980), who analyze the metaphorical basis of conventional everyday language ("conventional metaphors" or "dead metaphors"). It should be noted that Indurkhya is not the only researcher who defines the essence of *metaphor* in synecdochic and metonymic terms. For instance, another group of researches suggests that metaphors are "class-inclusion assertions" or a type of "categorization process" (Thomas and Mareschal 2001; Glucksberg et al. 1997; Glucksberg and Keysar 1990). According to Glucksberg, Keysar and Mareschal, metaphors function as claims that describe categorical relations. Thus in a metaphor of the form "A is B", A is assigned to a category denoted by B. For example, in the metaphor "My job is a jail" the job is perceived as if it belongs to a category of unpleasant places which is represented by jails.

Are the categories themselves non-metaphorical? Let us reexamine the metaphor of "ideas as living beings". In this example Nick Hornby describes his doubts as "sickly kittens" that become "sturdy, healthy" cats (Barnden 2004: 15 – 17). Can we claim that the category of "ideas" and the category of "living beings" are pure literal categories from the outset, and now all that we have to do is to match between these two literal categories? In my opinion, the answer is no. Notice that the term *idea* is described metaphorically mainly because a literal definition of the term does not exist. One can perceive *ideas* in different ways. For instance, ideas are often perceived as food and this metaphor itself is based on other metaphors, such as "the mind is a container", "ideas are objects" and the conduit metaphor (Lakoff and Johnson 1980: 214 – 215). The same applies to the category of "living beings". The endless discussions about the definition of life and the characteristics of life demonstrate that the category of “living beings” cannot be defined as a literal category which does not depend on metaphors and techno-cultural frameworks. As I will show in the following chapters, living beings are perceived very differently in different cultures and in different eras.

Metaphors conflict with the myth of objectivity and therefore they conflict with the ethos of modern science. Following McLuhan (1962; 1964), Havelock (1963), Ong (1958; 1982), and Lakoff and Johnson (1980), I have argued that the objectivist view is based on the *conduit* metaphor and on the characteristics of print culture. The phonetic alphabet and scrip culture promoted the transformation of the *word* from an oral event (the spoken word exists only as an event, and any attempt to freeze the spoken word will cause it to disappear) into a static object. Moreover, the letters of the phonetic alphabet were free of ambiguity: “This was accomplished both by one-to-one matching of sign and sound, and by rendering the signs themselves inherently meaningless” (McLuhan and McLuhan 1988: 14). Script culture, which was represented by scholars like Plato, pushed aside the oral technique of mimesis that stood in the way of the autonomous *rational* personality. A new alternative developed on the phonetic ground: instead of mimesis and contextual-situational thinking, the phonetic alphabet enabled the appearance of abstract, analytic thinking, the logic of containers and the ideas of *detachment* and *objectivity*. Oral communication is much more dialogical, contemplative, personal and situational in comparison to writing, but the paradigm of the printed textbook, which was developed by Peter Ramus during the 16th century, created a very different trend: the new textbook tended to be factual, analytic, divided into separate subjects, standard, self-evident, self contained and complete. Print culture strongly promoted the objectivist approach and the idea of *literal meanings* that define the objective truths. The industrial homogeneity of print enabled the abstraction of contextual meanings, the mass production of standard, homogenous definitions and dictionaries and the standardization of literal *correctness*. Even local dialectics were replaced by the standard national languages. The endless identical copies of the printed book create “a sense of closure” and *finalization* of the text, as Ong calls it.

Ong describes the fundamental flaw in the *conduit* metaphor as follows: “Human communication, verbal and other, differs from the ‘medium’ model [the *conduit* model] most basically in that it demands anticipated feedback in order to take place at all. In the medium model, the message is moved from sender-position to receiver-position. In the real human communication, the sender has to be not only in the sender position but also in the receiver position before he or she can send anything. To speak, you have to address another or others" (Ong 1982: 176 – 177). Modern literate society tried to establish literal meanings "in terms of collectively endorsed standards of correctness for use" (Rommetveit 2003: 214; Rommetveit 1988; Gibbs 1994: 71 – 75), but the new currents in humanities and social sciences challenge the modernist-objectivist program. For example, following Bakhtin and his colleagues, Ragnar Rommetveit suggests that the meanings of words are not fixed. According to his view, words are associated with meaning potentials and their actual meanings are dialogically constituted in inter-subjective acts of communication (Hagtvet and Wold 2003; Linell 2003). Similarly, a new current of cognitive psychologists argue that the understanding of sentences and texts does not depend on the access to pre-stored prototypes (i.e. abstract concepts which are defined by a set of necessary and sufficient conditions and which are constructed in the mind from concrete exemplars), but on a dynamic process of composing context dependent information and meanings in concrete situations and in the moment of understanding (Gibbs 2003b).

Psychological studies disconfirm the belief in the priority of *literal processing* over *metaphorical processing*. According to these studies, the understanding and paraphrasing of metaphorical expressions are no more difficult than the understanding and paraphrasing of non metaphorical expressions. At this point I would like to emphasize again that conventional categories are themselves metaphorical and therefore I accept the idea of *literal processing* only in a relative sense and I do not think that we can make clear distinctions between the *metaphorical* and the *literal*.[29] Psychological studies show that the reading time and the time required to comprehend metaphorical statements are longer than the reading time and the time required to comprehend literal statements only in a minimal context, but not in a wider context of passages (and we usually encounter statements in a broad context). The context is important for the creation and understanding of meaning in both *literal* and *metaphorical* statements. Metaphorical interpretations of sentences do not appear after the attempt to create a literal meaning is failed. Actually, metaphorical meanings are automatically produced even when literal meanings are available as well. For example, in a certain experiment the participants have read the sentence “Bob Jones is a magician” in a context that includes both literal and metaphorical meanings. The participants have read this sentence in a passage describing Bob as a successful performer who can *saw* people and pull rabbits out of hats, although the money he earns *disappears into thin air*. The literal meaning (or the more conventional meaning) corresponds to Bob's occupation (a magician). The metaphorical meaning relates to Bob's business skills. Now the participants were asked to decide whether the sentence “Bob Jones is a magician” is literally true or false. However, since the literal meaning and the metaphorical meaning are in conflict with each other in the given context, it took the participants a longer time to give a positive answer, in comparison to another context in which Bob was described as a successful businessman (for references, review and discussion see: Coulson and Matlock 2001; Gibbs 1994: 99 – 106; Thomas and Mareschal 2001: 6).

The inability to define what *purely literal* meanings are weakens the objectivist program, to say the least.[30] The objectivist model of meaning and communication itself is based on metaphors and especially on the *conduit* metaphor. Hence the idea that one can generate *objective literal* truths using the metaphorical models of the objectivists is not very convincing. Moreover, even Lakoff"s examples of *simple* literal sentences that describe direct physical experiences, e.g. “the cat is on the mat”, are problematic. As Ludwig Fleck (1979), Thomas Kuhn (1970) and Norwood Russell Hanson (1958) have shown, observational language itself is theory laden, and I think that Lakoff would agree that (a) theories have many metaphorical aspects (b) meanings cannot be ascribed to the isolated sentence because they depend on the context. The objectivists (for example, the logical positivists) have tried to fix the literal meanings of sentences by defining the conditions under which the sentences would be objectivley true or false. Supposedly, in order to define the literal meaning of the sentence “the cat is on the mat” one has to specify the combined truth conditions of the sentence and its constituents (“cat”, “mat”, “on”). Nevertheless, as Coulson points out, the philosopher John Searle has shown that even simple cases such as this are not context-independent. If the cat and the mat are floating in outer space, outside the Milky Way galaxy, than “there is no gravitational field relative to which one is above the other.” What are the conditions under which we can determine whether the cat is on the mat or the mat is on the cat? In another hypothetical situation the cat and the mat are in the same position, but the cat is "suspended by wires so that she places no pressure on the mat." Is the cat on the mat? In each of these cases there is no clear answer which is determinate and context-independent (Coulson 2001: 4 – 10). The objectivists, and even non-objectivists like Lakoff, fail to notice the hidden context of simple *literal* statements. We tend to ignore the context or take it for granted, but simple *literal* statements are not *really* isolated and the meaning of each of them depends on an inclusive context that contains many metaphorical aspects. The meaning of the sentence "the cat is on the mat" depends on many issues, aspects, problems and metaphors, such as the theory of gravity, the theory of relativity, the concept of *gravitational field* and other aspects which relate to the constituents of the sentence and the potential situations which are described in the sentence.

Similarly, in his attack on the positivistic program, the philosopher W.V. Quine (1961) showed that the verification theory of meaning, i.e. the reductionist dogma of Rudolf Carnap and the logical positivists, failed. Meaningful statements, according to the dogma of reductionism, should contain only terms that refer to immediate experience, logic and mathematics. The positivists argue that literal meanings could be defined according to the verification theory of meaning: if one can specify the truth conditions of the statement, i.e. the empirical and logical conditions which confirm or disconfirm the statement, then the statement is meaningful; a sentence which fails to provide its truth conditions is *meaningless*, e.g. any *metaphysical* statement (Ayer 1946). Conversely, Quine argues that an isolated statement cannot be regarded as an atomic unit of meaning, because "statements about the external world face the tribunal of sense experience not individually but only as a corporate body." For example, the statement "Quality q is at x; y; z; t" cannot be translated into terms of immediate experience and logic, because it is not clear at all how could we define the connective "is at" using terms of immediate sense data (Quine 1961: 40 – 41). According to the *Duhem-Quine Thesis*, the encounter of any statement with sensory experience always depends on explicit or implicit background assumptions. In fact, our entire system of theories and beliefs is subjected to empirical testing even when we focus on a specific proposition and take for granted the background assumptions. Moreover, when readjustments and revisions are needed in the holistic belief system due to inconsistencies between the system and sensory experience, they are not determined by sense experience in itself but by conventional considerations. Our belief system is dynamic and it includes statements which are close to the *periphery* (to the *boundary* of experience) and statements which are more *central*. Although there is a tendency to make minimal changes in the system, we sometimes choose to replace central statements and make larger revisions, for example "Revision even of the logical law of the excluded middle has been proposed as a means of simplifying quantum mechanics" (Duhem 1954; Quine 1961).

In this chapter and in the previous chapter, I have argued that metaphors shape human thought, from everyday language, through the basic concepts of language, and to the objectivist ideas and the structure of logical arguments. Moreover, as I will show in part II, scientific theories largely depend on techno-cultural metaphors. Now, I do not deny that *literal* meanings can appear in these grand metaphorical frameworks. However, since they depend on the metaphorical frameworks, *literal* meanings are *relative* and not *fixed* or *absolute*: they exist only temporarily and locally as fragments in the dynamic web of metaphoric knowledge.[31] It is hard to identify the hidden metaphorical ground of literal statements in a narrow context, but in a broad context the task is easier, especially when an old metaphorical framework is replaced by a new metaphorical framework. Let us take Aristotle as an example. For him, the movement of a solid body towards the center of the universe due to its *telos* is a simple literal description of a direct observation: "The observed facts about earth are not only that it remains at the centre, but also that it moves to the centre…the natural movement of the earth, part and whole alike, is to the centre of the whole...The goal, surely, must be the centre of the whole" (Aristotle, *On the Heavens*, 1985, vol.1: 295a – 297a). Yet this *simple* description depended on an entire way of thinking that shaped the Aristotelian Universe and attributed *telos* to each of the five elements (see, for example, the discussion in chapter 4 on Aristotle and the *macrocosm*↔*microcosm* metaphor). The grand metaphorical framework that underlies the *observed fact* of Aristotle can be easily identified, because the Aristotelian Universe collapsed hundreds of years ago. The Clockwork Universe that took the place of the Aristotelian Universe collapsed as well.

3

The Electronic Prosthesis of the Nervous System and the Collapse of the Old Categories

Having extended or translated our central nervous system into the electro-magnetic technology, it is but a further stage to transfer our consciousness to the computer world as well (McLuhan 1964: 60)

In this sense a handicap opens up a veritable terrain of anticipation, an objective experimentation on the body, the senses, the brain, in particular in its relation with computers (Baudrillard 1988a: 51).

In this chapter I will begin to examine the reciprocal interaction between the two domains of the *body↔machine* metaphor. Technologies are extensions of the body which are designed by metaphorical thinking. While simple tools are motionless extensions of organs, machines are extensions of bodily functions or processes. Furthermore, while mechanical automata are based on fragmentation, specialism, linearity and standardization, the new electronic automata are based on totality, implosion, circularity and flexibility. In addition to these observations, which were described by McLuhan, there is another important difference between mechanical and electronic extensions: the electronic implosion fuses the *body* with the *machine*, and thus the old categories of the *natural* and the *artificial* began to collapse. Metaphors are dynamic and in this context we will see that the relationship between the domains of the *body↔machine* metaphor has become less analogical and more metonymic and synecdochic. The cyborg has created a new domain that unifies the organic and the technological. Recombinant DNA technology turns the body into an imploded technological prosthesis of itself and together with the technology of stem cells transplantation it creates an inter-species implosion. Therefore the term ***ex**-tension* does not accurately capture the characteristics of the electronic prosthesis.

In the previous chapter I interpreted McLuhan's assertion that technologies are extensions of the body, by using the terms of the conceptual theory of metaphor. I have argued that the *body* is the source domain and the *environment* is the target domain. Organs and bodily functions are the basic models according to which tools and machines are designed. In other words, we reshape our environment and design artificial environments as functional extensions of the body. A shovel, for example, is an extension of our hand, i.e. a physical metaphor that translates the environment into an artificial hand. Additionally, I have noted that the body is only the basic source domain of each technological extension: in order to create extensions for the body we use additional source domains, such as cultural metaphors (the *more is up* metaphor), bodily characteristics of other species (wings of birds and insects as models of aircraft wings) and existing technologies (the computer screen as a desk). One of the main ideas in the conceptual theory is that the source domain is not affected by the metaphorical interaction. Nonetheless, I will show that the relationship between the domains of the *body↔machine* metaphor is reciprocal: due to its interaction with technology, the body is modified perceptually, conceptually, theoretically and even physically (see the schematic representation of the thesis in fig. 0.1, in the Abstract). In the present chapter I will focus more on the physical aspects of this interaction and in part II I will focus on the perceptual, conceptual and theoretical aspects.

Technologies are not passive extensions of the body. The reciprocal interaction between the two basic domains of the *body↔machine* metaphor is flexible and multidirectional:

- **(1-a)** Technology is designed as an extension or prosthesis of the body which enhances and amplifies organs or bodily functions by translating them into a new medium / a new form.

- **(1-b)** Organs and bodily functions can serve as models for the design of technologies that in return serve as extensions of different organs or bodily functions.

- **(2)** Technology serves as a perceptual/conceptual/theoretical/physical model for experiencing, understanding and redesigning the body as a machine.

Metaphorical relationship is not symmetrical. In most cases, people tend to use the *body↔machine* metaphor without being aware that the technology which appears in their metaphor is an extension of certain aspects of the body. Even when a person builds a machine as an extension of certain aspects of the body, he or she may still freely use the *body↔machine* metaphor in both directions. For example, Norbert Wiener, one of the founding fathers of cybernetics, discussed the connection between negative feedback and organic homeostasis, although the negative feedback is not an extension of homeostasis (as I explained in the previous chapter, the negative feedback is an extension of the mental-manual control). In other words, Wiener focused in this case on the connection between (1-b) and (2), and he was not limited by the connection between (1-a) and (2). On the other hand, when inventors develop a technology, or when cyberneticists, biologists and M.D.s develop cyborgs, they focus on (1-a) and not just on (1-b) and (2). The overall pattern of the interaction between the *body* and the *machine* depends on many other domains and metaphors. On the one hand, we utilize natural, organic and social sources in order to create the extensions. On the other hand, the technological extensions modify the natural, organic and social environments in many respects, such as the creation of the artificial environment, ecological changes, the development of the *body↔machine* metaphor, the creation of farm animals and cybernetic organisms, and the appearance of perceptual and socio-cultural modifications which are related to media and technology (*the medium is the message*). In short, the *body↔machine* metaphor is part of a total field.

❖ *Electronic Technology as an Extension*

McLuhan argued that the electronic media is “the second great extension of the central nervous system.” According to this metaphor, in the electronic age humans *wear* their brains outside their skull and their nervous systems outside their skins (McLuhan 1964: 57, 269). Note that in the previous chapter we have already discussed the “first great extension of our central nervous system”, the spoken word, which amplifies mental abilities, translates all senses, even to one another (“loud color”, “bright sounds”), and serves as an extension of consciousness in the social world. Now, if the electric medium is an extension of the nervous system, and the cybernetic feedback is an extension of the mental-manual control (as I have argued in the previous chapter), then electronics, or the electro-cybernetic technology, creates very efficient extensions of bodily functions that integrate the neural and the manual. I will try to explain why the electronic technology is a metaphorical extension of the nervous system and the brain and how it reshapes the body. By using mechanical instruments, humans amplified each of their senses separately (although changes in each of the senses affect the other senses, as McLuhan emphasized): lenses, such as glasses, microscopes and telescopes, enhance the visual sense; stethoscopes enhance the sense of hearing. I think that the only exceptions are animals which were selected and domesticated, e.g. hunting dogs: animals are not simple tools or mechanical automata and they can serve as extensions of most senses, and of some physical abilities of their owners, simultaneously. Let us examine the functions of electronic technology in relation to its users. The *essence* of electronic media is amplifying the senses and transmitting sense data. In other words, electronic media are extensions/prostheses of their users. Electric light, for example, enhances the ability to see; telephone and radio enhance the sense of hearing and the transfer of voices; cinema enhances the visual sense and the sense of hearing and it transfers the image of the body, its gestures and voice from place to place. According to McLuhan, television is the most interesting prototype of the new stage, since it integrates the senses. Televisions and monitors can enhance the visual sense and the sense of hearing simultaneously, and thus they render the limitations of space and time obsolete. Yet McLuhan argued that monitors are actually tactile because they are based on “light through” technology and they project the objects on the users.[32]

Notice that today touch screens are becoming more and more popular and sophisticated. Additionally, the television of the future will be able to transfer smells, but television is only the prototype of what McLuhan predicted. The computer has opened up a new range of possibilities. Virtual Reality can enhance all the senses simultaneously and it is therefore the ultimate expression of the electronic prosthesis of the senses. [33]

Synesthesia is a unified field of all sense experience or the meeting and translation of all senses one into the other. If the nervous system creates inner synesthesia, as language and consciousness show ("loud color", "bright sounds"), then it could be argued that electronic media creates an outer simulation of synesthesia. According to McLuhan, an old dream of poets and artists was realized in the age of television: television, as a prototype of what we call today virtual reality, is the closest technological form to *synesthesia* or *haptic* sense (the sense of touch as a unifying sense; note that touch is the sense from which all other senses had evolved) (McLuhan 1964: 60, 107 – 108, 315, 333; McLuhan and Powers 1989: 5, 94). The electric medium enables to make various translations of the senses one into the other. In 1953 the cyberneticist Gordon Pask and the mathematician Robin McKinnon-Wood managed to build the first Musicolour. The Musicolour is an electronic instrument that translates sounds into a play of lights, an idea which was suggested by artists who had dreamt about synesthesia. As Pask explains: "The Musicolour system was inspired by the concept of synaesthesia and the general proposition that the aesthetic value of a work can be enhanced if the work is simultaneously presented in more than one sensory modality. This notion is old enough. Baudelaire played with it in 'Les Fleurs du Mal'. Scriabin wrote a part for a 'light keyboard' in one of his symphonies and Kleine (among others) realized a 'light keyboard' in the metal. Walt Disney's *Fantasia* (1940) is a synaesthetic film. Nowadays, when psychedelic effects are commonly synchronized with music, the whole idea of augmenting sound by light is almost as banal as another happening. However, it was not so in the early 1950s" (Pask 1971: especially page 77; Pickering 2002: 426 – 427). There are numerous other examples of the electronic capability to translate the senses one into the other. For instance, the cyberneticist Norbert Wiener developed the "hearing glove": this instrument translates voices into touch by stimulating the fingers of a deaf man with electromagnetic vibrations that are analogous to sound frequency (Hayles 1999: 99).

Voice prints are translated into visuals patterns by using electronic recording of sounds (McLuhan and Fiore 1967: 118). Another example is the translation of visual text, e.g. SMS, into voice.

- Extensions that are physically linked to the human body are called *prostheses*. Electronic prostheses are the ultimate expression of the reciprocal interaction between the *body* and the *machine*, and they physically redesign the body: in the past tools and the artificial environment in general indirectly contributed to the evolution of the body, but through the electronic prostheses we directly reconstruct the body as a machine.

In medicine the electronic prostheses are used for enhancing or restoring damaged functions of different organs. Hearing aids serve as electronic extensions of the sense of hearing. Small electronic devices, the cochlear implants, can transform sound waves into electric signals that the brain can use. Already in the 1950s' scientists were able to implant electrodes inside the brain with the purpose of recording and stimulating. Today researchers in the field of brain–machine interfaces (BMIs), or brain–computer interfaces (BCIs), are attempting, for example, to restore sight (Friehs et al. 2004). In January 2000 a successful surgery on a blind man was reported: a patient named Jerry, who lost his sight decades ago, began to see in a limited way. William Dobelle, who developed the system, reports:

> We report the development of the first visual prosthesis providing useful "artificial vision" to a blind volunteer by connecting a digital video camera, computer, and associated electronics to the visual cortex of his brain. This device has been the objective of a development effort begun by our group in 1968 and represents realization of the prediction of an artificial vision system made by Benjamin Franklin in his report on the "kite and key" experiment, with which he discovered electricity in 1751 (Dobelle 2000: 3).

The system is composed of a miniature TV camera and an ultrasonic sensor (mounted on the two lenses of the patient's sunglasses) that receives the data and sends it to a small computer the patient carries with him in a belt pack. The computer processes the data and stimulates the brain using 68 platinum electrodes implanted in the surface of the brain's visual cortex (see fig. 3.1).

An Electronic Prosthesis of the Brain and the Visual Sense

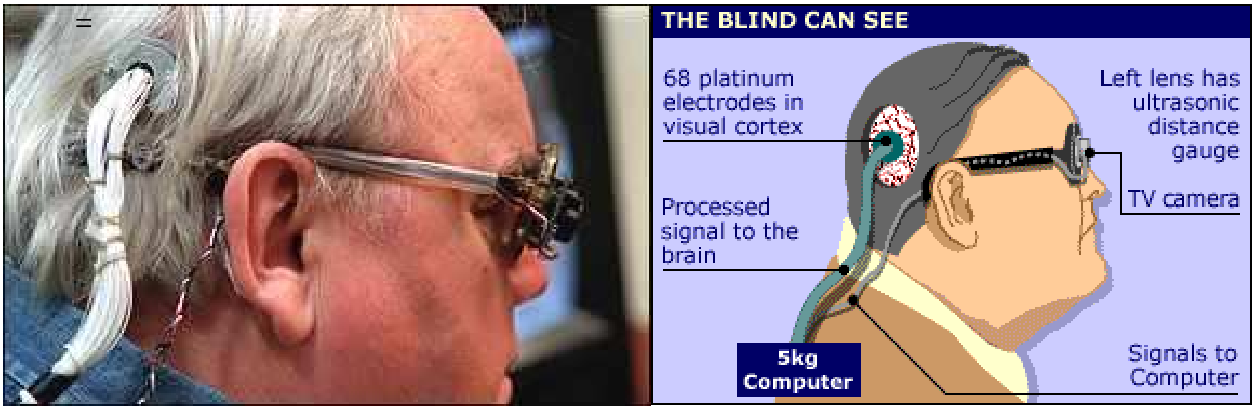

Fig 3.1: The electronic prosthesis of Jerry's eyes and brain (Taken from BBC News: 18 January, 2000)

This prototype solves the problem of blindness only to a small degree. Jerry cannot see an image in the same way a healthy person can. He sees up to 100 specks of light outlining the edges of objects in front of him. Furthermore, the visual cortex of another patient, who has lost his eyesight as a child decades ago, failed to interact with the system of Dobelle. Nonetheless, according to Dobelle, the system enables Jerry to recognize 5cm long letters from 1.5m away. The system also helps Jerry to navigate, and when the camera is replaced with an electronic interface he can use a computer (Dobelle 2000).[34]

The electronic technology enables us to amplify other functions that are attributed to the brain and to the central nervous system. Computers enhance mental and cognitive abilities, such as memory, calculation, information processing, analysis of situations and decision making. McLuhan believed in the potential of the electronic prosthesis to enhance consciousness and thought. He argued, for example, that:

[A future medium like a kind of computerized ESP would process] consciousness as the corporate content of the environment - and eventually maybe even [lead to] a small portable computer, about the size of a hearing aid, that would process of private experience through the corporate experience, the way dreams do now (McLuhan1996 [1965]: 297).

Indeed, by using electronic prostheses, practitioners in the life sciences are trying to enhance the brain and the nervous system directly: the computer itself is analogous to the body, but it can also become part of the body. The goal is to develop extensions that can enhance different functions of the brain, mind, consciousness and thought, inside and outside the body. These new types of BMIs or BCIs are called “neuromotor prosthetics”. To some extent “neuromotor prosthetics” can bypass the spoken language, “the first great extension of our central nervous system”. This technology is composed of three elements: (1) Data acquisition module - a receiving technology that records neural input non-invasively using EEG (recording field potential from the cortical surface), or invasively using extracellular brain recording (2) Data interpretation module - a unit that processes the input signal and translates it into the *desired* motor action (3) Data output module - a device or an “effector organ” which is controlled by the processed signal, e.g. a computer cursor, a robotic arm or patient's limbs. Since the end of the 1990s, progress was made in teaching normal subjects, and patients with motor disorders, to move a cursor on a computer screen, to move a robotic arm, and to open and close a motionless hand. Some groups of researchers have succeeded in training monkeys to perform the same tasks, while electronically amplifying their brain (Friehs et al. 2004). The BMI/BCI method serves as an alternative for healing spinal cord injuries. The origins of this method can be traced to E. M. Schmidt's proposals from 1980, which were based on the experimental work of E. E. Fetz and his colleagues in the late 60s – early 70s (Carmena et al. 2003: 193).

The progress in the field of BMIs was demonstrated by studies on human subjects and animals in the late 20th century. One of the earlier studies has shown that an electronic spelling device can bypass damaged motor neurons of paralyzed patients who cannot speak and write (Birbaumer et al. 1999). During the trial slow cortical potentials were recorded using EEG, while two patients were trying to focus their attention on moving a cursor on a video screen. After a training period the patients succeeded in selecting letters and writing messages (up to 85% of success). Another study has shown that it is possible to train rodents to control a robotic arm using a BMI (Chapin et al. 1999). In this experiment the activity of neurons was recorded and analyzed using electrodes implanted in the motor cortex. At first, rodents were trained to pull a lever to obtain water. Brain signals associated with the forelimb movements were analyzed and electronically translated into commands that control robotic arm movements. When the trial switched from the *lever movement* mode to the *neuro-robotic* mode, the rodents had to produce a similar neuronal activity in order to obtain water. In the *neuro-robotic* mode the information that controls the water dropper was taken directly from brain activity. Immediately after switching modes the rodents continued to press the lever, but finally, after training in the *neuro-robotic* mode, their arm movements were diminished (trials without pressing the lever), and in one case they even stopped (a trial without a forelimb reaching movement).

At the beginning of the 21st century, Miguel Nicolelis, Johan Wessberg and their colleagues showed that primates can learn to control objects with an enhanced brain (Wessberg et al. 2000). The experiments continued and the results were published in another article (Carmena et al. 2003). The researchers were able to teach two macaque monkeys to indirectly control reach-and-grasp movements without using their arms. First, the monkeys were connected to the BCI/BMI system. Then they have learned to move a cursor on a screen and to change its size by using movements and gripping force applied on a joystick (see fig. 3.2a). The joystick controlled a robotic arm: its movements were translated into the cursor's position on the screen (representing the reaching arm), and the gripping force was translated into the cursor's size (representing the grasping task). The monkeys received a visual feedback through the screen. In the *pole control* mode brain signals from frontal and parietal cortical areas were recorded and analyzed. After the system analyzed the relevant motor parameters (hand position, hand velocity and gripping force), the trial switched to the *brain control* mode. In this mode the data controlling the robotic arm (and the virtual objects on the screen) is taken directly from the brain. The system processed the data in real time. When the monkeys realized that they do not control the cursor with their hands, they stopped moving their arms while performing the task. Their enhanced brains were able to control reach-and-grasp movements of a robotic arm. Today, lab monkeys with implants in the primary motor cortex, composed of arrays of microelectrodes, can operate prosthetic arms using their enhanced brains. The monkeys can feed themselves and perform other physical tasks via the prosthetic arms (Velliste et al. 2008; see fig. 3.2b).

A Direct Electronic Prosthesis of the Brain

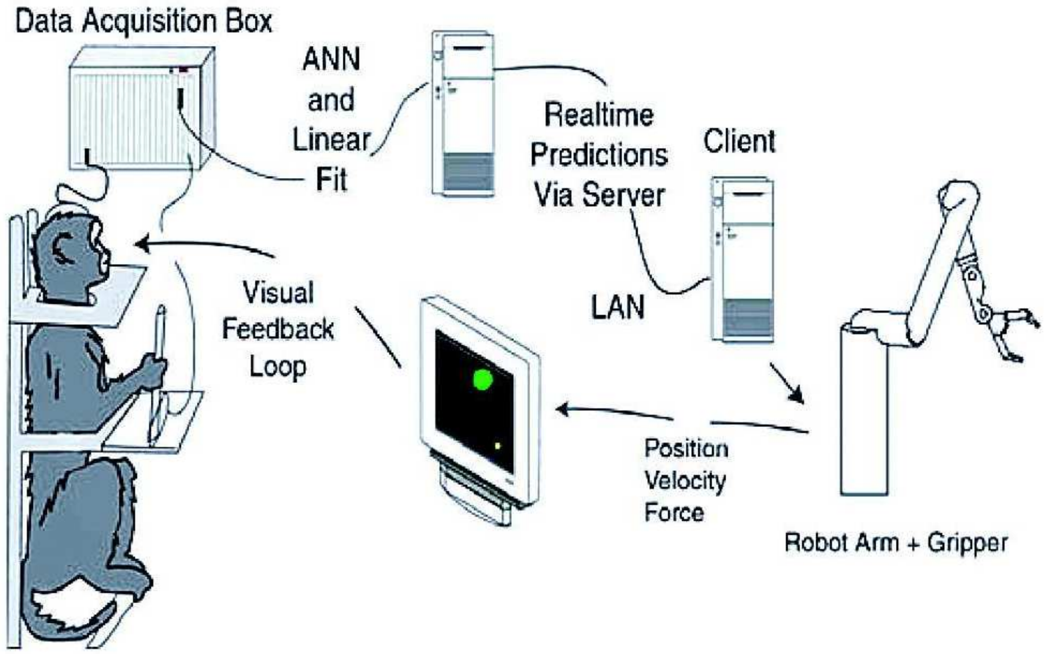

Fig 3.2a: An example of a BCI. A macaque monkey learns to indirectly control the movements of a robotic arm, by using an enhanced brain and a feedback loop from the data output module (the robotic arm). Her direct task was to grasp virtual objects and move them to their targets on the screen. In this case the task is to move the little cursor to the big green target. In the *brain control* mode the monkeys realized they do not perform the task with their hands. Thus they stopped moving their arms, and the researchers removed the joysticks (Taken from Carmena et al. 2003: 195).

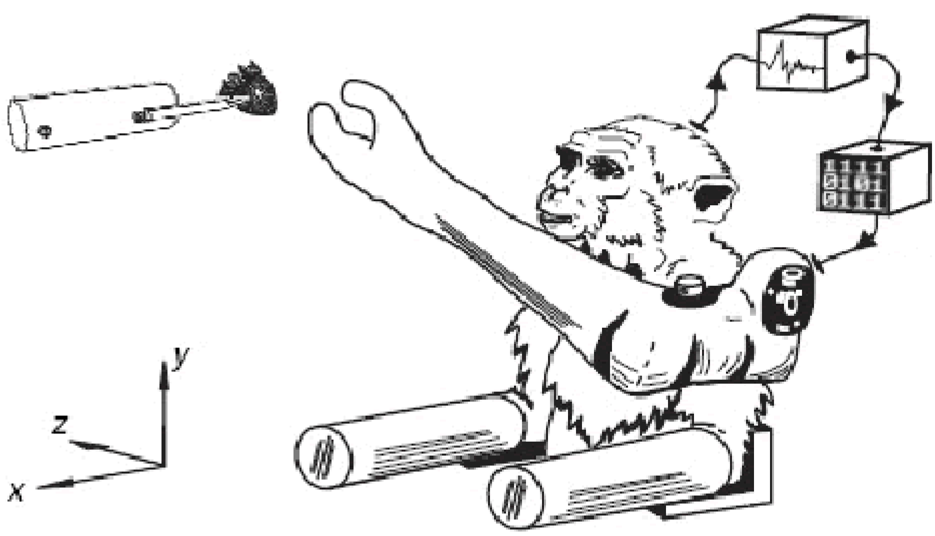

Fig 3.2b: An advanced BCI. A macaque monkey operates a prosthetic arm to reach food. The arms of the monkey are restrained by tubes and a computer-brain system guides the robotic arm which is positioned next to the shoulder (Taken from Velliste et al. 2008: 1099).

In the summer of 2004, at the New England Sinai Hospital in Massachusetts, a *mind reader* chip, commercially known as the *BrainGate*, was implanted in the motor cortex of Matthew Nagle, a man paralyzed from the neck down (quadriplegic). The chip was developed by John Donoghue and a group of researchers from Brown University, and it was manufactured by Cyberkinetics, Inc. Nagle uses the *BrainGate* chip as an extension of the nervous system that helps him to overcome motor disabilities. The chip consists of about 100 electrodes that send brain signals to a computer serving as a data interpretation module. The interpreted data is translated into cursor movements, which are controlled by the user's mind. Nagle is able to perform different tasks with devices attached to the system, such as turning lights on and off, switching channels on TV, opening e-mails, moving a prosthetic arm, grabbing and passing. Future developments of BCIs are expected to enable finer and easier arm movements (Hochberg et al. 2006; Friehs et al. 2004: 2704).[35]

Disabled people are only the *avant-garde* of the new trend. A growing number of people who work in a computerized environment adapt their bodies to technological systems. The easiest way to make one's body a part of a technological system is to insert a RFID (Radio Frequency Identification) implant beneath the skin. RFID tags are composed of chips and antennas and they can be used to monitor machines, industrial products, animals and humans. The tag is inserted in the back of the hand and it enables a direct interface with electronic devices. A new generation of cyberneticists is trying to realize the vision of the founding fathers of the field. Kevin Warwick, a cyberneticist from the University of Reading in England, is one of the representatives of the new generation. He believes that humans will become inferiors compared to intelligent machines and cyborgs. Warwick's *project cyborg* is aimed at transforming the *human* into the *cyborg*. In 1998 Warwick implanted a RFID chip inside his arm (Warwick 2000). By using the chip, he can operate doors, lights, heaters and other computerized systems "without lifting a finger" (*project cyborg 1.0*). On March 2002 a micro electrode array consisting of 100 individual electrodes was implanted in the median nerve of Warwick's arm (*project cyborg 2.0.*). By using the chip, Warwick was able to control an electric wheelchair and an intelligent artificial hand. In order to overcome the limitations of speech, and to create in the future a direct link between different nervous systems and telepathic communication, Warwick's wife, Irena, was implanted with a simpler chip. The nervous systems of the Warwicks were electronically linked by making a connection between the two chips and a computer. When Irena's nervous system generated a motor neural signal, Kevin's nervous system was stimulated and vice versa. Warwick believes that the first step in direct communication of thoughts requires that the implant will not be positioned in the peripheral nervous system but directly in the motor neural brain region (Warwick 2002; Gasson et al. 2002; Warwick 2003). Today commercial companies, such as Applied Digital Solutions, sell the RFID chips for human use: identification, direct interface, controlling various devices, storing medical records, monitoring patients and tracking people.[36] The discussion on direct prostheses as extensions that enhance the body is explicit. Warwick, for instance, proclaims:

Humans have limited capabilities. Humans sense the world in a restricted way, vision being the best of the senses. Humans understand the world in only 3 dimensions and communicate in a very slow, serial fashion called speech. But can this be improved on? Can we use technology to upgrade humans?
The possibility exists to enhance human capabilities. To harness the ever increasing abilities of machine intelligence, to enable extra sensory input and to communicate in a much richer way, using thought alone. Kevin Warwick has taken the first steps on this path, using himself as a guinea pig test subject receiving, by surgical operation, technological implants connected to his central nervous system (from Warwick's homepage: http://www.kevinwarwick.com/ICyborg.htm).

Although he did not believe in technological utopianism, McLuhan observed that a "global network" of collective consciousness has begun to take shape through the electronic extension of our central nervous system (McLuhan 1964: 60 – 61, 80, 227, 252, 348; McLuhan 1996: 295 – 297).[37] The World Wide Web, virtual reality, BMIs and neural-prostheses are a step in this direction. Since the early 1980's, and later with the development of virtual realty and the internet, writers from the *cyberpunk* genre like William Gibson, and script writers of popular Hollywood movies and TV series, such as *Star Trek*, *Matrix* and *Sliders*, have been fantasizing about electronic and computerized devices which are directly connected to the nervous system and the brain and thus making consciousness socially accessible on a global scale, as in a collective virtual dream. The implosion and blend of science and science fiction is evident. Science fiction writers are influenced, of course, by scientists and cyberneticists. At the same time, scientists are influenced by the society in which they live, and it may be said that the techno-cultural environment that characterizes contemporary society is the *matrix* of the *hyperreal*, as described by Baudrillard (see the following section). In other words, science and culture influence each other, as researchers from the field of BMIs admit: "The idea of connecting the human brain to a computer or machine directly is not novel and its potential has been explored in science fiction" (Friehs et al., 2004: 2702). Kevin Warwick, for example, is deeply influenced by Isaac Asimov. As a paraphrase of Asimov's *I robot*, he called his book: *I Cyborg* (2002). Note that Asimov himself was both a biochemist and a science fiction novelist.

The experiment of Kevin and Irena Warwick is part of the attempt to create global electronic extensions of the human nervous system. In an article entitled *"Extending the Human Nervous System through Internet Implants - Experimentation and Impact"*, Warwick and Mark Gasson describe the following experiment (Warwick and Gasson 2004). In May 2002 a connection was established between the chip that was implanted in Warwick's body and a robotic hand, through the internet. Warwick was at Colombia University in New York and the robotic hand in Reading University, UK. When Warwick operated his own hand, the neural signals that regulate the movements of his hand were transmitted to the robotic hand via the chip and regulated its movements. A feedback sensory data was sent from the robotic hand to Warwick's Nervous System, and thus Warwick was able to control the robotic hand blindfolded. McLuhan's assertion that in the electronic age we *wear* our brains outside our skulls and our nervous systems outside our skins is realized in the new environment of BMIs, neural-prostheses (implosion of the organic and the technological), internet and VR (implosion of space and time). Implosion is the electronic message:

> Instead of tending toward a vast Alexandrian Library, the world has become a computer, an electronic brain, exactly as in an infantile piece of science fiction (McLuhan 1962: 32).

The interaction between the domains of this metaphor, the nervous system and the electronic communication system, is reciprocal and complex and experientially speaking it is well founded. First, the phenomenon of electricity characterizes both electric machines and the nervous system. Moreover, as I have already explained, electronic technology serves as an extension of functions that are attributed to the brain and the nervous system, and on the other hand the brain and the nervous system are being physically redesigned using electronic technology. The origins of the metaphorical view that is described in the citation above can be traced to the development of commercial telegraph in the 1840s. In 1851, for example, the author Nathaniel Hawthorne described the characteristics of the new techno-cultural environment as follows:

> Is it a fact, or is it a dream, that, by means of electricity, the world of matter has become a great nerve, vibrating thousands of miles in a breathless point of time? Rather, the round globe is a vast head, a brain, instinct with intelligence! Or, shall we say, it is itself a thought, nothing but a thought, and no longer the substance which we deemed it! (Hawthorne: *The House of the Seven Gables* 1851; cited in McLuhan and Powers 1989).

Similarly, Emerson asked, "What shall we say of the ocean telegraph, that extension of the eye and ear...?" (Emerson 1968 [1870]: 161). In the second half of the 19^{th} century many biologists perceived the electric telegraph as an extension of the nervous system and at the same time they used the telegraph as a model of the nervous system. Leading physiologists, such as Hermann Von Helmholtz and Emil Dubois Reymond, had a close relationship with electric engineers. The influence was reciprocal. In 1851, Reymond explained that the electric telegraph is "modeled in the animal machine" and that there is a kinship between them (Otis 2002: 105; Helmholtz 1962 [1868]: 97 – 99, 119 – 121). Rudolf Virchow concluded that "the same kind of electrical process takes place in the nerve as in the telegraph line or the storm cloud" (Virchow 1958 [1858]: 107). When the telephone was invented the metaphor was updated. The philosopher Henry Bergson described the activity of the brain as a "central telephonic exchange" (Gere 2004: 358), and Frederick Gates, pointed out that neuronal communication resembles an array of telephone cables (Martin 1987: 36 – 37).

- So far I have argued that electronic systems and computers are not passive extensions of the nervous system and the brain: through electronics, the brain and the nervous system are being physically redesigned as machines. Yet, I would like to emphasize that the interaction of the *body* and the *machine* is not only physical but also perceptual and conceptual.

First, electronic systems and computers are used as models for the function of the nervous system and the brain. Consequently, as the debate between John Searle (1990) and Paul Churchland & Patricia Smith Churchland (1990) demonstrates, the following questions arise in the cognitive science: is the brain a certain type of computer? Can one define consciousness and intelligent behavior as computer programs?[38] Moreover, the metaphoric interaction is not limited to the characters that are enhanced by the electronic technology, e.g. the senses or mental and cognitive abilities: the new technology can serve as a metaphorical model for any other character of the body, for example, in molecular and evolutionary biology the DNA is described as a computer program (see, for example, Dawkins 2000 [1986]; see also the discussion in the following sections). Is the DNA a computer program? These questions are part of a larger discussion. Tools and machines were always used as metaphorical models of the body and its organs. Herman Boerhaave and the mechanists promoted the idea that the body is composed of axes, fences, levers, pumps etc (see, for example, Boerhaave 1766 [1708], vol. 1: 80 – 95). Their successors in the industrial age updated the mechanistic view with new metaphors, like the *body↔engine* metaphor (see, for example, Helmholtz 1962).

The simple answer to the above mentioned questions is that the body and its organs are not axes, hammers, cogwheels, engines, cameras or computers. As metaphorical extensions of the body, tools and machines resemble the body in some respects, but they are also different from it in other respects. Technology translates the body into a new form which is not identical to the body. However, there is a more complicated answer which is related to the developments that I reviewed before. In the cybernetic age the boundaries between the *organic* and the *artificial* fade away, both conceptually and physically. The two domains are imploding and creating a new biotechnological body. Disabled people, and others like Kevin Warwick, are becoming cyborgs. As Warwick argues, in the future people may prefer "better" artificial enhancements to their own organs. As opposed to the old mechanical prostheses, the new electronic prostheses, such as the C-Leg (Perry et al. 2004; Marks and Michael 2001), or the new prosthetic hands (Kuiken 2006)[39], are flexible, bidirectional, "intelligent" and efficient. Thanks to the carbon-fibre prosthetics, the disabled sprint runner Oscar Pistorius a.k.a. *Blade Runner,* participated in the 2012 London Olympics. Prosthetic limbs of the future will be much more efficient. There are other types of techniques, on a completely different level, that contribute to the fusion of the organic and the artificial. In principle, already today we can replicate the body artificially, although the “replicant” will not be identical to the original body (the concept *replicant* appears in the movie *Blade Runner* and it is based on the biological concept of *replication*). In the future, what would be the differences between a leg artificially reproduced via embryonic stem cell technique and a natural human leg?[40] The only substantial difference that will remain relevant is that artificial legs are reproduced in the lab and not by sexual reproduction. Nonetheless, in the age of in vitro fertilization, molecular genetics and genetic engineering (recombinant DNA technology / cloning) even human reproduction becomes dependent on technological manipulations.

The *cyborg*, that merges the technological and the organic, has become a symbol of the electronic culture. He stars in the movies, as well as in TV series, pc games, music, comics and books, together with his older brother the robot or android. Both the characters of the cyborg and the android reflect the duality between technological utopianism and technophobia. On the one hand, the cyborg or android can appear as a hero who protects society and fights for justice, like Steve Austin or the naïve, brilliant android Data from *Star Trek*. On the other hand, he can appear as a villain who threatens humanity, like the emotionless collective of the Borg which is trying to assimilate individuals, groups and intergalactic cultures into the cybernetic nest of the collective. There is a dialogue between the utopian and technophobic myths, for example in *Star Trek*, Data has to deal with his evil Twin - Lore; similarly, in the first episode of *The Terminator* Arnold Schwarzenegger plays the role of the villain cyborg who threatens the future of humanity, but in the next two episodes the character is re-programmed by humans and he becomes the hero who fights against intelligent computers and cyborgs that have taken over the world. The famous novel of Aldous Huxley, *Brave New World*, which was published in 1932, is one of the prominent examples that reflect the fear of dehumanization in the technological society (Huxley 1965). Huxley describes a society of industrialized human beings which are manufactured in bottles on an assembly line which is modeled on the car factory of Henry Ford, the idol of the new society. The mass production of human beings in this future society is achieved through: (1) Biotechnology- genetic selection, in vitro fertilization, physical and chemical manipulations which are used to control embryogenesis and budding of homogenous embryos; "Solved by standard Gammas, unvarying Deltas, uniform Epsilons. Millions of identical twins. The principle of mass production at last applied to biology" (Huxley 1965: 4); (2) Conditioning techniques- classical conditioning, hypnopaedia and media; (3) Drugs- especially the *soma holiday* drug and adrenaline treatment.

In the discussion on the social and cultural implications of the cybernetic environment and cybernetic organisms, Warwick represents the technological utopianism. However, Warwick refers, for example, to *How We Became Post Human* of Katherine Hayles (1999), and thus, to some extent, he is aware of the historical context, sociological analysis and skepticism about the cybernetic program (Warwick 2003). Another distinguished representative of the utopian view is the inventor and futurist Ray Kurzweil, who along with the computer scientist Vernor Vinge promotes the idea of *technological singularity* (Kurzweil 2006). According to Kurzweil, in a few decades humans and machines will merge with one another, due to technological progress in robotics, artificial intelligence, genetics and nanotechnology. He argues that by the 2040s a cybernetic shape-shifting body (human body version 3.0.) will become available and by 2050 artificial intelligence will become so powerful that it will take over humanity. The revolutions that will take place afterwards are unpredictable by human intelligence. Professor of robotics and futurist Hans Moravec promotes similar ideas (Moravec 1999; 1988). He argues that around 2050 artificial intelligence will rival human intelligence. Moravec and Kurzweil believe that these developments will enable us to *upload* the human consciousness into a computer. As explained in the description of Moravec's book *Robot*:

> Far from railing against a future in which machines rule the world, Moravec embraces it, taking the startling view that intelligent robots will actually be our evolutionary heirs. "Intelligent machines, which will grow from us, learn our skills, and share our goals and values, can be viewed as children of our minds." And since they are our children, we will want them to outdistance us. In fact, in a bid for immortality, many of our descendants will choose to transform into "ex humans," as they upload themselves into advanced computers (Moravec 1999).

The technological utopianism of Warwick, Kurzweil, Moravec and the movement of *transhumanism* is at one extreme. The technophobic pessimism of Jean Baudrillard and other intellectuals is at the other extreme. According to the *bubble* metaphor of Baudrillard, the new cybernetic environment *exterminates* humanity:

In the rituals of transparence one must include the entire prosthetic and protective environments as substitutes for the natural biological defenses of the human body. We are all bubble-children, like the boy who died recently in the United States. He lived in his bubble, inside the medical surroundings of the NASA space suit, protected from all infection by the artificially immunized space; his mother caressed him through the glass with rubber gloves, as he laughed and grew up in his extraterrestrial atmosphere under the observation of science (he is the experimental brother of the wolf-child, the savage child adopted by wolves — today computers take care of the disabled child). This bubble-child is the prefiguration of future, of total asepsis, the elimination of all germs, which are the biological form of transparency. He is the symbol of existence in a vacuum, until now exclusive to bacteria and particles in laboratories, but which will increasingly become ours: that is, to be pressed in a vacuum like records, preserved under vacuum like frozen foods, dying in a vacuum like the victims of unrelenting therapy. We will be thinking and reflecting in a vacuum, as illustrated everywhere by artificial intelligence (Baudrillard 1988a: 36 – 37).

Baudrillard adds that "The increasing cerebral capacities of machines would normally lead to a technological purification of the body." The cybernetic environment, media, science and medicine destroy and replace the immune systems of the biological body and of humanity:

Divested of his defenses, man becomes eminently vulnerable to science. Divested of his phantasies, he becomes eminently vulnerable to psychology. Freed of his germs, he becomes eminently vulnerable to medicine (Baudrillard 1988a: 38).

Humanity in the *bubble* metaphor of Baudrillard not only depends on its interaction with germs, but it becomes a bacterial colony:

It would not be too far-fetched to say that the extermination of mankind begins with the extermination of germs. Man, with his humors, his passions, his laugh, his genitalia, his secretions, is really nothing more than a filthy little germ disturbing the universe of transparency. Once everything will have been cleansed, once an end will have been put to all viral processes and to all social and bacilliary contamination, then only the virus of sadness will remain, in this universe of deadly cleanliness and sophistication (Baudrillard 1988a: 38).

The ideas of McLuhan about the impact of technology, as I have already noted, were ambivalent. On the one hand, the writing of McLuhan is satirical and provocative. In fact, McLuhan tried to make his readers aware of the dangers of media and technology, although, to some extent, he was skeptical about the ability of societies to deal with the psychological and social implications of new technological environments (see, for example, McLuhan 1964: chap. 4 and chap. 7). On the other hand, McLuhan often attributed to the new electronic environment positive effects. Moreover, some of his statements about the collective electronic consciousness were interpreted as utopian statements (McLuhan 1964: 60 – 61, 80, 227, 252, 348; McLuhan 1996: 295 – 297). In this context he clarified: "…I brought the bad news with aches and pain, and am branded as a Utopian" (McLuhan cited in Gordon 1997: 99) McLuhan rejected the moralist approaches, which he identified with visual space and outdated fixed points of view. Thus, he said, for example: "I don't approve of the global village. I say we live in it" (McLuhan and Stearn 1997: 58). Nonetheless, the approach of McLuhan was far from the pessimism of Baudrillard, who adopted the insights of McLuhan but took exception to the more optimistic statements that are found in McLuhan's work (Baudrillard 1983: 153; 1988b: 207 – 208). Baudrillard feared that humans are assimilated into their technological prostheses via cyborgization and biotechnological mutability (recombination techniques / molecular cloning). In his opinion, the cybernetic experimentation on disabled people makes them the avant-garde of "mutation and dehumanization" (Baudrillard 1988a: 51 – 52).[41] If I may use the title of the popular comics and film series, it is the fear of the *X-Men*.

I would like to conclude this section with a remark on the human body, extensions, and scientific theories. In the previous chapters I have argued that human knowledge is metaphorical. Paradoxically theories that explain the *metaphorical* aspects of human knowledge are metaphorical themselves. Therefore, we should be careful and not take the definition of electronic technology and computers as *extensions* of the nervous system for granted. Moreover, the identification of electronic technology and computers as *extensions* of the nervous system depends on scientific theories that are themselves metaphorical. In practice, the electronic technology and computers are used as metaphorical models of the nervous system and the brain. In other words, both technology and the body serve as source and target for each other. This is the circular metaphorical connection which I have defined as the thesis of the *Metaphoric Body*.

Nonetheless, metaphors are not arbitrary and they always have to deal with sensory experience or empirical data. The *extension* metaphor is based on examination of the uses of technology. In this context, we can identify that electronic technology is used as an *extension* of the senses (sight, hearing, touch, smell and taste) and the mind (thought, mental-manual control etc). Since modern science identifies the senses and the mind as activities of the nervous system, electronic technology can be defined, with many objections, as an extension of the nervous system. From many aspects, this definition is dynamic and not absolute. First, the scientific explanations of the mind and consciousness are partial and metaphorical. Secondly, mental activities, consciousness and thought depend on a complex interaction of the body with the environment, and thus the attempt to *place* mental phenomena is problematic. Thirdly, according to the idea of *Ontological Relativity* (Quine 1969a), any language or a worldview has its own ontology: definitions, classifications and interrelations of objects depend on different linguistic and cultural frameworks. Even the understanding and definition of the senses depend on techno-cultural environments (see for example: Howes 2005a, Howes 1991, Foster 1988), and, as McLuhan argued, new technological environments change the interrelationship of the senses.

❖ *From McLuhan to Baudrillard: Prostheses, Implosion and "the Orders of Simulacra"*

In this section and in the following section, I will review the techno-cultural context in which the modern prostheses of the body had evolved. The focus will be on the electronic implosion of the organic and the technological, which is manifested by the cyborg and by genetic engineering. Perceptually and conceptually, cybernetics and genetics have transformed the body into an *information* pattern or a *code*. Furthermore, I will show that the technological implosion also leads to an interspecies implosion, i.e. to the creation of human-animal hybrids through genetic engineering, synthetic biology and stem cells transplantation.

First we need to define and analyze the relevant techno-cultural developments. In two of his books, Jean Baudrillard summarized his ideas from the 1970s about the development of the relationship between the *real* and its simulacra/signs (Baudrillard 1983; 1994). In some respects, Baudrillard's orders of simulacra were a response to the historical analysis of Michel Foucault, who had identified sharp epistemic breaks in the modern history of western civilization. Yet Baudrillard severely criticized Foucault (Baudrillard 1987). The main influences on the work of Baudrillard were the techno-cultural analyses that McLuhan and Walter Benjamin suggested. Baudrillard argued that Benjamin and McLuhan were the first intellectuals who understood the postindustrial situation, or as he called it, the age of third order simulacra, which is dominated by the signs of electronic media. On the other hand, Foucault and many others intellectuals still focused on the characteristics and trends of the industrial world, i.e. on second order simulacra. Furthermore, it should be noted that the transformation from one order of simulacra into another is not sharp and sudden, as in Foucault's epistemic breaks or the paradigm shifts of Thomas Kuhn.

A simulacrum (plural: simulacra) is a copy, a representing image or a sign. Baudrillard describes how the simulacrum became a sign which does not *represent reality* and a *copy* which does not refer to the *original*. According to the analysis of Baudrillard, a system of *natural* signs preceded the first order simulacra that developed during the Renaissance. Until the 15th century, the sacred cosmos was organized according to *natural* signs and a rigid social-religious system of classification. For example, a man who was born as a vassal was obligated not just to his social position and class but also to the natural signs of his position in the cosmos and society. He could not have suddenly decided to dress as an aristocrat. In the feudal world, *fashion* did not exist, moving up and down the social class ladder was very limited, and the religious-social law protected the meanings and references of signs. During the Renaissance the bourgeois society appeared and it was characterized by first order simulacra or *counterfeit* simulacra. In this techno-cultural environment the old feudal order was broken, democracy and free representation were born and signs were released from their rigid obligation. Yet the boundaries between reality and signs, originals and copies were not erased: simulacra or signs still represented nature, reality and natural rights and laws.

Baudrillard identifies the appearance of second order simulacra, or the simulacra of *production*, with the development of industrial society. At this stage, the appearance of industrial mass production blurred the distinction between the original and its copies and between the real and the signs that represent it. This is the effectiveness of industrial simulacra: each copy is practically identical to all the other copies. In other words, the *original* had transformed into the technique of mass production that depends on market forces and can produce endless homogenous copies. The second order was dominated by factories, mechanical automata, materialism, forces of production, and the ideas of capitalist and socialist intellectuals like Karl Marx. .Baudrillard describes the ideas of Marx from a McLuhanite perspective that belongs to the third order:

McLuhan has said, with his usual Canadian-Texan brutalness, that Marx, the spiritual contemporary of the steam engine and railroads, was already obsolete in his lifetime with the appearance of the telegraph. In his candid fashion, he is saying that Marx, in his materialist analysis of production, had virtually circumscribed productive forces as a privileged domain from which language, signs and communication in general found themselves excluded. In fact, Marx does not even provide for a genuine theory of railroads as "media," as modes of communication: they hardly enter into consideration. And he certainly established no theory of technical evolution in general, except from the point of view of production – primary, material, infrastructural production as the almost exclusive determinant of social relations (Baudrillard 1981: 164, referring to McLuhan and Fiore 1968: 4 – 5; see also McLuhan 1964: 38, 49; McLuhan and Nevitt 1972: 58 – 78).

The stock market is a prominent example of second order simulacra. Economically speaking, the evolution of the sign is manifested by the transformation from the physical world of exchange trade into money and then into the speculative exchange of free and arbitrary signs in the stock market. The trade in the stock market is no longer necessarily subordinated to *real* production. What were, then, the relations of the *real* and the *original* with signs and copies in the techno-cultural environment of the industrial age? According to Baudrillard, the relations had become problematic; the distinction between them had blurred; the real was *covered*; the "original" had become the mass production technique of the object.

The third order is the *simulation* order that appeared in the 20th century. Baudrillard identifies this order with the techno-cultural environment of the information age, which can be characterized as digital and post-industrial. In the third order, the *social* dimension and *reality* have imploded into the *hyperreal*, i.e. into the signs of electronic media matrix. Baudrillard claims that Benjamin and McLuhan were the first intellectuals who analyzed the impact of the third order and that "the medium is the message" is the slogan of the simulation age. *Reality* in the third order became a "desert" which was assimilated by the digital, binary code and by the *hyperreal* (or as we call it today: *cyberspace*): the sign, which supposedly had to represent the existence of a referent, has swallowed the reality; representation has become obsolete; production was swallowed by reproduction. Signs today are self-referential: they *represent* themselves and refer to other signs in a closed circuit.

I will try to explain the assertions of Baudrillard about the new simulacra. The stock market in the age of computer and internet is a good example of the trends of the third order. I pointed out that the trade in the stock market is no longer necessarily subordinated to *real* production. Notice that in the age of computer and internet this trend has become much more radical. One can see it, for example, in the speculations of hedge funds on interest rates, or in trade strategies which are based on abstract technical analysis of indexes, futures contracts, options and stocks. These abstract strategies developed in the shift from the second order to the third order and they became very dominant. Furthermore, the internet promotes rapid, speculative day trading. The immediate access to the stock market, and the availability of information, has transformed the trade into a virtual gambling game, which is fueled by news websites, business websites, virtual headlines that change every few minutes, and forums of traders and investors. Today, computer algorithms and trading robots are taking over the stock market.

According to Baudrillard, Disneyland is a prominent example of the third order. Actually, he defines Disneyland as a third order simulacrum that pretends to be a second order simulacrum (Baudrillard 1983: 23 – 26). Disneyland pretends to be a play of illusions and phantasms, or an idealized fantasy of the *real* American society and culture, although Disney itself, its images and signs, as well as the whole matrix of electronic media, has absorbed the *real* American society. Indeed, Disneyland is self-referential: from Mickey Mouse to the Indiana Jones attraction it refers to the cultural products of Disney. Disney and the electronic media have become the cultural measure of the American citizens, who already as infants sit in front of the Disney Channel and the TV screen. Today the movies of Disney are based on computer animation and they blend "real people" and "real places" with cartoon characters and computer graphics. But even in the old cartoons recorded voices of real people were used as the voices of the cartoon characters. 20th century art, in general, became less and less "representational" (e.g. cubism, abstract art), until eventually third order simulacra appeared. Fredric Jameson's (1984: 75) example of a third order simulacrum or pure simulation is the genre of photorealism: the painting in photorealism is a copy of a photograph and not of reality.[42]

Ironically one of the prominent manifestations of the absorption of the real by the hyperreal is called a "reality show", in which reality is subordinated to virtual space and time, to the production, to the type of the show, to its rules and tasks, to the camera, to the script, to the typecasting, to tendentious editing and directing (editing and directing are always tendentious), to the framing, to the achievement of desired outcomes and to the creation of stereotypes and token characters, such as the *intriguer*, the *stupid* and the *bitch*. Camera angles, editing of the scenes and the talks, close up on the eyes, music and other manipulations transform the real into the hyperreal. This is another example of a third order simulacrum that pretends to be a representation of the *real* or equivalent of the *real*. Satirical television programs illustrate how much the matrix of electronic media is self-referential. These programs refer mainly to occurrences and events that appear on the media, to events that are created for the media or due to its existence (e.g. news conferences) and to people who have become *celebrities* through the media (famous for being famous, or as Daniel Boorstin defined it, "a person who is known for his well-knownness"). In programs like *The Daily Show* and *Saturday Night Live,* or sitcoms like *30 Rock* and *Entourage,* the references are to mass media in general, celebrities, actors, media personalities, events on the news, politicians that appear on the news, other satirical programs and in general other TV programs. Notice that talk shows devote much of their time to promote other programs, celebrities, actors, pop stars and movies. In the closed circuit of the electronic matrix, actors, celebrities, newspersons, politicians, media personalities, and former participants in reality shows, participate as guests in the same satirical shows: they play themselves and they also play the role of other characters. More than anything else, the dominant matrix refers to itself and represents itself. The comedy series *Entourage*, for example, revolves around Hollywood and movie stars, and famous actors play themselves in the show. *30 Rock* is a comedy series based on behind the scenes of a sketch comedy show, namely *Saturday Night Live*: Tina Fey, the former head writer of *SNL*, plays the role of Liz Lemon- the head writer of TGS, and the actor Tracy Morgan, a former cast member in *SNL*, plays the role of the actor Tracy Jordan. Similarly, *Studio 60 on the Sunset Strip* is a TV drama series based on behind the scenes of a sketch comedy show / SNL. The TV sitcom *The Office* does not simulate reality but a documentary film or a reality show. All hidden camera prank shows absorb and transform reality. In *Scare Tactics* the circularity of the matrix that refers to itself is clearly illustrated: the victims find themselves in scenes from horror movies and TV action thrillers.[43]

The free signs of the third order are everywhere. As McLuhan and Baudrillard observed, ads and commercials have little to do with *rational* arguments and with the qualities of the products, i.e. the referents. The commercials of the electronic age are based on symbolism, desires and on the selling of images. For example, cola commercials do not sell the beverage *itself*, but youth, sexiness, excitement, coolness, fun and the American way of life. Notice that today the virtual signs themselves have become products and they are sold as *virtual goods* in online communities and online games. Similarly, as McLuhan noted (e.g. in McLuhan 1970), in the electronic age the characteristics of modern politics, which were based on ideologies (the fixed points of view of modern visual space), party platforms and policies, are being pushed aside in favor of the “image hunting”, which is based on the search of the *right* images, and on turning the candidates into *brands* and selling them like products using commercials and advertising campaigns. The actor Arnold Schwarzenegger is a good example of a third order politician: in 2003 he used the image of the *cyborg*, the role he played in three episodes of *The Terminator,* and eventually he was elected as the governor of California (the *Governator*). Elections and the political simulacra in the electronic age are run by the advertisers, spin doctors and advertising campaigns. The third order is cybernetic and digital: politics and businesses are being managed by surveys in a binary fashion (question/answer, yes/no), control group, models, scenarios, simulations, photo ops, media events, virtual ceremonies and immediate responses which are required due to the speed of electronic occurrences and reactions.

We can see the impact of the electronic matrix, and the domination of third order simulacra, through the world of crime. In his book, *Gomorrah*, Roberto Saviano describes how the gangsters of the Italian mafia, the Camorra, as well as the gangsters of the Sicilian mafia, are influenced by the images of the Mafia in the electronic media. The bosses of the Camorra have begun to measure their lives by the Hollywood images of the gangster, as reflected in their life-style and villas. Walter Schiavone’s villa is called *Hollywood* and it was modeled on the villa of the Miami Cuban gangster Tony Montana from *Scarface* (the character played by Al Pacino), with whom Schiavone identified. Already, in the original version of *Scarface* from 1932, which was based on the public image of Al Capone, the famous gangster, who understood the power of the movies, came to watch and supervise the shooting of the movie and eventually the character of Tony Camonte reflected in him. After *The Godfather* came out, Italian Mafia families in America have adopted the term *godfather* instead of *compare*. Furthermore, young Italian-American gangsters have adopted the dark glasses, pin-striped suits and solemn speech. John Gotti, the famous boss of the Gambino family, aspired to be like Don Vito Corleone from *The Godfather* (the character played by Marlon Brando), and Cosa Nostra boss Luciano Liggio jutted his chin in photographs as an imitation of the same character. Today, bodyguards of female bosses in Sicily dress like Uma Thurman in *Kill Bill*. Moreover, according to an expert who worked in the legal system of Naples, the movies of Quentin Tarantino, and the genre to which they belong, influence the way the hit men of the Camorra handle a gun: they don't keep the gun straight anymore, they shoot in every direction, and they wound the victim seriously in different organs until finally they have to kill him with a bullet to the back of his neck (Saviano 2007: 244 – 258). The new bosses of the Sicilian Mafia are no longer seen as simple and ignorant peasants who are closely connected to the "authentic" rural tradition of Sicily, like the old school boss Salvatore Riina. For instance, unlike Bernardo Provenzano, the successor of Riina who was arrested in an old farmhouse, dressed in ragged clothes and sleeping in a simple bed, Salvatore Lo Piccolo, a senior mafia boss, was arrested in a modern apartment. Contrary to the expectations of the Italian press, his style and appearance resembled the style and appearance of a gangster from Hollywood (Meron Rapoport, "Is this the Boss?", Haaretz Newspaper, 9-11-07).

On television, actors, politicians, newspersons, and other celebrities usually play themselves in comedy bits and satirical shows. Three of the actors in the movie adaptation of *Gomorrah* were gangsters who were arrested after the shooting of the movie. The TV series, *The Sopranos*, was very popular among gangsters. In a recording of the FBI which was released to the media, members of the DeCavalcante crime family from New Jersey discussed *The Sopranos* which is loosely based on their family. "What characters. Great acting", said one of them. They agreed that due to the TV series they have gained respect whereas before New York gangsters regarded them as farmers. According to Louis Ferrante, author of the book *Unlocked* and a former US gangster who worked for the Gambino family, many gangsters quote lines from the movies of Al Pacino that they have memorized (just like Silvio from *The Sopranos* who loves to imitate Michael Corleone, the character Pacino played in *The Godfather*; furthermore, in the six season of *The Sopranos*, Christopher Moltisanti, one of the main characters in the series, produces a gangster movie). Sometimes, notes Ferrante, you imagine that you take part in a movie scene.[44] Our perception and way of life are reshaped by the electronic environment in which we grow. Not only the gangsters, but also law enforcers, internalize and adopt images from the electronic media. Kiefer Sutherland, who plays the role of a US agent in the TV series *24*, told in an interview that the cast of *24* went to Washington to meet with the FBI task force and the Counter Terrorist Unit (CTU). They noticed that their offices looked exactly like the set of *24*. When they asked the agents of the CTU, the director admitted that they “did that in purpose” (*Late Night with Conan O'Brien*, NBC, 21-11-2008).

The idea that the real is absorbed by the *hyperreal* penetrated to the heart of the public awareness during the 1990s, with the development of the PC market, VR technology and the internet. The roots of the new trend were already found in books like *The Futurological Congress* of Stanislaw Lem which was published in 1971, although the virtual world in Lem’s book is not the result of computerized environment, virtual reality, internet and microchip implants but the result of hallucinogenic drugs. During the 1980s, William Gibson and other science fiction writers developed the genre of *cyberpunk*. Gibson has coined the term *cyberspace* prior to the internet revolution: the term first appeared in the short story *Burning Chrome* which was published in 1982 and then in the famous novel *Neuromancer* which was published in 1984. A similar trend can be identified in movies from the same years. Disney's *Tron* from 1982 (which was based on computer animation) and David Cronenberg's *Videodrome* from 1983 (Cronenberg was inspired by McLuhan and one of the characters in the movie, Professor Brian O'Blivion, is based on McLuhan and on his television performances), have anticipated the flood of successful movies which appeared since the 1990s, e.g. *The Lawnmower Man*, the hit movie trilogy *The Matrix* (which is a Hollywood popularization of Baudrillard's *Simulacra and Simulation*; the book appears in the first movie for a fraction of time), Cronenberg's *eXistenZ*, *Inception* and popular TV series, such as *Star Trek* and *Sliders*. The main theme of these movies is the power of the electro-cybernetic environment, VR technology, simulations, BCIs and neuro-chemical prostheses to generate a matrix of hyperreality and to take over the old reality.

Practically, the internet, social media and cellular phones create new forms and new ways by which virtuality takes over reality. The data matrix code, for example, is a barcode that can be scattered across the city. A camera of a cellular phone can read the barcode and send the user to the virtual world , i.e., to search for information or to different websites. The technology of *Google Glass* completely takes over the user and mediates his experience of reality through virtual reality. Another example is the *flash mob*, that transforms reality into an entertaining clip or a movie scene (from song clips to wedding proposals) for *Youtube* and other websites.

❖ *The Body as an Information Pattern and Interspecies Implosion*

In the new techno-cultural environment, not just the reality that *surrounds* the body was translated into the hyperreal but also the body itself: the cybernetic body belongs to the information age, i.e. to the post-industrial world. Norbert Wiener was influenced by the stories of Rudyard Kipling. He defined the science fiction story that Kipling published in 1905, *With the Night Mail*, as innovative and at the same time a little bit outdated. The story is about an Aerial Board of Control that has gained control over the planet through the management of air traffic. Wiener notes that Kipling was a man of the colonial age who loved noisy mechanical gadgets and rotating wheels: he was interested in material transport and not in information transport. When Wiener and his colleagues developed the science of cybernetics and information theory during the 1940s and 1950s, they began to perceive the physical body as a manifestation of information pattern. Consequently, according to the cybernetic view, one could translate the body into a code, transmit it from place to place as a *telegram* through the virtual world of information and translate it back into a material form (Wiener 1954: 95 – 104).

Besides teleportation, there are endless potential ways to manipulate the body and the identity of its *owner* in the virtual world. As part of the discussion on simulacra and signs, Baudrillard (1983: 5 – 6) cites the following medical question: can a person who tries to imitate a disease and his body is able to produce the necessary symptoms be considered as a person who suffers from the disease? Well, in the VR facility of *Star Trek* (the Holodeck) you can be pregnant without *really* becoming pregnant. With the development of microchip or nanochip implants, virtual reality could become part of the technological implosion that transforms the human body into a cybernetic body. Notice that hyperreality does not entail the absence of the body, but the evolution of a new body which is controlled and manipulated by cybernetics, VR technology, BCIs and neuro-chemical prostheses. As the character of Max Renn proclaims in *Videodrome*, "Long live the new flesh!" Even when the body is translated into digital information, it does disappear but turns into a virtual body, like the body of Kevin Flynn in *Tron* which is teleported into cyberspace.

Let us examine the prostheses of the body in relation to the three orders of simulacra. According to Baudrillard, in the pre-simulacra stage the sign was a reflection of "a basic reality"; in the first order the sign masked and perverted "a basic reality"; in the second order the sign masked the *absence* of "a basic reality"; in the third order the sign turned into a pure simulation which is not subordinate to "any reality" (Baudrillard 1983: 11). The simple automaton belongs to the first order; the machine/robot/android belongs to the second order; the cyborg and genetic engineering (i.e. recombinant DNA technology and cloning)[45] belong to the third order:

TABLE 3.1: Prostheses and the Orders of Simulacra

First order:	Counterfeit	Renaissance	Natural law of value	**Automaton**
Second order:	Production	Modern – industrial	Commercial law of value	**Robot / Android**
Third order:	Simulation	Postmodern/ post-industrial	Structural law of value	**Genetic Engineering / The Cyborg**

Functionally the automaton of the Renaissance did not *pretend* to be equivalent to humans and it did *aspire* to replace them. In some respects the automaton was analogous to humans, but as part of the first order the differences between humans and machines were still obvious, like the differences between the origin and the imitation. Baudrillard defines the automaton of the first order as an *interlocutor* of the human being: it was used in theatrical and social games, and it even played chess together with humans (the fake chess machine which was operated by a hidden human player inside the machine). Eventually, the robot/android of the second order or the industrial age *aspired* to be equivalent to humans (Baudrillard 1983: 92 – 96). The practical aspects of this trend already appeared in the 18th century. For example, Claude-Nicolas Le Cat, head surgeon at Rouen's municipal hospital, had tried to develop a machine that would simulate all the functions of the human body, including respiration, circulation, digestion, secretion, the heart, the liver and even sickness. The mechanical imitations of animals and humans that appeared during the 18th century were very impressive. In a deterministic limited way they succeeded in imitating different aspects of the body. The mechanical duck (1738) of the French inventor Jacques Vaucanson imitated the following functions: drinking, eating, digestion (separate segments of the digestive process), cackling and flapping wings. Another mechanical figure that Vaucanson had built, the flute player, moved his fingers, lips and tongue and played twelve different tunes. Similar automated puppets were built by the Swiss watchmaker Pierre Jaquet Droz. One of these puppets imitates a boy who is seated at a desk and writes (up to forty letters). The writing boy is in the History Museum in Neuchâtel and it still functions (Riskin 2003; Mazlish 1993: 35 – 36; Roger 1997: 168).[46]

The science of genetics is one of the ultimate expressions of the simulation culture. In the second part of this work, I will show that the mechanical environment and then the industrial environment shaped the metaphorical perception in the life sciences. During the 20th century, the electronic environment has begun to create new alternatives. Around the mid 20th century, cybernetics, information theory, and then the computer world, helped to shape new paradigms in biology, including the genetic paradigm which is based on metaphors such as *information*, *code*, *program* and *algorithm*. The DNA is not a "representing" sign: as a digital code, the genetic *information* is a third order simulacrum. The industrial metaphors put the emphasis on matter and energy, but in the DNA metaphor the *real* (i.e. the material, the energetic, and the mechanical) is absorbed into the hyperreality of the code. According to the cybernetic view, information is the essence of life. In the course of life, the body produces substances and decomposes them. Similarly energy is created and spent. The body does not preserve matter and energy. In fact, only the information pattern of the organism is preserved and transmitted from generation to generation. The cyberneticists argue that even the chemical composition of the body is incidental because the information pattern of the body could be translated, preserved and reactivated in computerized systems. For example, Moravec and many others believe that in the future the mind could be uploaded into advanced computers.

In a short essay, *The Metaphysic of the Code*, Baudrillard defines the genetic theory as an exemplar of third order simulacra (Baudrillard 1983: 103 – 115). The essay begins with a citation of McLuhan who refers to Leibniz. According to McLuhan, "the mathematical Leibniz" perceived the "mystic elegance of the binary system" as a sufficient quality by which God could have created the world and all beings from nothingness (McLuhan 1964: 114). In this passage, McLuhan wears the mask of the mystic and not one of his two other masks: the mask of the Delphic oracle that launches probes and maps the hidden environment of the present and the mask of the vicious satirist. Yet Baudrillard, the postmodernist, remarks in a cynical way that indeed digitality is the God of Leibniz and the DNA is the prophet of this God upon earth. As the noted cyberneticist John Von Neumann, and the noted physicist George Gamow, claim: the DNA is "a four-digital system" (in Doyle 1997: 43 – 44). The connection that Baudrillard sees between Leibniz and the DNA is more than just an amusement. Surely, the connection between the two is complicated and indirect, but the reflection of the Leibnizian view in the genetic paradigm is manifested by its great influence on cybernetics: Wiener, for example, refers to Leibniz as the "patron saint" of cybernetics (Wiener 1948: 12).

In 1944, Erwin Schrödinger, one of the fathers of quantum mechanics, published the book *What Is Life?*. In the book, which became one of the most influential theoretical texts in 20th century biology, Schrödinger argued that the chromosomes contain the *law-code* and *executive power* responsible for the entire pattern and characteristics of the body (Schrödinger 1979). In the cybernetic view, the real is absorbed by the hyperreal. As Wiener claimed, only the form of the body is preserved during life and in future generations and not the matter that composes the body. Thus the organism is essentially an information pattern. The cybernetic vision which influenced the geneticists included not just the ideas of *information*, *code* and *computer program*, but also the idea of *teleology* which was retrieved on the new technological ground. In 1943, Norbert Wiener, the physiologist Arturo Rosenblueth, and the cyberneticist and computer engineer Julian Bigelow, introduced a new definition of teleology. According to the new cybernetic approach, *teleology* is a behavior directed to a goal which is achieved through a mechanism of negative feedback. In this respect, the "broad classes of behavior are the same in machines [servomechanisms or cybernetic machines] and in living organisms." It should be noted that Rosenblueth worked with Walter Cannon who developed the theory of homeostasis. The cybernetic approach united the *negative feedback* and *homeostasis* under the teleological principle (Wiener 1954: 102 – 103; Rosenblueth et al. 1943; Wiener 1948: 44).

The impact of the electronic-cybernetic environment on the development of the new biological view was crucial. In this context, Baudrillard refers to the semiotician Thomas Sebeok, who claims that there is a close relationship between information theory and the DNA and that the terminology of genetics is full of expressions that were taken from cybernetics, such as *feedback* and *information* (Sebeok was a friend of the primatologist Stewart Altman, one of the many biologists who promoted the cybernetic view in the life sciences). Following the book *Chance and Necessity*, which was written by the molecular biologist Jacques Monod, Baudrillard, defines the DNA as an "operational simulation" that *represents* nothing but itself: since the *genetic code* is a third order simulacrum, the reference of the DNA is to itself. The *code* in the scientific discourse of Monod and his colleagues still requires an *objective* basis in the *real* biological world, although Monod himself admits that the scientific discourse is possibly based on *conventional* principles. Notice that today computer scientist Christopher Langton and his colleagues in the field of *artificial life* refer to pure simulations, i.e. computer models and *genetic algorithms*, as examples of life itself (Langton 1997 (ed)). Without addressing the scientific content of Monod's assertions, or the failures of the reductionist models in genetics, Baudrillard clarifies that scientific *objectivity* is based on conventional logic[47] and that beneath the current discourse in molecular biology lies the "neo-capitalist cybernetic order". The satirical reference of Baudrillard to Leibniz and the digital God continues with Monod, who perceives the *genetic code* as the *teleological* principle that controls life. Baudrillard links the DNA to God/Adonai (A.D.N.) and adds that "Monod is the strict theologian of this molecular transcendence, Edgar Morin the rapt disciple". He notes that Monod and his colleague François Jacob are among the *technocrats* of the new biological science, which is an integral part of the social and historical program of cybernetics. This program aims to create a new social order encompassing all aspects from linguistics to sociology and political economy. “Thus we find once more in history that delirious illusion of un[i]ting the world under the aegis of a single principle” (Baudrillard 1983: 106 – 115).

Already during the Macy conferences in the 1940s and 1950s, cybernetics developed as a trans-disciplinary program that unites engineering, physics, biology, sociology, psychology linguistics, philosophy etc. Jacob, Monod and their friend, the philosopher and sociologist Edgar Morin, have continued this tradition. With the help of biologist Salvador Luria, philosopher, economist and psychoanalyst Cornelius Castoriadis and political philosopher Claude Lefort, they founded in 1972 a center that organized trans-disciplinary international symposiums, dealing with the connection between “biological man and psycho-cultural man”.[48] Jacob and Monod were among the prominent biologists who studied the body as a cybernetic-computerized system. In 1965 they won the Nobel Prize for analyzing the *feedback* mechanism of the Lac operon. Influenced by the cyberneticists, they promoted the idea that the DNA is a computer program which is based on cybernetic teleology. Jacob, for example, defined the organism as “the realization of a programme prescribed by its heredity” (Monod 1971; Jacob 1973: especially p. 2).

The *genetic code* is the ultimate expression of third order simulacra. In the simulation culture, information, codes and algorithms have become the essence of the organism. As the evolutionary biologist Richard Dawkins proclaims in *The Blind Watchmaker*:

> It is raining DNA outside…it is the DNA that matters... The whole performance, cotton wool, catkins, tree and all, is in aid of one thing and one thing only, the spreading of DNA around the countryside… It is raining instructions out there; it’s raining programs; it’s raining tree-growing, fluff-spreading, algorithms. That is not a metaphor, it is the plain truth. It couldn't be any plainer if it were raining floppy discs (Dawkins 2000 [1986]: 135).

The motivation behind the mapping of the human genome, one of the largest scientific programs in history, is the translation of organisms into information and codes, i.e.

into the sequences of DNA bases. The new perception is based on the hyperreal. As Walter Gilbert, who won a Nobel Prize for developing a DNA sequencing technique, clarifies:

> Three billion bases of sequence can be put on a single compact disc (CD), and one will be able to pull a CD out of one's pocket and say, “Here is a human being; it's me!” (Gilbert [1992], cited in Fox Keller 2000b: 6).

Although the above mentioned metaphors deal with the *information pattern* of the organism, they are not entirely electronic and post-industrial. In fact, these metaphors still express the mechanistic perception and industrial program, whose development I review in part II. As McLuhan observed, the drama of our age is living in an environment which is both mechanical and electronic. Accordingly, the traditional mechanistic approach did not vanish from biology, although it loses power to the electronic approach. Biologists like Jacob, Monod, and Dawkins, and cyberneticists like Wiener, had begun to develop a new biological approach which is based on electro-mechanistic hybrids. On the one hand, the new *body↔machine* is explored through digital metaphors, such as feedback, cybernetic teleology, computers and programs. On the other hand, the characteristics of the industrialized body, i.e. fragmentation, reductionism, atomism and linearity, are still dominant. When Dawkins discusses *The Selfish Gene* (1976; 2000 [1986]) in digital terms, he squeezes the electronic order into the industrial program of genetic reductionism and neo-Darwinism. In other words, he perceives the new *body↔machine* through the rear view mirror. Genetic reductionism emphasizes the action of discrete genes. This approach is in conflict with the antireductionist models of the electronic world, e.g. feedback mechanisms, total field and systems theory. Gradually the new developmental biology is becoming more electronic and less mechanistic. Genes, according to the new epigenetic approach, do not have effects of their own, since their actions and regulation depend on complex interaction and feedback of many factors: the genome, the systems of proteins which are found in the egg cell and in the organism and environmental factors. Evolutionary biology, as well, is becoming less mechanistic and more electronic (*Evo-Devo*).[49]

- The cloning technique transforms the body into an imploded prosthesis of itself. Through cloning, the body can replicate itself like products on an assembly line - a function that could have never existed under the conditions of sexual reproduction.

The genetic-cybernetic approach has produced a new type of prostheses which are based on molecular techniques. Huxley's *Brave New World*, in which humans are produced by biotechnological techniques, has begun to take shape. In the early 1980s Baudrillard wrote a short essay, *Clone Story*, inspired by a report which was published in the US about a cloned child (Baudrillard 1994: 95 – 103). He observed that the old idea of the double was materialized by the cloning technique and at the same time became obsolete. Cloning is the ultimate prosthesis of the body, since it can create endless *identical* copies of the body (1+1+1…). Following Benjamin, Baudrillard compares it to the fate of the work of art in the industrial age. As a technique of the simulation age, cloning erases the uniqueness and originality of the body: the original is replaced by information which can be processed, manipulated and replicated. We can characterize this stage as a "protozoic" retrieval which makes sexual reproduction and death obsolete. This is the end of the history of the body that has become the metastatic cancer of its basic formula. Baudrillard does not fall into the trap of the reductionist approach in molecular biology. At the end of the article, he notes that he does not believe the cloned boy would be identical to his father. The body/organism/human being cannot be reduced to DNA or *information*: "Millions of interferences", writes Baudrillard, will make the boy different from his father and they will not be identical if only because the father preceded the boy (indeed, on the time axis, the person or organism cannot be "identical" even to himself/itself). Thus the cloning experiment will demonstrate its own the limitations.

The impact of any technological invention depends on its interaction with an entire techno-cultural environment. Hence the fate of sexual reproduction depends not just on the cloning technique but on a complex interaction of various media, on human actions and human ingenuity, on psycho-cultural factors, medical factors and evolutionary factors. Mutations, of course, may disrupt the reproduction of "genetically identical" organisms. Moreover, the characters of the organism depend on epigenetic and environmental factors. Notice that the cloned DNA is inserted into an egg cell of a different organism (although potentially the DNA could be inserted into a stem cell of the same organism). The nucleus of the foreign cell is removed, but not all the genetic information is contained in the nucleus, and furthermore the environment of the foreign egg cell affects the development of the cloned organism. Finally, even asexually reproducing unicellular organisms, such as bacteria, transfer genetic material to one another via *transformation* (bacterial DNA taken by a microbe from the environment), *conjugation* (transference of genetic material by a “mating” process of two bacteria), or *transduction* (transference of genetic material between bacteria using a viral agent - bacteriophage).

Through the electronic implosion, the body becomes a technological *extension* of itself. In *Clone Story* Baudrillard distinguishes between industrial prostheses that belong to the second order and the cybernetic prostheses that belong to the third order. The industrial prostheses are external, i.e. they are *ex-tensions* of the body. The post-industrial prostheses are internal, i.e. they infiltrate the body and become part of its matrix. There are two other differences between the industrial and the cybernetic prostheses. First, the industrial prostheses are *hardware* prostheses, while the cybernetic prostheses are *software* prostheses that manipulate *information* (genetic, neural etc). Secondly, mechanical extensions are specialized prostheses, while the cybernetic prostheses are much more flexible and total. Cloning, for example, enables each cell of the body to become an embryonic prosthesis of the entire body.

The android and the computer that tries to pass the Turing test accomplish the goals of the second order: to imitate and to become equivalent to humans. The cyborg, on the other hand, does not try to imitate humans. As a product of the third order, the cyborg fuses together the biological and the technological. Gradually, technology becomes part of the regulated system of the body, that is, part of homeostasis: already today computerized-cybernetic systems are integrated into the feedback mechanism of the body and in the future the trend will increase due to nanotechnology. Hence the *posthuman* situation is not just social and psychological but also biological. The new technological prostheses are absorbed by the human body or vice versa: humans are absorbed by the new technological environment, as in the vision of Ray Kurzweil, which I have mentioned before (Kurzweil 2006). The BCI systems, for example, are only a prototype: the dream of many science fiction writers and cyberneticists, such as Hans Moravec, is to *upload* human consciousness into a computer as an information pattern (Moravec 1999; 1988). Yet, as McLuhan and Hayles note, the concept of information is an abstract engineering instrument which is designed for efficient transmission of messages. *Information*, as defined in the Shannon-Weaver model, cannot deal with contexts, media, meanings and the complexity of human thought (McLuhan and McLuhan 1988: 85 – 87; Hayles 1999: xi - xii, 1, 53 – 54; Shannon and Weaver 1949). The abstract approach of scientists and futurists like Moravec does not take into account that consciousness depends on a complex interaction of the body with the environment.

In *Clone Story* Baudrillard refers to organ transplantation as a prosthesis that belongs to the second order or the industrial society. As he explains, organ transplantation is just a “traditional prosthesis, which serves to repair a failing organ, [and] changes nothing in the general model of the body.” Psychotropic drugs, on the other hand, model the body “from the inside, no longer passing through the perspectival space of representation…” (Baudrillard 1994: 101), and therefore they belong the third order. Indeed, the first prototypes of the cyborg were based on chemical and mental prostheses. Donna Haraway, who has adopted the ideas of *extension* and *implosion* following McLuhan and Baudrillard, identifies among the first prototypes of the cyborg a rat from the end of the 1950s with an implanted osmotic pump that injects chemicals to the rat's body with the purpose of modifying and regulating its homeostatic states, and mental patients from the 1960s with neuro-chemical implants (Haraway 1997: 12, 51; Haraway 1995: xvi – xvii; Haraway 1991: chap. 8; Haraway 2000: 99; Clynes and Kline 1960). As I have shown, the new cyborgs that Nicolelis Warwick and their colleagues try to develop are based on information, software and computerized systems.

In the late 1980s, Baudrillard added a fourth stage to the orders of simulacra: the simulacra of *proliferation* (Baudrillard 1993; Genosko 1994: xv-xvi, 41 – 55). The distinction between the third stage and the fourth stage is not clear. Perhaps Baudrillard simply analyzes our time in higher resolution. The development of the hyperreal and cyberspace in our time creates an infinite “viral” proliferation of signs and simulations, and the hypertextuality of the global electronic matrix leads to maximal implosion and disappearance of differences, boundaries and strict meanings. Fourth order simulacra have achieved full emancipation from rigid significations which were replaced by "fractal", elusive, multiple significations. [50] The result is a total insignificance/meaninglessness and non-metaphorical synonymity: *everything is political*, *everything is sexual*, *everything is entertainment*… Paradoxically, Baudrillard uses a similar metaphor, *metastasis,* in order to clarify that the implosion of meanings in the postmodern situation puts an end to the metaphorical relationship:

> …it is no more a metaphoric figure, it is a figure of metastasis; a deprivation of meaning and territory, lobotomy of the body resulting from the turmoil of the circuits…The religious, metaphysical or philosophical definition of being has given way to an operational definition in terms of the genetic code (DNA) and cerebral organization (the informational code and billions of neurons). We are in a system where there is no more soul, no more metaphor of the body – the fable of the unconscious itself has lost most of its resonance. No narrative can come to metaphorize our presence; no transcendence can play a role in our definition; our being is exhausting itself in molecular linkings and neuronic convolutions (Baudrillard 1988a: 50 – 51).

In chapters 1 and 2, we saw that metaphors are based on analogies between two domains that language and culture define as separate domains. Following McLuhan, I have explained that in comparison to the discontinuous, analogical form, the relationships in metonymic and synecdochic sentences are more *literal*, since they appear within the *same* domain or the *same* system: in metonymy something is described as one of its attributes or adjuncts, and in synecdoche the part is described as the whole or vice versa. Unlike Baudrillard, I do not argue that the simulation culture has eliminated the metaphorical, and yet in this chapter I have tried to show that through the dynamic of techno-culture the relationship between humans and machines has become less analogical and more metonymic and synecdochic. The extensions of the body were created as metaphors which translated the body into the environment, but eventually the reciprocal interaction fused together the two domains - the body and the artificial environment. The electronic prostheses have imploded into the body and penetrated the homeostatic regulation of the body. On the physiological level and on the molecular level, the body and the machine have become part of the same system. The body is redesigned as a machine: feedback mechanisms, electrodes, chips, neuro-chemical implants and other devices/prostheses are integrated with the new body which is transformed into an informational-cybernetic, biotechnological body. Finally, the cybernetic approach in biology and the metaphor of *information* led to the development of the cloning technique, which makes the body the ultimate technological prosthesis of itself. Yet, any technology and any metaphor have limitations, and eventually their failures promote the appearance of new alternatives.

- Conceptually and practically, the genetic paradigm, recombinant DNA technology, synthetic biology and stem cells transplantation create an *inter-species implosion*.

According to the genetic view, we are about 98% *identical* to chimps. In practice, recombinant DNA technology and the field of *synthetic biology* close the inter-species gap. The manipulation of genetic *information* enables the production of endless chimeras, such as microbes and rabbits with human genes or insects and goats with spider genes. Notice that the inter-species implosion is a result of the technological implosion. Recombinant DNA technology and biotechnology have transformed micro-organisms into micro-factories that produce materials for the medical industry. The insertion of human genes into bacteria and plants enables the mass-production of interferon, hormones like insulin and other materials. Inter-species implosion also serves the food industry. Genes of different species are inserted into plants and crops in order to produce genetically modified food that can withstand extreme conditions, such as cold, salty soil and drought. Researchers are trying to develop, for instance, transgenic tomatoes and strawberries with DNA sequences of cold-water fish that will be resistant to frost. Inter-species implosion has many other industrial applications. Spider silk, for example, is a very strong elastic fiber that can be used for many purposes, from manufacturing of bulletproof vests to repair ligaments in the human body. However, farming spiders is not a practical way to produce spider silk, since spiders are aggressive and territorial. Instead, other organisms have been *reprogrammed* to do the work, for instance, transgenic goats with spider genes that produce milk containing spider silk proteins. The origins of synthetic biology can be traced to the work of biologists such as Jacques Loeb (1859-1924).[51] Synthetic biology today applies the engineering principles of the information age in biological systems. As the professor of biological engineering Ron Weiss explains: “I decided to take what we understand in computing and apply that to programming biology. To me, that's really the essence of synthetic biology.”[52] Although synthetic biology has developed from the reductionist currents of genetics, Weiss and some of his colleagues proclaim: “Synthetic biology extends the spirit of genetic engineering to focus on whole systems of genes and gene products. The focus on systems as opposed to individual genes or pathways is shared by the contemporaneous discipline of systems biology, which analyzes biological organisms in their entirety. Synthetic biologists design and construct complex artificial biological systems using many insights discovered by systems biologists and share their holistic perspective” (Andrianantoandro et al. 2006). According to the authors:

> The goal of synthetic biology is to extend or modify the behavior of organisms and engineer them to perform new tasks. One useful analogy to conceptualize both the goal and methods of synthetic biology is the computer engineering hierarchy. Within the hierarchy, every constituent part is embedded in a more complex system that provides its context. Design of new behavior occurs with the top of the hierarchy in mind but is implemented bottom-up. At the bottom of the hierarchy are DNA, RNA, proteins, and metabolites (including lipids and carbohydrates, amino acids, and nucleotides), analogous to the physical layer of transistors, capacitors, and resistors in computer engineering. The next layer, the device layer, comprises biochemical reactions that regulate the flow of information and manipulate physical processes, equivalent to engineered logic gates that perform computations in a computer. At the module layer, the synthetic biologist uses a diverse library of biological devices to assemble complex pathways that function like integrated circuits. The connection of these modules to each other and their integration into host cells allows the synthetic biologist to extend or modify the behavior of cells in a programmatic fashion. Although independently operating engineered cells can perform tasks of varying complexity, more sophisticated coordinated tasks are possible with populations of communicating cells, much like the case with computer networks (Andrianantoandro et al. 2006).

New techniques in molecular and developmental biology physically retrieve ancient myths, such as the *Chimera* or the *Centaur*. Beyond the genetic level, human-animal hybrids can be created through stem cell transportation. The transplantation of pig heart valves into humans was only one of the first steps in the field of Xenotransplantation. Modern molecular techniques enable the transplantation of stem cells from one species into another species, either in embryonic stages or in adults. Some groups of researchers inject human neural stem cells into mice's or rodents' brains (Brüstle et al. 1998; Fricker et al 1999; Rubio et al. 2000; Englund et al. 2002;

Buchet et al. 2002). Other groups inject human neural stem cells into monkeys' or apes' brains (Ourednik et al. 2001; Bjugstad et al. 2005). Another group injects human stem cells from bone marrow of adults or from embryo lines into fetal sheep. At the early stages of its development, the fetal immune system does not reject the human cells. The goal is to grow human stem cells in a host body and afterwards to extract and use them for regenerating healthy tissues in diseased organs. Alternatively, one could use entire organs that developed in the host body and transplant them into the body of the human who donated the bone marrow. According to the plan, the chimeric stage would last only in the sheep's body: once the chimeric organ is transplanted into the human body, the sheep's cells would be rejected by the body. Human stem cells can develop in different organs of the sheep, e.g. the skin, the liver, the heart and the pancreas. In practice today about 7% - 15% of these organs are composed of human cells (Almeida-Porada et al. 2004a; Almeida-Porada et al. 2004b; Narayan et al. 2006).[53]

In the comedy *The Animal*, the hero receives organ transplants from various animal donors and as a result he gets out of control. Ethically, legally, socially and psychologically, it is much easier to perform transplants from human to animal than vice versa, although the fear of creating a rat or a primate with human consciousness still exists. In addition to the transplantation of animal heart valves into humans, xenotransplantation from animal to human today includes transplantations of porcine fetal neural tissues into the brains of Parkinson's and Huntington's disease patients in order to improve their functioning (Fink et al. 2000). In these cases it is argued that the use of porcine tissues and organs is ethically preferable to the use of human tissues and organs. According to the authors of the article, the use of porcine tissues is also preferable due to infection risks and other practical reasons, although one of the risks in this kind of project is that animal viruses would mutate and infect humans.

In 1997, the biologist Stewart Newman and the social activist Jeremy Rifkin filed a patent application to the U.S. Patent and Trademark Office. The application dealt with human-animal hybrids, such as the “humouse”. Except for promoting public discussion, Newman and Rifkin wanted to force the US PTO either to reject their application so that no one else could receive a similar patent or to approve their application so that no one else could receive a similar patent for the next 15-20 years.

Their proposal was ultimately rejected by the US PTO in 2005. According to Newman, the patent examiners have rejected different versions of their application for technical reasons, or because they were not original enough, or because the specifications was too vague, but the main reason was that some versions of the invention were too human.[54]

The old categories are collapsing. A group of biomedical practitioners, philosophers and law experts, that had discussed the ethical and social aspects of creating human-animal hybrids, published its conclusions in *Science* (Greene et al. 2005). Despite controversies and differences regarding the necessity, contribution and ethics of experiments on primates, the group has unanimously rejected ethical objections “grounded on unnaturalness or crossing species boundaries”. First, they claim: “Whether it is possible to draw a meaningful distinction between the natural and the unnatural is a matter of dispute.” Moreover, modern medical practice is based on tools, machines, artificial materials etc. Finally, biology was not able to define fixed boundaries between species (and furthermore the definitions of the term *species* are problematic, to say the least). However, the key question is “Could we change the capacities of the engrafted animal in a way that leads us to reexamine its moral status?” Thus the authors recommend tightening the regulation of “neural grafting experiments”, especially when relatively large number of human cells are implanted in the brains of monkeys and apes in early stages of development. In addition, they recommend that the researchers will have to examine the engrafted animals and report changes in cognitive function.

Part II

The Transformation from the Organic Perception of the Body to the Mechanistic Perception

The metaphoric interaction between technology and the body is reciprocal. Technologies are designed as extensions that translate the body into new forms. At the same time they modify the way we perceive and experience the body. Additionally, they can physically redesign the body. Thus, as I have argued in the previous part, the body and the machine serve as *source* and *target* for each other. In this part the focus will be on the machine as a *source* and the body as a *target*. I will analyze the development of life sciences using the meta-narrative of McLuhan and his insights. Generally, I will demonstrate how the medium becomes the message and how techno-cultural environments modify the way we perceive and understand the body through metaphorical reconstructions. Using an extensive analysis I will try to identify historical patterns concerning the development of the *body↔machine* metaphor. In chapter 3, I have discussed several aspects of the electro-cybernetic impact on the life sciences during the 20th century. In the following chapters I will discuss the impact of the mechanical world and industrial society on the life sciences (1600-1900 A.D.).

Along the history of the life sciences many different and contradicting theories concerning the *body↔machine* had been developed. Nevertheless, using a low resolution analysis, I will try to reveal general historical trends and patterns in the development of the *body↔machine* metaphor. The differences between types of the *body↔machines* and their technical specifications are less relevant to this discussion, as long as they are based on certain basic principles and characteristics of the mechanistic framework. It is, therefore, important to stress that competing paradigms and contradicting views may articulate the same general trends.

Technological environments develop through *hybrid energy* (see chapter 2). Correspondingly, when the medium becomes the message, society, culture, human perception and the sciences are modified through *hybrid energy* and *rear view mirrors*. In the following chapters I will focus on the shift between pre-modern perception and modern perception in the life sciences. Compared to the transition from the animistic and organic universe to the mechanical universe in natural philosophy or physics, the transition from the organic, spiritual body to the mechanical-industrial body was relatively more complicated. Experiential failures of the mechanical metaphor, religious values, moral implications, cultural atmosphere and social institutions interrupted the complete reduction of humans by the mechanistic program. Nevertheless, in just a few centuries - since the invention of the first assembly line of the printing press in the 15th century, and through the development of the modern-industrial environment - the mechanistic perception became dominant and the old organic perception declined. In my analysis of the life sciences, I will use the term ***Organic*** (in a different sense of the term *organicism* in modern biology) as a generic name that represents ancient and pre-industrial perceptions, traditions and values.[55] It is important to note that the terms *organic* and *mechanical* correspond to the McLuhanite notions of *acoustic space* and *visual space*, as were previously defined. Visual space is the environment that began to develop with the invention of the phonetic alphabet. This environment became dominant by print culture, mechanical inventions and the industrial society. Acoustic space is the environment of oral cultures. McLuhan often uses expressions such as “organic wholeness” and “complex, organic interplay of spaces” in relation to the acoustic space. Similarly he refers to the post-industrial, electronic age as “not mechanical but organic”, since the electronic age retrieves, on a new ground, elements of pre-modern acoustic space (McLuhan 1962: 31, 45, 135).

- **The main characteristics of the organic order**, as I define it, were based on essence, wholeness, telos, the soul or any other holistic force that regulates the body as a whole, and on the religious, mystic and animistic universe that resonated within the body.

With the development of the phonetic alphabet and the invention of *visual space*, the organic world was gradually modified. Literate cultures became less *organic* than preliterate cultures, although the organic order remained dominant until the appearance of print culture and industrial society. For example, the power of animism gradually declined with the development of script culture and the appearance of monotheism, but animism did not disappear even during the Renaissance and residues of animism were found in the work of intellectuals from the early modern age.

The medium becomes the message through hybrid stages. Indeed, the shift from the organic perception to the mechanistic perception occurred in a gradual manner. Yet there was a clear trend leading from the organic perception of the pre-modern world, through the organo-mechanical perception of early modern science, and to the growing dominance of the mechanistic perception in the industrial era. At the end, vitalism, that had suggested an organo-mechanical approach, lost its power. It should be emphasized again that techno-cultural orders are trans-paradigmatic. Vitalism itself was in many respects a compromise of the traditional organic view that had to negotiate with the growing dominance of the mechanistic perception and with the instrumental success of the industrial environment. Thus, *Mechanism* and *Vitalism*, the two competing paradigms, were an expression of the mechanical age and the industrial world that gradually consumed the organic perception. Ironically, prominent vitalists, such as Xavier Bichat, Jean Corvisart, Rene Laennec, Henri Milne-Edwards and Erasmus Darwin, were among the pioneers who made an enormous contribution to the mechanistic perception of the body. Moreover, the clear distinction between *mechanists* and *vitalists* is completely blurred when we examine scientists like Pierre Maupertuis. In many other cases the so called "vitalistic" approach was practically a mechanistic approach that emphasized the autonomy of life sciences from the physical sciences. Moreover, this emphasis also characterized the view of many scientists who were anti-vitalists and promoted a strong mechanistic approach, e.g. Rudolf Virchow. Hence, the organic perception and the belief in the autonomy of life sciences do not overlap.

We should therefore be aware that even the theories and thought of practitioners and scholars who are labeled as *vitalists* or *romanticists* (e.g. the romantic view of Alexander von Humboldt) can implicitly and explicitly express the impact of industrial society and the mechanistic order. Additionally, we should not regard mechanism and vitalism as two incommensurable paradigms, but as a group of different paradigms that over the history of modern science dealt with and expressed the development of a common techno-cultural environment. In general, the vitalistic approach was still trying to preserve elements of the organic perception, but the vitalists themselves were promoting a soft mechanistic view. Moreover, prominent vitalists were among the pioneers of the mechanistic program. From a historical perspective, then, the construction of knowledge is based on dissonance, tension and the formation of hybrids. The organic outlook was finally dismissed by the industrial society. Nonetheless, the electronic environment has begun to retrieve elements of the organic perception in a new form.

Finally, I want to stress that the metaphors we are dealing with cannot be dismissed as superficial images or as verbal ornaments annexed to the scientific knowledge. Scientific metaphors manifest the impact of powerful, techno-cultural environments that transform modes of perception, conceptions, mentalities, as well as societies and institutions.

4

The Organic Perception and the Fate of the Four Aristotelian Causes

The organic perception was shared by all ancient oral cultures, despite the great differences between them. Using a low resolution analysis, I will try to define the organic characteristics that united different systems and worldviews. The body in the organic perception was endowed with essential, holistic, purposeful and spiritual forces and qualities. In this framework one cannot reduce the body to linear chains of mechanical causes, to the movement of discrete particles or to a set of functional units that can be measured and standardized. For example, in the Aristotelian view, living beings were defined by the *psyche*, a non-spiritual soul which is characterized by essence, wholeness and purpose. According to Aristotle, the *psyche* is both the formal cause and the final cause of the living being (Aristotle, *On the Soul* and *Parts of Animals*, 1985, vol. 1: 402a – 435b, 640b – 641a). I would like to stress that holistic-vital forces were key elements not just in the traditional organic approaches of Western cultures, but also in the organic approaches of non-Western cultures. For example, according to traditional Chinese medicine (Bray 1993), health and disease depend on an essential, vital and holistic force named *qi* which circulates throughout the body. If the modern mechanistic approach defines the disease as a malfunction located inside a certain part of the body, in Chinese medicine the disease is perceived as a disharmony of qi.

Based on an entirely different metaphorical framework, modern physicians began to see diseases as lesions or malfunctions which appear in specific parts and tissues of the *body↔machine*. The developments in pathological anatomy were not isolated, but they were part of a great revolution in the techno-cultural environment and in the mode of perception: the body in the industrial society became part of the mechanical universe and the nation-state, just as in the ancient world, The Middle Ages and the Renaissance the body was part of the religious, mystic and animistic universe Although the monotheistic traditions rejected animism to a large extent, the animistic perception was still present in the early modern age. From the ancient world, through Shakespeare's plays and to the modern world, the complex interrelations of the body, the universe and society reflected techno-cultural developments and alterations in the *body politic*. Indeed, modern science aspires to produce *objective*, non-metaphoric knowledge, but even its success in avoiding the explicit use of metaphors is only partial. For example, during the 19th century the eminent pathologist Rudolf Virchow and his colleagues developed the *cell↔state* metaphor, which articulated the worldview of the industrial society (Virchow 1958 [1859]: 130).

Mysticism and animism dominated the organic world. The ancients perceived the universe as a living being. The macrocosm (the universe) echoed in the microcosm (the human body) and vice versa. According to the traditional religious belief, God had created the universe, and from the dust of earth He created Man as a microcosm. Paracelsus (1493-1541), for example, defined the universe as a "Big man" which was born as an infant, grew and aged. In this view, the human body is the child of the big man; it is characterized by all the essences and properties of the universe (including the bestial nature of snakes, sheep, wolves etc), and it also corresponds to the universe in its structure and organs, in health and sickness. This metaphoric perception led Paracelsus in his search for a cosmic anatomy. According to the traditional view represented by Paracelsus, the origin of diseases lies in the celestial bodies and in cosmic events. An ulcer or a skin disease can only be explained in relation to the origin of thunders, winds and storm and in relation to the celestial bodies and the elements that compose them. Again, the organic perception of Paracelsus was far from the modern mechanistic perception that tries to locate diseases in certain body parts through autopsies (Temkin 1977: 279 – 280).

The mystical metaphor of the *macrocosm↔microcosm* was a key element in the organic perception. In one of the Hippocratic books the earth is represented through a seven part map in which the Peloponnesus serves as the head, the Isthmus as the spinal cord and so forth. The different regions, it was claimed, influence the moral and intellectual qualities of their inhabitants. In script the phrase *microcosm* appeared for the first time in the work of Aristotle, who claimed that if something happens in the "little world [microcosm]", it also happens in the "All", i.e. in the "great" world. The Greek Stoic philosophers perceived the universe as an animate, rational being. The Roman philosopher and statesman Seneca explained that nature and the body correspond to each other: watercourses to the veins, the substances of earth to the flesh, earthquakes to convulsions etc. Traditional Islamic philosopher Abu Hamid al-Ghazali (1058-1111) argued that the structure of the microcosm should be studied not just by doctors, but also by those who wish to know God. The rudiments of the organic perception can be identified even in the early modern age. For example, the eminent physician Andreas Vesalius affirmed in 1543 (the same year in which the work of Copernicus was published) that the human body corresponds to the structure of the universe (Jackson 1989: 137).

Indeed, as Frances Yates argued, the figure of the modern scientist developed in a hybrid manner. Yates has specifically suggested that the immediate ancestor of the 17th century scientist was the *magus* of the hermetic movement in the Renascence. The hermetic movement promoted the development of the mechanical and mathematical sciences and the idea of a utopian society that is led by wise men who can control and manipulate empirical phenomena. Yet the magus was still a scientist-wizard who combined applied knowledge and mechanics with animism, hermetic mysticism, magic, Kabbalah and the use of talismans. Mystical and magical relations between the macrocosm and the microcosm played a major role in the hermetic tradition which still referred to the universe as a living being with a soul. One can see this in the work of Marsilio Ficino (1433-1499), an Italian physician and a distinguished philosopher who was influenced by the hermetic tradition and promoted it. His medical practice involved astrology and magic which aimed at understanding and curing the body through its relations with the cosmos. For example, according to Ficino, intense study may bring students and scholars under the influence of Saturn, and thus they tend to become ill or melancholic. Ficino advised them to keep away from objects, plants and animals that are under the influence of Saturn and to surround themselves with objects, plants, animals and people that are under the influence of Jupiter or Venus, since these planets are associated with health, life and good spirits. Ficino's suggestions also included a non-Saturnian diet and the use of talismans (Yates 1964; Yates 1967).

Similar relations between the macrocosm and the microcosm can also be found in the organic perception of non-Western societies. In traditional Chinese philosophy the universe was a living being and a resonant whole in which everything is mutually dependent. Since the inner and the outer worlds share the same physiology (qi, yin yang and the five phases: wood, fire, earth, metal and water), the aim of Chinese medicine and mysticism was to maintain the harmony between the macrocosm and the microcosm. The Hindu scriptures, as well, describe the universe as a living being: the sun is the eye of the universe, the wind is its breath, the sacrificial altar is its breast, the earth is its feet etc. According to the Vedic hymns, the universe was created from the body of Purusha, an ancient mythic giant who was sacrificed by the Gods. Society is an integral part of the universe, or vice versa. The myth of Purusha articulated the existing order of Hindu society and the early forms of social fragmentation and specialization that appeared in the ancient world. According to the myth, the social classes were born from the body of Purusha: the Brahmin (the high class of scholars and priests) from Purusha's mouth, the Rajanya (warriors and rulers) from his arms, the Vaisya (traders and agriculturalists) from his thighs, and the Shudra (the lowest class – laborers and artisans) from his feet. In Tantric philosophy and in yoga one can identify the same mystical relations between the macrocosm and the microcosm (Bray 1993; Jackson 1989: 137 – 138).

This ancient metaphoric perception of the body is unintelligible in modern terms. As Virchow put in 1859, "In medieval times it was customary to say that an organism was a microcosm, a little world. Nothing of the sort!" (Virchow 1958 [1859]: 130). The philosopher Carl Hempel (1966: 48) responded in a similar way to the *macrocosm↔microcosm* metaphor and to the organic perception. As a logical positivist, Hempel was a representative of modern *rationalism* and of the reductionist-mechanistic approach: in general the verification theory of meaning of the positivists was based on reductionism; in particular Hempel explicitly defended the mechanistic approach in biology (Hempel 1966: 101 – 106). In this context Hempel criticized the 17th century Italian astronomer Francesco Sizi, due to the way in which Sizi rejected Galileo's observations and Galileo's claim that there are satellites circling around

Jupiter. According to Sizi's argument, there are seven *windows* in the head (two nostrils, two ears, two eyes and a mouth), and therefore there must be only seven planets in the universe ("two favorable stars, two unpropitious, two luminaries, and Mercury alone undecided and indifferent"). Moreover, he noted, the importance of the number seven is evident in many other natural phenomena e.g. the seven metals. Sizi concluded that the *satellites* of Jupiter "can have no influence on the earth and therefore would be useless and therefore do not exist". Hempel asserts that even if we accept the "facts" as described by Sizi, his argument is invalid: from the number of openings in the head one cannot conclude that there are seven planets in the universe and that the satellites circling around Jupiter do not exist. Indeed, in modern eyes Sizi's argument is incoherent. Nevertheless, we have to acknowledge that Sizi's argument was based on the organic framework, and thus the relevance of the facts in this argument should be examined in light of the belief in the animistic cosmos. The abstract analysis of Hempel ignores the socio-cultural context of scientific knowledge. In fact, the logical positivists separated the *context of discovery* from the *context of justification* and assigned the socio-cultural aspects of science to the *context of discovery*. In other words, using the principle of fragmentation the logical positivists avoided dealing with the socio-cultural aspects of science. However, once we take into account the pre-modern perception, the organic framework, and the *hidden* assumptions in Sizi's argument (e.g. essence, wholeness and the analogies in the grand-metaphor between the macrocosm and the microcosm), Sizi's facts become relevant to his argument. It is interesting to note that the Copernican revolution and the new mechanical sciences greatly contributed to the downfall of organic medicine. First, the mechanical sciences directly influenced the life sciences, for example, Galileo's mechanics influenced the development of iatro-mechanism in the 17th century. Secondly, organic medicine had relied on astrology, but the Copernican revolution made astrology obsolete.

- How do media and technology associate with the way in which the body is perceived and studied?

Well, the most obvious aspect in this context is that technological developments facilitate the accumulation of new knowledge and enable scientists to make new discoveries. But that is only part of the answer. From the McLuhanite approach we learn that the meaning of new media or technological environments is a new ground of *services* and *disservices*, new situations, new patterns of social organization, a new mode of perception and the formation of a new mentality. In other words, the characteristics of new technological environments have a deep psychological and social impact that can transform mindsets as well as the foundations of society. The development of the *body↔machine* metaphor, on the expense of the organic metaphors, was part of a great change in the techno-cultural ground. The basic conditions for this process appeared with the transition from oral culture to script culture, but it was not sufficient, to say the least. With the development of the mechanical environment the *body↔machine* metaphor began to modify the old traditions and to replace them. As we will see, the process matured in the industrial society: the social and psychological conditions of the industrial society, its forms of organization and institutions, reshaped the way in which the body was viewed, studied and analyzed. For example, the trend of specialization in the industrial society had a great impact on the professionalization of scientists and on their practice. This trend also had a great impact on the way in which scientists perceived, analyzed and described the body as an aggregate of fragments each having a special function. One can identify the impact of technology on scientific theories in the life sciences through the explicit use of mechanical metaphors in the scientific discourse, through the characteristics of the *body↔machine* as described in scientific works and through the hidden assumptions of scientific studies.

The transformation from oral culture into script culture modified the organic world. Significant cracks in the organic world appeared with the development of the phonetic alphabet in ancient Greece. Through the phonetic alphabet the Greeks developed a new mode of perception. The new medium broke down ideas, sentences, words and semantic meanings through abstract bits of sound (consonants and vowels) which are reduced to abstract visual signs. According to this technique, meaning is constructed by connecting the abstract signs in a linear fashion, step-by-step. Preliterate societies were characterized by situational/contextual thinking, mimesis, holistic approach, and by other characteristics that were modified, devalued and vanished in literate and highly-literate societies. A new set of values and techniques was created in literate and highly-literate societies: detachment, rationality, objectivity, abstraction, linear argumentation/formal logic, and analytic approach based on fragmentation and reduction (see, for example, McLuhan and McLuhan 1988; McLuhan 1964; McLuhan 1962; Ong 1982; Havelock 1963; Goody 1990; Goody and Watt 1968). *Objectivity* and *detachment* were alien to ancient oral cultures. These values began to develop in script culture and they were important to the development of modern science. In his book *Preface to Plato*, Eric Havelock reviews Plato's hostility towards the oral educational system. Mimesis, the oral technique for learning and knowing, was based on imitation and identification with the described events, i.e. with a person, an object or a situation. The preliterate did not aspire to learn from a detached, objective perspective using an analytic-critical approach. On the contrary, the preliterate revived the situation and became the thing they learned:

> You threw yourself into the situation of Achilles, you identified with his grief or his anger. You yourself became Achilles and so did the reciter to whom you listened. Thirty years later you could automatically quote what Achilles had said or what the poet had said about him. Such enormous powers of poetic memorisation could be purchased only at the cost of total loss of objectivity. Plato's target was indeed an educational procedure and a whole way of life (Havelock 1963: 45).

Plato's campaign against the oral tradition, and his wish to create a solid *psyche*, i.e. an autonomous *rational* personality, were two complementary aspects of the same agenda. The psyche is a relevant notion to the main issue of this chapter. On the one hand, as Havelock maintains, the psyche in the Platonic view, and in the view of his successors, disconnected from the preliterate perception. On the other hand, as I will explain below, the notion of psyche in the Platonic and Aristotelian views still pertained to the organic framework and was far from the mechanistic framework. This observation corresponds to the distinction made by McLuhan between the earlier phase and the advanced phase of *visual space*: the earlier phase was script culture based on the phonetic alphabet (the *genesis of visual space*), and the advanced phase was print culture or the highly-literate industrial society (*visual space in use*). In any case, the preliterate experienced and perceived the body in an entirely different way compared to the literate. Plato rejected the preliterate polyphonic and polymorphic self, the collective psyche and mind. The metamorphic identification with different people, objects and situations did not coincide with the construction of a rational and solid self who can detach from and analyze the object of study. Script culture headed by Plato had replaced the *poetic* or *oral* state of mind with rationalistic, abstract, analytic state of mind. The medium of the phonetic alphabet enabled the reader to try and neutralize the emotional identification which was rooted in the oral tradition and in the technique of mimesis. Plato urged the literates to separate themselves from the issues and objects through analysis, examination and reexamination. Eventually mimesis had given way to dialectic. Paradoxically the phonetic alphabet which freed the Greeks from the oral culture was assimilated through the technique of mimesis, i.e. through a hybrid process. In practice, the alphabetic *revolution* was a gradual process that developed over a few centuries (Havelock 1963: 45 – 47, 197 – 214; McLuhan and McLuhan 1988: 13 – 33).[56]

Socrates was in between the preliterate and literate worlds. He did not trust the alphabet and probably never wrote down his ideas. According to Plato's *Phaedrus*, Socrates warned that the alphabet "will introduce forgetfulness into the soul of those who learn it", since they will trust the written text and learn nothing. Yet Socrates contributed to the development of the early form of dialectic that challenged the oral tradition (see previous note). His followers, Plato and his student Aristotle, were already deep into the script culture and promoted a new form of rationality. In ancient Greece the meaning of *common sense* was a faculty that translates each sense to all other senses. This faculty creates consciousness and *ratio* among the senses. The literate transformed the meaning of *common sense*. Rationality became identified with classical logic, i.e. with the uniform, continuous, sequential, abstract logic of *containers* which, as I pointed out in chapter 2, detached from the oral, contextual thought. For example, the meaning of the modern phrase "I don't follow you" is "I don't think what you're saying is rational". This process began to take shape in the age of Plato and Aristotle. In his *Prior Analytics* Aristotle formulated the laws of classical logic. His rules of syllogism are abstract and linear following the characteristics of the phonetic alphabet. Instead of mimesis, polyphony, metamorphosis, emotional identification and contextual thought, Plato and Aristotle helped to design a new mind and a new *self* based on abstract rationality and on the logic of containers (Havelock 1963: 208, 303; McLuhan 1964: 15, 60, 85, 108; McLuhan and Fiore 1967: 45, 113 – 114; Plato, *Phaedrus*, 1995: 79 – 80; Aristotle, *Prior Analytics*, 1985, vol. 1: 24a – 70b).

Religion, mysticism and the practice of medicine contributed to the way in which the body was perceived and described, but the study of nature and life in the pre-modern world was also part of philosophy. In ancient and medieval times the prominent authority in all branches of philosophy, science and thought was Aristotle (384 – 322 BC). At the end of the medieval times, and in the renaissance, the writings of Aristotle were considered to be the canonic texts by the religious establishment in Europe, although we have to remember that the Catholic Church interpreted the Aristotelian philosophy in the framework of Christian theology and faith. In addition, Aristotle's study on animals is considered to be the most comprehensive empirical study in zoology before the early modern age (for instance, his classic study on embryonic development). Eventually Aristotle became the main rival of early modern thinking and early modern science. I would like to show that although Aristotle detached from the oral culture, the Aristotelian view still belonged to the organic world.

A brief definition of the four Aristotelian causes:

- Formal cause - the essence of the thing, the whole pattern of the thing, what the thing is, its logos, its formula, its definition.
- Material cause - the materials from which the thing is composed, its constituents.
- Efficient cause - the mechanism that produces the effects, the source of the change or rest, the agent that produces the thing.
- Final cause or teleology - the inherent goal of the thing, its purpose, the reason for which it was made (Aristotle, *Metaphysics*, 1985, vol. 2: 1013a – 1013b).

The Aristotelian causes are applied to nature, to living beings and to artifacts. Let us take as an example a bronze statue, i.e. an artifact: the idea of the statue, or the plan of the statue, is its formal cause - its essence (a figure of Hermes, an idea, a myth etc.); bronze is the material cause of the statue; the sculptor and his art are the efficient cause of the statue; and the reason for which the statue was built is its final cause (teleology). The formal cause was the most important cause, since it defines the essence of the thing. A sculpture of Hermes would still be a sculpture of Hermes even if it was made of wood instead of bronze. In *Parts of Animals* Aristotle explains the priority of essence and wholeness in the understanding of life. One cannot give an account of humans, animals or plants by simply stating their material components. In order to explain what living beings are, and to explain their behavior and functions, we need to seek their definition, their formal causality:

> For it is not enough to say what are the stuffs out of which an animal is formed, to state, for instance, that it is made of fire or earth – if we were discussing a couch or the like, we should try to determine its form rather than its matter (e.g. bronze or wood), or if not, we should give the matter of the *whole*. For a couch is such and such a form embodied in this or that matter, or such and such a matter with this or that form; so that its shape and structure must be included in our description. For the formal nature is of a greater importance than the material nature (Aristotle, *Parts of Animals*, 1985, vol. 1: 640b).

In *De Anima* Aristotle elaborated his view on the body. *De Anima* is the Latin translation of *Perì Psūchês*, and its English translation is entitled: *On the Soul* (Aristotle, *On the Soul*, 1985, vol. 1: 402a – 435b). In this treatise Aristotle defines the nature of living beings in relation to the causes. The composition of the body is the material cause. The *psyche*, or the *soul* (in the English translation), is the formal cause of living beings, i.e. the soul is the definition of life, its form of organization and its essence. For instance, the eye is part of the material cause, but sight is part of the formal cause, part of the essence or the soul. When the living body can no longer see, the matter which composes the eye is an eye by name only, like the eye of a statue or a painted figure. The soul is the actuality of the material living body. I would like to stress that although the concept of psyche in the Platonic and Aristotelian views was part of the visual space and script culture, it was still organic in the sense that I have defined before. Unlike the Platonic soul or the notion of the soul in monotheistic religions, the Aristotelian notion of *psyche*, is not a spiritual essence external to the organic body: though he was later interpreted in theological frameworks, for Aristotle the soul was rather the dynamic organization of the living body which defines its essence. However, in the framework of the low resolution analysis that I apply in this part, both views of the *soul* are classified as organic and pre-mechanistic, since both are based on essence and wholeness (formal cause) and on telos (purpose, final cause), which cannot be reduced to an end state of a series of efficient causes as in the mechanistic order. We will later see that the *machine* metaphor did shape Aristotle's perception of the body, but only within the organic framework. For example, when Aristotle describes the movement of the body as the movement of an automatic puppet working by springs, the movements described are still regulated by the soul, that is, by essence and telos. Similarly, in Aristotle's analysis of the embryonic development, efficient causes are still working under the guidance of the final causes (telos) which are part of the soul of living beings.

Contrary to previous animistic views, in *De Anima* Aristotle drew a clear line between non-living and living natural bodies. The formal cause, or the soul that defines the essence and special organization of living bodies, is a combination of several powers. According to Aristotle, self-nutrition is the most basic of all psychic powers possessed by mortal living beings – plants and animals. The nutritive power of the "primitive" or "first soul" is manifested through the acts of reproduction and feeding which are followed by development, growth and decay. Animals are separated from plants due to their psychic powers of sensation, and touch is the primary form of sense which is shared by all animals. Animal souls could be further classified to those which posses the power of locomotion and to those which posses the power of thinking (human beings).

The telos of a living body, claims Aristotle in *De Anima*, is derived from its essence: the final cause is part of the soul, and thus in living creatures the formal and the final causes are merged. The plan of the organism already contains its telos, its purpose. For that reason Aristotle states in *Generation of Animals* that we may regard these two causes as one and the same (Aristotle, *Generation of Animals*, 1985, vol. 1: 715a). Since the nature and goal of the nutritive soul is to live and survive, the ordinary developed living being tries "to continue its existence in something like itself" by the act of reproduction. Therefore, contends Aristotle, the first soul should be named the "reproductive soul". When Aristotle explains the goal of the reproducing body he slides towards a cosmic teleology:

...it may partake in the eternal and divine. That is the goal towards which all things strive, that for the sake of which they do whatsoever their nature renders possible. The phrase ‘for the sake of which’ is ambiguous; it may mean either the end to achieve which, or the being in whose interest, the act is done… It is manifest that the soul is also the final cause. For nature, like thought, always does whatever it does for the sake of something, which something is its end (Aristotle, *On the Soul*, 1985, vol. 1: 415a – 415b). [57]

According to Aristotle’s teleological view, the organs of a living body serve different purposes which are derived from the essence and telos of the soul, for example, from the essence and telos of the nutritive soul: the leaf serves to shelter the pericarp, the pericarp to shelter the fruit and the mouth in animals and the roots in plants serve for the absorption of food (Aristotle, *On the Soul*, 1985, vol. 1: 412b). The movements of animals are purposeful: they try to reach an object of desire, or to runaway from what they identify as harmful. For instance, the appetite of the nutritive soul can originate a movement in order to reach the food (Aristotle *On the Soul*, 1985, vol. 1: 433a; Nussbaum 1978: 85 – 88). Even when a mechanical explanation is evoked by Aristotle it is always in the framework of essence and purpose. For instance, anger may be defined by the material and efficient causes as the boiling of the blood or warm substance surrounding the heart, but it should also be defined by the formal and final causes: anger is the appetite for revenge, a feeling of the soul, an intentional act regulated by the soul. In the same way, a house is more than the composition of stones, bricks and timbers: the essence and purpose of a house is to shelter from weather conditions and it is what defines a house as a house (Aristotle *On the Soul*, 1985, vol. 1: 403b). Similarly, in *Movements of Animals* Aristotle uses the movements of automatic puppets and a toy wagon as models for the movements of the body, but he immediately clarifies that the movements of the body are always regulated by the soul and they always work for the sake of something. Living beings move by appetite, wish, purpose, imagination and intellect (Aristotle, *Movements of Animals*, 1985, vol. 1: 700b – 701b).

While Socrates still represented the oral culture, acoustic space and the organic perception, Plato and Aristotle were pioneers of the script culture, visual space, and of the proto-mechanistic perception (a phonetic mode of perception, analytic approach, objectivity and detachment). Yet even Plato, Aristotle and their followers in the pre-modern world retained key elements of the organic perception. Thus the proto-mechanistic elements in the Aristotelian outlook were still subordinated to the organic perception. The decline of the organic perception was gradual, and the fragmentation of the body became dominant only through the industrial revolution. Actually the mechanistic perception began to develop gradually and in a hybrid manner in print culture, as part of the scientific revolution of the 16th and 17th centuries. In Plato's book, *Phaedrus*, Socrates declares that one cannot understand the nature of the soul without understanding the "nature of the whole" or the "nature of the world as a whole". Phaedrus replies that if Hippocrates is right one could not understand the nature of the body without understanding the nature of the whole. Owsei Temkin notes that historians interpret Hippocrates in two different ways. According to the first interpretation, the body can only be accounted for as an integral part of the entire universe. According to the second interpretation, the body can only be accounted for as a whole. The first interpretation is more accepted than the second (Plato, *Phaedrus*, 1995: 71; Temkin 1977: 141). In my opinion, both interpretations are correct and they manifest two complementary aspects which went hand in hand in the organic world. Hippocrates, or the Hippocratic corpus, emphasized the circularity of causes and effects within the body. This is the Hippocratic tradition that was handed down from antiquity to modernity:

…every thing in the human Body is disposed in manner of a Circle, that you will find the End where you would look for the Beginning, and the Beginning where one might expect the End (Hippocratic corpus; cited in Boerhaave 1766 [1708], vol. 1: 95).

Similarly, the Hippocratic Corpus also teaches the holistic relations between the body and the cosmos. In the treatise *The Nature of Man*, which is ascribed to Polybus, the son in law of Hippocrates, the writer explains how health is related to the seasons of the years through the four qualities: hot, cold, dry and moist. The four humors which make up the body are derived from these qualities. Notice that the explanation is given in terms of cosmological holism:

For just as every year participates in every element, the hot, the cold, the dry and the moist–none in fact of these elements would last for a moment without all the things that exist in this universe, but if one were to fail all would disappear, for by reason of the same necessity all things are constructed and nourished by one another–even so, if any of these congenital elements were to fail, the man could not live (Hippocrates, *The Nature of Man*, 1943-1995, vol. IV: 23).

Traditional humoralism considered illness in a holistic manner and diseases were defined in an inclusive context. Yet, as noted below, the analytic tendency that developed in script culture left its mark on the humoral approach (one can see it, for example in the work of Galen). The earlier version of humoralism appeared in ancient Greece during the 6th and 5th century BC, although humoralism is mainly identified with the views of the eminent physicians Hippocrates (ca. 460- ca. 375 BC), and Galen (129 – ca. 216 AD). The Hippocratic Corpus is a collection of different writings and views and the humoral theory is primarily presented in the treatise *The Nature of Man*. Galen later modified the humoral theory and combined the Hippocratic Corpus with the ideas of Plato. Humoralism continued to thrive during the days of the Roman Empire, in the Middle Ages and in the early modern age. From the 16th century on, Galen's anatomical and physiological theories declined and humoralism was greatly modified, until it lost power to modern medicine. According to the humoral approach, illness is caused by a disturbance to the natural balance of the body, or more specifically to the natural balance of humors. As the writer of *The Nature of Man* defined it, in health the humors are "duly proportioned to one another in respect of compounding, power and bulk" and "they are perfectly mingled", but in a disease state "one of these elements is in defect or excess, or is isolated in the body without being compounded with all the others." The humoral theory defined four types of humors or body fluids: the first three are blood, phlegm and yellow bile, and eventually the fourth humor was identified as black bile. Cosmologically speaking, the four humors corresponded to the four elements of the universe (earth, water, wind and fire), to the four seasons, to the life cycle, and to astrology. For example, blood is predominant in spring and childhood, yellow bile in summer and youth, black bile in autumn and adulthood, and phlegm in winter and old age. Humoralism went hand in hand with astrology: the humors were under the influence of cosmic sympathy and the divine regularity of the cosmos echoed in the regularity of the body. The balance and imbalance of the humors depend on the entire aspects of life: diet, life-style, habits, environmental conditions, emotions, season of birth, astrological data etc. Thus the humoral approach emphasized that diagnosis must be performed on the specific background of each patient. Humoral therapy is based on restoring the natural balance to the body by changing its overall mixture through diet, lifestyle and prophylaxis or by removing the harmful humor through bloodletting or drugs (Hippocrates, *The*

Nature of Man, Regimen in Health and *Humours*, 1943-1995, vol. IV: 3 – 95; Nutton 1993).

The impact of techno-cultural patterns is inclusive. Throughout history social structures resonated in the way the body was perceived. The pre-Socratic philosopher Alcmaeon defined the healthy body through the notion of *isonomia*. For the Greeks isonomia meant social balance achieved through equal political rights, and Alcmaeon used this notion as a balance between the qualities the body. Conversely, he defined the state of a disease as a "monarchy' of one of the qualities. The metaphoric thought of Galen was different. As a citizen of the Roman Empire, he adopted the maxim "To each his own", which articulated the social order of the Romans. The meaning of this phrase is that each person is entitled to a share according to his rank. Galen thought that nature works according to the same principle of justice: the size of each organ in the body depends on the purpose which it serves; the number of nerve fibers in each part of the body depends on the sensitivity that is needed for its function, and so on. The *social* organization of the body was also manifested in other aspects. Galen, for instance, imagined the body as a city in which the chyle is carried by vessels to the liver, just as food is transported to the bakeries through many routes. He attributed growth and nutrition to the nature (*physis*) of plants and animals. On the other hand, he attributed feeling and voluntary motion to the animal soul (the *psyche*). Galen remarked that some make a distinction between the *vegetative* soul and the *sensory* soul: plants are governed by the *vegetative* soul, while animals by the combination of the two souls. This view, explained Galen, is not different from his own view, although it contains inaccurate concepts (Temkin 1977: 271 – 279; Galen, *On the Natural Faculti*es, 1952: 3, 17 – 27).

- Hippocrates and even Aristotle had still emphasized the totality of living beings. In the work of Galen one can already detect the analytic tendency. Indeed Galen's perception belonged to the organic world, but it was already very far from the *primitive* perception. Galen was partially biased towards fragmentation. He divided the body into a collection of particular activities.

In Galne's program all different parts of the body had to be studied separately, because each of them contains a unique faculty adapted to a specific activity, e.g. the veins contain a faculty for producing blood and the heart contains a faculty for producing pulses. Consequently, in many respects the totality of the living being and the essential force that regulated its activity were decomposed and replaced by the autonomous activities of organs. A fundamental metaphor that shaped the perception of the body already in the pre-modern world defined the *organs* as *instruments*. Similar to Aristotle, Galen argued that the organs/instruments of the body may work mechanically. Nevertheless it is important to note that the pre-modern thinkers, i.e. Aristotle, Galen and their followers, squeezed this conviction into the organic framework. Galen believed that the body was designed by a divine craftsman as an instrument of the soul: the body is adapted to the needs and characters of the soul that controls it. Thus, for example, a species of brave animals must have a different body type in comparison with a species of coward animals. Nature, in Galen's view, always strives to protect and to cure the body: when the body is injured, nature works in order to heal the wound. Additionally, according to this view, a *formative* teleological faculty is responsible to the development of the body. Galen compared the matter from which the body is made to the wood from which the ship is built, and the formative faculty to the highest and the most creative art form (Galen, *On the Natural Faculti*es, 1952: 3, 17 – 27; Temkin 1977: 271 – 279; Roger 1997: 41 – 62). In conclusion, according to Galen, the formative faculty is –

"…doing everything for some purpose, so that there is nothing ineffective or superfluous, or capable of being better disposed" (Galen, *On the Natural Faculties*, 1952: 25 – 27).

❖ *The Industrial Revolution and the New Mechanistic Program*

The organic universe had given way to the mechanical universe in a gradual manner. In script culture the organic perception was still dominant. However the industrial society shattered the organic universe. The *macrocosm↔microcosm* metaphor had lost its power. In the new techno-cultural environment an entirely different metaphorical framework developed that transformed the universe and the body into machines.

The symbol of the mechanical world was the mechanical clock. Yet the movable type was the prototype of the industrial world. The Printing press was the first assembly line that enabled the mass production of uniform products. As McLuhan argued, "Printing from movable types was the first mechanization of a complex handicraft, and became the archetype of all subsequent mechanization…Like any other extension of man, typography had psychic and social consequences that suddenly shifted previous boundaries and patterns of culture" (McLuhan 1964: 170 – 171). Print diffused and enhanced the social and psychological effects of the phonetic alphabet. Moreover, as noted in chapter 2, print had served as the industrial model for analyzing and for solving complex problems. The industrial method is based on fragmentation, i.e. on breaking the complex problem/process into fragments/special functions. Then the fragments are reassembled in a linear fashion, step-by-step, through a chain of causes. The result: a process which is characterized by specialization and standardization. From the work of McLuhan and others we learn that the medium becomes the message on many levels - the social, the cultural, the perceptual and the scientific. The mechanistic order was replicated throughout modern history. For instance, the appearance of modern nationality depended on the mental and social characteristics of industrial society. The printing press played a major role in this process, which involved the standardization of national languages, bureaucratic centralization and standardization, the appearance of the *masses*, the homogenous citizenship of individuals etc (McLuhan 1964, McLuhan 1962; Ong 1982: 115 – 135; Ong 1958; Eisenstein 1979; Anderson 1991).

In this work I'm trying to reveal the complex relationship between the body and the technological environment, but in the following chapters we will also see the complex relationship between the organic body and the *body politic*. Thus the technological environment, the *industrial society*, the *body politic* and the life sciences created a *total filed* (in the terms of the electronic metaphor that McLuhan adopted). Indeed, the transformation of the organic body and the body politic into mechanical automata was a multi-dimensional phenomenon. During the 17th century, the mechanistic view appeared in natural philosophy and life sciences as well as in social and political theories. The impact of the mechanical metaphor and the mechanistic order was evident, for example, in the work of the philosopher and economist William Petty who perceived the body politic as a quantifiable mass. In the *Leviathan*, one of the most important books of the 17th century, Thomas Hobbes identified both the organic body and the body politic as mechanical automata: if the body is a mechanical watch, explained Hobbes, the commonwealth/ the state/ *Leviathan* is an *artificial man,* i.e. a great extension of man the aim of which is to protect and defend man. The socio-political philosophy of Hobbes was based on a mechanistic description of human beings and on the fragmentation of society. Ironically Hobbes projected the modern situation and the individualism of print culture on the "nature of man". According to Hobbes, in ancient times human populations were not governed by a central power, and therefore in state of nature humans were separate individuals and every man was enemy of every man. Society, on the other hand, is a result of the interests and *rational* decisions of individuals who want to achieve security and to resolve the conflicts between themselves. In this view, sovereignty is an *artificial soul* that gives life and motion to society/the artificial man (Hobbes 1904 [1651]: especially pages xviii, 83 – 86; Keller 2000: 324).

During the 18th century, the basic formula of the printing press successfully conquered all fields of production, as described in Denis Diderot's *Pictorial Encyclopedia of Trades and Industry* (Diderot 1959 [1763]). The social thought of the 18th century was an integral part of the industrial revolution. As we saw in chapter 2, Adam Smith described, in his canonical text on the principles of capitalism, the wonders of fragmentation. His text demonstrated how the human-mechanical encounter dictates the division of labor and specialization (Smith 1981 [1776]), but there were also less obvious connections between the mechanistic order and the characteristics of modern society, such as the mechanistic perception of modern thinkers like Montesquieu that reshaped the socio-political power through fragmentation and specialization (the principle of *separation of powers*). The universe and the body became a mechanical clock in the natural and life sciences of the 17^{th} and 18^{th} centuries, although the mechanization trend in the life sciences was more moderate and the mechanical metaphor encountered more problems with regards to the body than with regards to the universe. One can identify the same mechanistic relations in Diderot's social-economic theory and in his perception of the body. Yet, it should be noted that the impact of media is gradual and it is not necessarily simultaneous on all levels and in all cases. We will see, for example, that at first many physiologists and naturalists adopted the mechanistic perception in physiology, while holding less revolutionary views in regard to the design and adaptation of the *body↔machine*. Slowly but surely the new mechanistic environment had consumed the organic world.

Indeed, the mechanization of the mind and of society was a multidimensional phenomenon. In his article, *Enlightened Automata*, Simon Schaffer demonstrates how the automaton became a key element of the social outlook in modern Europe. Already during the Renaissance purely mechanical automata were constructed. At the beginning they were placed in palaces and churches, but with the development of early modern cities they were placed in fairgrounds, showrooms and saloons. By the 18^{th} automata became very popular in shows and in entertainment. The fake automatic chess player, Vaucanson's mechanical figures and other automata attracted the public attention. The new industries and the figure of the automaton played a major role in social philosophy. For example, the Scottish philosopher and historian Adam Ferguson considered the workshop to be an engine, in which the workers are mechanical parts that function automatically and with no need of reflection. The increase in mechanization was manifested in other spheres like the army: soldiers were trained through mechanical repetition (e.g., standard paces) and military activity was decomposed through the division of labor (loading, firing etc). Political order (or the *political machine*), as it reflected in the theories of enlightened thinkers, functioned as automatic machinery. For instance, the English philosopher and reformer Jeremy Bentham saw himself as a social, self-regulated machine (Schaffer 1999).

- In this field of events science was an important factor that influenced and contributed to the industrial revolution and at the same time was influenced by the new program of industrial society.

The main *messages* of the movable type, as defined by McLuhan, were very important for the development of modern science: fragmentation and specialization, mass production, standardization and uniformity. In general, print was the ground on which the *masses* and the reading public appeared, and modern scientific communities were an integral part of this process. Some of the main aspects regarding print and the birth of modern science are discussed in Elizabeth Eisenstein's book, *The Printing Press as an Agent of Change*. Print enabled the rapid and efficient diffusion of knowledge. The mass production of uniform texts, tables, charts, calculations and formulas, drawings and illustrations, maps, textbooks and journals, was the keystone of modern scientific community. Ancient texts were rediscovered and republished. Consequently internal inconsistencies in the ancient traditions were discovered. For instance, the calculations of Ptolemy in astronomy did not coincide with the physics of Aristotle. Yet before the development of print culture only a small circle of professional astronomers had copies of Ptolemy's *Almagest* and usually these copies were not available to Aristotelian philosophers. Similarly when the full Galenic corpus became available, inconsistencies between Arabic and Galenic doctrines were discovered. In other words, a significant change was developing through the mass production, standardization and the uniformity of the printed text: "Once printed editions of Averroes and Ptolemy, Avicenna and Galen could be studied in the same place at the same time, contradictions previously concealed by glosses and commentaries and compilations were laid bare." New theories and observations were also rapidly diffused. The efficient and rapid diffusion of new data and the standardization of knowledge had led to the development of systematic research. Rigorous analysis and thorough comparison between the old texts and new observations revealed discrepancies and anomalies. Ancient texts and traditional views were criticized and disconfirmed, and the authority of Aristotle, Galen, Ptolemy and others was challenged (Eisenstein 1979; especially Vol. 2: 523).

The development of modern anatomy was closely linked to print industry. The art of book editing became useful in anatomy not only due to the illustrations: from editing ancient works one could learn medieval and ancient nomenclature, Arabic and Greek, as well as Latin terms which were relevant to anatomy. The physicians who revolutionized anatomy, e.g. Andreas Vesalius and Michael Servetus, worked in a new framework and they were close to the printing industry. As a student during the 1530s, Vesalius helped professor Guinther of Andernach who edited the important rediscovered work of Galen, *Anatomical Procedures*. Servetus received the same assistant job after Vesalius, and in addition he also worked during the 1530s in a publishing firm as a book editor and proof reader. In the same years Charles Estienne, who came from a family of scholar-printers, helped one of his relatives to edit and publish Galen's work. Eisenstein asserts that a master-printer like Estienne contributed to the development of modern anatomy more than a master-artist like Leonardo da Vinci. Da Vinci did not complete or publish his work in anatomy, which remained hidden in personal notes and drawings. Furthermore, da Vinci's lack of education in Latin prevented him from gaining a thorough acquaintance with classical anatomy. Vesalius, Servetus and their colleagues learned to work with printers, professional illustrators and engravers. The benefits of print - especially the mass and uniform production of old and new texts, of images and labels, and the rapid and efficient diffusion of knowledge - promoted new forms of science and scientific communities: "Once the full [Galenic] corpus had been fixed in print it could be subjected to critical scrutiny. It became possible to perceive discrepancies between data and description that had not been perceived or disclosed before" (Eisenstein 1979, vol. 1: 267 – 269, vol. 2: 484, 523, 565 – 574, 687).

Eisenstein emphasizes the social impact of print on science, but as McLuhan argued typography have had both psychic and social consequences. The psychological impact of print, and its contribution to the mentality of modern philosophy and science, was analyzed by Ong and others. The printed text reinforced and transformed the effects of writing. First, print creates a strong sense of closure, or finalization, through endless identical copies. Already during the 16th century the French humanist and educationalist Peter Ramus created the paradigm of the printed textbooks. In comparison with oral culture, and even to script culture, the printed textbook was less discursive and it tended to present facts rather than proverbs, disputations, personal reflections and comments, interpretations and reinterpretations. Standardization characterizes the printed page: standardization of fonts, the spaces between letters, words and lines, and outlines. Script had enabled to abstract nouns and adjectives from social situation and linguistic context, and print reinforced the use of lists. In the oral tradition nouns were rarely extracted from sentences in order to create an abstract list. The spatial organization of the textbook promotes abstraction and dichotomy of each subject through lists, indexes, charts, diagrams, schemes and outlines. In script complex lists and charts cannot be efficiently reproduced. With the development of print the use of complex lists and charts became popular in the teaching of academic subjects. Similarly, the system of alphabetic index is not suitable for script work (the pages of script copies of the same text almost never correspond) and therefore it was rarely used until the appearance of print. The mechanistic mentality thrived on the printed text. Analytic fragmentation of each subject and specialization of fields of knowledge defined the Ramist program. As Ong explains, the Ramist textbook was based on "cold-blooded definitions and divisions leading to still further definitions and more divisions, until every last particle of the subject had been dissected and disposed of…if you defined and divided in the proper way, everything in the art was completely self-evident and the art itself was complete and self contained" (Ong 1982: 117 – 135; Ong 1958).

The mechanical environment and the metaphors of the *universe↔machine* and the *body↔machine* reshaped the modern mind. Since the 17th century the mechanical metaphor and the mechanistic solution became dominant in Western thought. Rene Descartes was one of the most distinguished representatives of the new trend in science and philosophy. It is important to emphasize that even the guiding principles in his famous book, *Discourse on the Method* (1850 [1637]), were clear manifestations of the mechanistic mentality. I think that the second and third rules of the Cartesian method are the condensed formula of the mechanistic approach in general and of the fragmentation principle in particular:

The *second*, to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution.
The *third*, to conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend by little and little, and, as it were, step by step, to the knowledge of the

more complex; assigning in thought a certain order even to those objects which in their own nature do not stand in a relation of antecedence and sequence (Descartes 1850 [1637]: 61).

- The mechanical outlook in the physical sciences was developed by transforming the world into an enormous machine. Though the universe became a mechanical clock, the mechanistic view certainly developed in gradual manner and through hybrid stages. In the mechanical universe matter became lifeless composition of particles with no final causes in the organic sense and with no internal aims or intensions. In the mechanical universe of Galileo, Descartes, Newton and their followers matter was moving and operating only through mechanistic laws, which were considered to be *external*, experimental, non-intrinsic and non-teleological. The laws were summarized mathematically in quantitative terms.

As McLuhan explains, out of the four Aristotelian causes only the efficient cause was compatible with the mechanistic order and the mentality of industrial society. The triumph of mechanics at the early modern age made the formal cause, the material cause and even teleology (final cause) obsolete, especially in the new scientific program. It was Galileo Galilei who redefined the efficient cause as the necessary and sufficient condition for the appearance of empirical phenomenon. For Galileo, the only valid cause is a cause which is sequentially followed by its effects: …"that and no other is to be called cause, at the presence of which the effect always follows, and at whose removal the effect disappears", wrote Galileo in 1623. Unlike the efficient cause, the other three causes could not have been reduced to the characteristics of the mechanistic order. Hence they were either totally transformed or became irrelevant. Formal cause practically disappeared. The notions of *matter* and *teleology* were totally transformed and received new meanings under the mechanistic order. Modern philosophy and science conceived a new concept of *matter*. The amplification of *visual space* in the industrial age was manifested by a new mode of perception: the new mentality was based on a search for abstract fragments and measurable characters which can be linked through chains of efficient causes. In this context, the mechanists of the 17th century, headed by Galileo, Rene Descartes and afterwards John Locke, distinguished *primary* and *secondary* qualities. The primary qualities of matter became its physical phases (solid, liquid and gaseous phases), its atomic elements, its size, its quantity, shape and motion. Only these primary qualities, which are measurable and quantifiable, were considered to be the *objective* qualities of matter. Secondary qualities, i.e. sounds, smells, tastes, colors, the sensation of tickling, the feeling of heat etc., were considered to be *subjective* and thus illegitimate qualities in the study of the physical world (colors, as McLuhan explains, are associated with the tactile sense). The secondary qualities were downgraded by the mechanical science and philosophy. In the life sciences we will see it, for example, in Linnaeus's new mode of observation and in his new system of classification (McLuhan and McLuhan 1988: 86 – 91; Galilei 1957 [1623]: 274 – 279; Locke 1849 [1690]: 76 – 82; Linnaeus 1775).[58]

Galileo clarified his position regarding the senses and the secondary qualities as follows:

> Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we place them is concerned, and that they reside only in the consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated. To excite in us tastes, odors, and sounds I believe that nothing is required in external bodies except shapes, numbers, and slow or rapid movements. I think that if ears, tongues, and noses were removed, shapes and numbers and motions would remain, but no odors or tastes or sounds. The latter, I believe, are nothing more than names when separated from living beings, just as tickling and titillation are nothing but names in the absence of such things as noses and armpits. And as these four senses are related to the four elements, so I believe that vision, the sense eminent above all others in the proportion of the finite to the infinite, the temporal to the instantaneous, the quantitative to the indivisible, the illuminated to the obscure-that vision, I say, is related to light itself (Galilei 1957 [1623]: 274 – 277).

Heat, for example, is a secondary quality that exists in the body alone and has no existence in external objects. According to Galileo, "heat" is a sensation produced in the body by minute particles that penetrate it. Thus the sensation of heat is the result of the touch of the particles on the body, but in themselves the particles are composed only of primary qualities, i.e. certain shapes and velocities.

Similarly, teleology, or final cause, conflicted with the mechanistic order, and therefore during the development of modern science it was gradually rejected. Teleology is potentially circular. For example, as Kant explained, a living being or a *natural end*, according to the teleological view, is "*both cause and effect of itself*" (Kant 2007 [1790]: 199). This approach did not coincide with the mechanical metaphor and therefore in the industrial science final cause was reduced to an end state of a series of efficient causes. In biology one can see it, for example, in the works of Theodor Schwann, Rudolf Hermann Lotze, Erasmus and Charles Darwin. To sum up, the following fundamental characteristics of the organic perception were filtered out or radically modified by the mechanical metaphor: essence, wholeness, circular causes which are based on purpose and intentionality, and cosmic teleology. Ideally, the business of the mechanical sciences was to explore and express in a quantitative-mathematical manner how particles of physical matter are set in motion, press on and move other particles in a sequential, deterministic fashion and in accordance with the way that mechanical automata function. The mechanistic order and the industrial environment promoted only the causes which are *effective* and *sufficient* for producing the phenomena. This perception applies both to the body which Descartes perceived as a mechanical clock as well as to the universe which Descartes and Newton perceived as a mechanical clock. Accordingly, in his 1687 *Principia*, Newton defined the first two rules of "reasoning in philosophy" (the first rule is the *vera causa* principle) as follows:

Rule I

We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.

To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes

Rule II

Therefore to the same natural effects we must, as far as possible, assign the same causes.

As to respiration in a man and in a beast; the descent of stones in Europe and in America; the light of our culinary fire and of the sun; the reflection of light in the earth, and in the planets... (Newton 1962 [1687]: 398).

The analytic-atomistic-reductionist approach in physics was based on perceiving the world as a mechanical automaton. Fragmentation became a fundamental principle in physics: under this perception complex phenomena can be explained and controlled by taking them apart, identifying the variables that comprise them, isolating and quantifying their effects, and finally summing up all the elements using an equation. The life sciences followed a similar path as the physical sciences and under their influence. The analytic-atomistic-reductionist approach in biology was based on perceiving the body as a mechanical automaton, and yet, compared to the physical sciences, the developments in the life sciences occurred with considerable delay and with much more difficulties. The experiential ground of the mechanical metaphor was not easily adapted to the life sciences and the metaphor encountered many problems on social, moral and religious level. Essence, wholeness and teleology were slowly and gradually replaced by fragmentation (reductionism, specialization and atomism) and efficient causes. The theories of industrial society rebuilt the body as the most sophisticated mechanical automaton ever built and afterwards as a complex assemblage of different automata and factories. Hybrids were formed between the traditional organic perception and the new mechanistic perception. Due to the hybrid development of perception, and due to the experiential problems of any metaphor (in this case the mechanistic metaphor), rear view mirrors can be found even in the work of faithful mechanists. For instance, in the mechanistic doctrine of 18th century radical materialists, the appearance of life was somewhat dependent on a materialistic version of animism. Thus, matter was not necessarily passive and inert even in mechanistic accounts of life.

- **The main characteristics of the mechanistic order are:** fragmentation (reductionism, specialization and atomism), the efficient cause, sequential operation, standardization (mechanical repetition of serial actions) and determinism. When the body becomes a mechanical automaton, it can be broken down into pieces or into special fragmented functions, which are arranged through series of standard actions and operate according to mechanistic laws.

5

The *Body↔Machine* Metaphor during the First Mechanistic Phase

This chapter deals with the origins of the *body↔machine* metaphor and with the development of the first mechanistic phase in the life sciences. The first phase, as we will see in the next chapter, was replaced by a second phase, the industrial–chemical phase that reinforced the characteristics of the mechanistic order. A clear cut between the two phases cannot be identified, because the techno-cultural environment, as well as human perception, thought and ideas, develop in hybrid manner. Like in a wave model, the two phases partially overlap. We will be able to identify a pattern of development which was based on the formation of hybrids between the mechanical and the organic, and also the gradual increase in the power of the mechanistic perception and its triumph over the organic perception. This pattern is repeated with regards to different aspects in the study of the body and in different fields of the life sciences.

In the 14th century Nicole Oresme, who held academic positions and finally became a bishop and an advisor of king Charles V of France, described the universe as a clock and God as a watchmaker. The roots of this view were already found in the ancient Roman culture, particularly in the work of the poet and philosopher Titus Lucretius who coined the prevalent *world↔machine* metaphor and in the work of the philosopher Marcus Cicero who described the universe as a clock and God as a clockmaker (Mayr 1986: 38 – 40; Cicero, *The Nature of the Gods*, 1998: 78). Yet the practical reduction of the universe to a mechanical clock began only in the 17th century. With the development of Newtonian mechanics the reduction of the universe through the metaphor of the mechanical clock was complete. The historical foundations of the *body↔machine* metaphor are also very ancient (Mazlish 1993: chap. 3). In ancient China, for example, there was a great interest in mechanical artifacts, especially in developing mechanical figures such as doves, angels, fish and dragons. The great human motivation to extend, translate and reproduce the body in new forms is manifested in a story which was written in China around the third century BC. The story tells of a man who brings the king a human-like machine. The king testes the machine, but he is unable to find any difference between its behavior and a human behavior. Then the king commanded to disassemble the machine. He finds that the man-machine is indeed a machine composed of leather, wood, glue, and different colors of lacquer. When the machine is reassembled it behaves like a human being again. But when the king pulls out the heart of the machine it cannot talk, and when the king pulls out the machine's liver the machine cannot see… At the end, the amazed king asks: Does man have the same power as the creator (Mazlish 1993: 32 – 33)?

The roots of the *body↔machine* metaphor in Western thought are also very ancient and had much to do with the authority and view of Aristotle who saw the body as a sort of machine. As I argued before, the work of Aristotle had manifested the *genesis of visual space* and the detachment of literate culture from preliterate culture. Although Aristotle did not believe that the body and the soul can be reduced through a series of efficient causes, he used in his explanations simple mechanical analogies. For instance, he explained the power of perception using the wax model. According to this model, we perceive the form of things without the matter that composes them, just as a piece of wax captures the form of a signet ring without the iron or gold of which the ring is made (Aristotle, *On the Soul*, 1985, vol.1: 424a). The impact of early mechanical development was evident in the Aristotelian view. In *Movements of Animals* Aristotle explained the movements of the body as movements of an automatic puppet: when the strings are released, the pegs strike against one another. In the same way, Aristotle described the movements of the body as a toy wagon mounted by a child: the bones are like the pegs or iron of the machine and the tendons are like the strings of the machine. Yet animal parts differ from mechanical instruments, because they are characterized by changes of quality and flexibility which are missing in mechanical instruments: animal parts can become smaller or larger, change their form, and increase by warmth and contract by cold. These movements and change of qualities are regulated by imaginations, sensations and ideas, i.e. by the soul. Therefore Aristotle wonders in *De Anima* whether the soul can be regarded as the actuality of the body, just as the sailor is the actuality of the ship (Aristotle, *On the Soul* and *Movement of Animals*, 1985, vol.1: 412b – 413a, 701b). The concept of the soul, which I have described before, helped the Aristotelians to prevent the reduction of life into mechanics (see Des Chene 2000). We will see below that to some degree, this approach characterized even early modern intellectuals and practitioners, like Descartes, who rejected the Aristotelian tradition and adopted the mechanistic perception. The triumph of the mechanistic perception and the vanishing of the organic perception were achieved through hybrid energy and rear view mirrors and not through a shift between incommensurable paradigms.

Already during the mechanical development in Europe of the Middle Ages different functions of the body were described and explained by using mechanical concepts (Mazlish 1993: chap. 2). One of the most important intellectuals and theologians of the Middle Ages, Saint Thomas Aquinas, wrote in the 13th century that animals behave like machines which are directed by God's wisdom. Elsewhere he described animals as clocks lacking of free will (Mazlish 1993: 19). Aquinas’s view was an organo-mechanical hybrid that combined the organic perception and sparks of a proto-mechanical perception. Yet it is important to stress that the mechanical metaphor of Aquinas was subordinated to the organic tradition of Aristotle and Christianity, and thus it was far from the mechanistic view and from the reductionist program that developed in the early modern age.

In scientific illustrations of the Renaissance the human body and its parts were described and represented as machines and tools. For instance, 16th century French physician, Ambroise Paré, designed and illustrated prosthetic hands and limbs working through gears and levers. In practice he produced, for example, a mechanical prosthesis for the thumb of a patient. The tendons that raise the thumb were cut during a battle and after healing the thumb remained flexed. As a result the patient could not hold a sword, a dagger and other weapons. Paré’s *Appliance for Extending Thumb* was made out of a tin instrument in which the patient put his thumb, and two lanyards connecting two little rings on the joints of the patient hand to the instrument. Thanks to this mechanism the patient's thumb remained raised. A new techno-cultural environment produced new ways to perceive and to experience the body. Thus, for example, the father of modern anatomy, Andreas Vesalius, described the human body in the mid 16th century as a factory (*fabrica*). Yet the development of the new perception appeared through hybrid energy. Even mystical traditions, such as the hermetic tradition, and the Golem myth in the Jewish kabbalism, influenced the development of the *body↔machine* metaphor. In her famous historical thesis, Yates has argued that modern science owes a great debt to the hermetic tradition and that the hermetic magus was the ancestor of the modern scientist. Although the hermetic philosophers promoted the development of applied knowledge, their mentality and practice were rooted deep in the organic order. They combined mechanics and mathematics with magic, mysticism and animism. Yates defined the hybrid stage of the Renaissance as "the prevalent confusion of thought between magic and mechanics". For example, in 1546 the Welsh mathematician and astronomer John Dee built a mechanical beetle (which simulated flying with a man on its back) for the play *Peace* of Aristophanes. Nevertheless, Yates emphasized that "for Dee his mechanical operations, wrought by number in the lower world, belonged into the same world view as his attempted conjuring of angels by Cabalist numerology" (Paré 1960 [circa 1563]: 99; Mazlish 1993: 17, 34 – 35, 39; Rabinbach 1990: 51; Yates 1964; Yates 1967: esp. 259 – 261). Leonardo da Vinci, according to Yates, was also a magus who combined the new mechanistic spirit with the mysticism and animism of the hermetic tradition. In his work one can find the rudiments of the mechanistic approach. Da Vinci suggested that in a functional manner the body and the machine are equivalent. He explained that both work according to mechanical-mathematical laws:

> Thus a bird is an instrument working according to mathematical law, which... is within the capacity of man to reproduce (in Mazlish 1993: 15).

In accordance with this view, da Vinci designed, for example, a military tank to replace elephants in the battlefield. Like da Vinci and Dee, there were others who had tried to produce mechanical simulations of animals, long before the attempts of Vaucanson and Droz in the 18th century. There are reports from the 13th century on mechanical doves and angels created by the French artist Vilard de Honnecourt. In the 15th century the German mathematician and astronomer Johannes Müller designed mechanical models of eagle and a fly which, according to Pierr Duhem, its wings could have probably been moved by inner springs and a magnet hidden on Müller's body (Mazlish 1993: 34 – 35).

The work of Rene Descartes (1596-1650) was a landmark in the development of a new mechanistic order. Descartes was one of the main advocates of the mechanistic program in the early days of modern philosophy and science. Mechanical automata, and especially the mechanical clock, had a great impact on the minds of Descartes and many of his contemporaries in the 17th century. For Descartes, the whole universe was a machine, and the laws of mechanics that govern human artifacts were equivalent to the laws of nature (see Mayr 1986; see also Turbayne 1970 - on Descartes and the metaphoric construction of the mechanical universe). As a 17th century pioneer of the mechanistic approach, Descartes significantly contributed to the mechanical perception of the body that became dominant through the industrial age. In fact, the roots of the mechanistic program in the scientific study of the body lie in the Cartesian archetype, i.e. in the metaphoric construction of the body as a mechanical automaton. In the work of Descartes the formal and the final causes of the body were absent and the organic approach was replaced by the analytic-mechanistic approach: unlike the body in the Aristotelian view which was still governed by essence, telos and holistic forces, the body in the Cartesian view realized the characteristics of the mechanical automaton and it was built through a casual chain of distinct parts with specialized functions. The tendency to solve complex problems through fragmentation was strongly rooted in the Cartesian approach to the body. Descartes even reduced the complex development of the embryo by a system of specialized particles each responsible for a different phenomenon.[59] However, for social, moral and philosophical reasons, he refused to reduce the human mind to a machine. The solution was an organo-mechanical hybrid which was based on the idea that the human body is a mechanical automaton connected through a casual chain to a soul (Descartes 1989 [1649]; 1972 [1664]). Although the electro-cybernetic environment has begun to reshape our metaphoric perception, the strong impact of this long tradition is still felt in the mechanistic/reductionist programs of the present age: just as Descartes and his contemporaries created organo-mechanistic hybrids in the early days of the mechanical age, scientists today create electro-mechanistic hybrids which, to a large extent, still rely on the mechanistic tradition. The approach of Dawkins, which is mentioned in chapter 3, is a good example of that.

Through the notion of *soul* Descartes prevented from making the human mind part of the *body↔machine*, but to a large extent the "rational soul" of Descartes articulated the mechanistic order: it was a non-polyphonic entity that operated through fragmentation and abstraction, i.e. through methodic analysis and formal logic. Even the basic Cartesian rules of method, as I explained before, clearly manifested the mechanistic mentality. The idea of the rational soul itself was developed on the ground of script (phonetic alphabet) and print cultures. Metaphors that are based on mechanical automata, and particularly the mechanical clock, shaped the minds of Descartes and many of his contemporaries. Hence the perception behind the Cartesian mind pertained to the *visual space,* as defined by McLuhan (Descartes 1850 [1637]: 61; McLuhan and McLuhan 1988: 13 – 38; see also Ong 1958). However, the notion of soul still helped Descartes to prevent the complete reduction of humans to no more than mechanical automata. Unlike the mechanical body, the soul, which as an idea belongs to the old organic perception, endows humans with emotions, consciousness and thoughts and with the ability to participate in an open dialogue. Descartes attributed the mind or the soul exclusively to humans, and thus all other animals were considered by him to be no more than automatic machinery.

Print culture created the techno-cultural ground for industrial society, the nation-state and the new forms of government and institutions of the modern world, but the new environment gradually developed and traditional centers of power did not disappear in a day. Like all other scholars and scientists in the catholic countries, Descartes had to consider the power of the Church. Already in 1629 he dissected animals on a regular basis in order to study their anatomy and physiology. He had also witnessed and participated in the dissection of human cadavers. Nonetheless, his *Treatise of Man* (Descartes 1972 [1664]) was not published in the 1630s, since Descartes was influenced by the trial of Galileo and his condemnation by the Church. Additionally, the *Treatise* itself is opened with the phrase "these men", as distinguished from the expression "us". This reservation emphasized that Descartes suggested a model of the body, without necessarily referring to actual men. The book was published only posthumously twelve years after his death, although Descartes did publish his ideas on the *body↔machine* in other works, including *Discourse on the Method* which was published anonymously in 1637 (Descartes 1850 [1637]).

The Cartesian theory represented the first phase of the mechanistic order. To a large extent, Descartes was trying to apply on the body the mechanics of corpuscular physics, geometrical thinking and images, and deductions which were based on “well established” principles and causes. Descartes, after all, was one of the founders of analytical geometry. The earthen body machines, claimed Descartes, were intentionally formed by God. As we will see in a following chapter, only since the 18th century radical materialists dared to suggest that the forces of nature created the *body↔machine* and not the Divine Artificer. The theory suggested by Darwin in the 19th century manifested the second phase of the mechanistic order. In any case, Descartes claimed that since clocks, artificial fountains, mills and similar man made machines have the power to perform various kinds of movements by themselves, then we can suppose that the living machines which were created by God can perform similar and additional sorts of movements. For example, the first mechanical function that Descartes chose to describe was the digestion of food. He perceived the process of digestion through a chemical model which was based on the principles of corpuscular physics. The *body↔machine*, according to Descartes, contains hot liquids that slide along the food particles while separating, shaking and heating them “just as common water does the particles of quicklime.” Consequently, the food particles are agitated and move according to their size in the conduits, pores and holes of the body (Descartes 1972 [1664]: 1 – 9). In the same way, Descartes explained the beating of the heart and arteries, breathing, the senses, memory and other functions of the *body↔machine*. The *Treatise* is concluded with the claim that the suggested model explains the actual body in mechanical terms alone. Consequently the Aristotelian notion of soul has no place in the new framework:

…these functions imitate those of a real man as perfectly as possible and that they follow naturally in this machine entirely from the disposition of the organs – no more nor less than do the movements of a clock or other automaton, from the arrangement of its counterweights and wheels. Wherefore it is not necessary, on their account, to conceive of any vegetative or sensitive soul or any other principle of movement and life than its blood and its spirits, agitated by the heat of the fire which burns continually in its heart and which is of no other nature than all those fires that occur in inanimate bodies (Descartes 1972 [1664]: 113).

According to the Cartesian view, the body operates through the *animal spirits*. The idea of animal spirits was first developed in ancient Alexandria and then by the noted Roman physician, Galen (second century AD). During the 17th and 18th centuries, the idea was still predominant. Animal spirits were considered to be weightless and invisible entities circulating through the hollow tubes of the nerves between the periphery and the brain while carrying sensations and activating the muscles. Descartes integrated the animal spirits into his mechanistic theory of the body, and as we will see below, they would still play a major role during the 18th century and in the beginning of the 19th century in the mechanistic theories of La Mettrie and Lamarck. In *Discourse on the Method*, Descartes described the animal spirits as a subtle wind, or a vivid flame, that continuously climbs from the heart to the brain, and from there it proceeds through the nerves into the muscles and cause the production of a variety of movements and actions. The arrangement of the nerves and muscles gives the animal spirits that are contained in nerves and muscles the power to move and produce different states in the *body↔machine*, as can be seen, for example, in the case of severed heads that move shortly after they were cut off the body; or in the changes that must take place in the brain for producing the states of waking, sleeping and dreaming; or in the case of the senses that carry the qualities of external objects to the brain which produces new ideas; or in the case of hunger, thirst and other internal affections that are also carried to the brain which produces new ideas, etc. Descartes clarified that these movements and actions of the *body↔machine* take place according "the rules of Mechanics, which are the same with those of nature". But while animals and the human body are equivalent to automatic machinery, the human soul is of a different nature (Descartes 1850 [1637]: 95 – 98). In *The Passions of the Soul*, which was published in 1649, Descartes explained again that all movements of the human body which are not directed by the soul depend on the arrangement of the *body↔machine* and on the animal spirits which it contains:

> Thus all the movements we make without our will contributing (as often happens when we breath, walk, eat, and in short do all the actions common to us and beasts) depend only on the arrangement of our members, and on the course which the spirits excited by the heat of the heart follow naturally in the brain, nerves, and muscles – in the same way in which a watch's movement is produced by the sheer force of its spring and the shape of its wheels (Descartes 1989 [1649]: 27).

In brief, all movements of the muscles and the senses are mechanically controlled by the brain through the "little tubes" of the nerves that contain animal spirits consisting of very fine air. The brain of the animal machine is on the top of the linear order. Descartes uses a simple experiment to demonstrate that the "machine of our body" is controlled automatically through the arrangement of its parts (apart from the control of the soul that exist only in humans). Suppose that a person knows that his friend is about to thrust his hands near the person's eyes, and that the person also knows that the friend is not really intending to touch and to injure his eyes. Yet, it would still be hard for the person not to close his eyes even if he wants to keep them open. Therefore, even in humans the *body↔machine* can act automatically and resist the volition of the soul. The movement of the hand towards the eyes excites a movement in the brain, and the brain guides the animal spirits into the muscles which lower the eyelids. A similar effect is observed when the vapors of wine enter the blood, rise from the heart to the brain, where they turn into animal spirits. These animal spirits are more numerous and stronger than usual, and they force the body to move in many unusual ways (Descartes 1989 [1649]: 22 – 26).

We have seen that the roots of the modern debate concerning the mechanical status of humans and animals could be traced to medieval times and even long before that. Mazlish claims on behalf of the historian George Boas that according to a widespread view in the Middle Ages animals are more natural and therefore more innocent and transcendent than humans. Moral and theological questions were at the heart of the discussion: do animals have the same moral status as humans? Do animals have sensitive souls or do they have rational souls? Do they differ from humans only to a degree? Are they entitled to immortality? Why do animals suffer if they don't sin? In the 17th century, Descartes rephrased these questions: instead of putting the emphasis on animals' possession of souls Descartes was concerned with the ability of animals to reason (Mazlish 1993: chap. 2). The Aristotelians denied the possibility of reducing animals to pure mechanical causes, and they therefore denied the possibility that life could be reproduced by mechanical means. For them life was a result of a divine art of soul creation. Humans, of course, do not posses the power to reproduce a divine soul (Des Chene 2005: 246 – 248). Descartes made this problem irrelevant by excluding the soul and the final causes from the material body. Moreover, God, according to Descartes, created matter and the laws of mechanics that govern the universe, but we cannot know his intensions and aims, neither through science nor even through metaphysics (Roger 1997: 181 – 182).

Descartes defined animals as mechanical automata, but he was careful not to be interpreted as arguing that humans are machines. At this point the dualistic separation between the body and the soul became relevant: on the one hand humans are made up of a physical, animal-like body that works under the same principles of the *animal↔machine*, but on the other hand the spiritual soul separates humans from animals. The soul, argued Descartes, is the place of reason, emotions and free will, and it is located in the brain's pineal gland. From there the soul guides the movements of the body. In his opinion, soul and reason liberate the human being from the physical and bestial. Animals do not have souls. Descartes used a behavioral model: if a theoretical machine has parts resembling the organs of a monkey, and it operates and behaves like a monkey, then the monkey and the machine could not be distinguished from one another. Therefore we have no reason to believe that animals need an immortal soul or that they are guided by reason. Descartes' *animal↔machine* metaphor expressed the mechanistic order: the animal organs are under the influence of a linear, deterministic chain of causes. In humans the soul is at the top of the hierarchal pyramid, and in animals the brain is at the top. The soul and the brain control the operation of organs that are placed on lower levels of the linear flow of causal influence. For example, what is a sensation of an external object, according to Descartes? A sensation of an external object, like fire, is comprised of a series of actions which resembles the pulling of a rope from one side and thus making a bell on the other side of the rope ring. In Descartes' example particles of fire pull a nerve filament in the skin area of the nearby leg. The filament leads to the brain, where the mechanical action of the particles opens a pore or a small conduit. The translator of *Treatise of Man*, Thomas Hall, points out that Descartes uses the term “action” to denote consequent events, but he does not use the term “stimulus” or even the term “response” in its modern sense. Nevertheless, Descartes did not deny completely the ability of the body to partially react in a semi-circular fashion: in the sequence of events, the opening of the pore or the small conduit causes the animal spirits from an adjacent cavity to enter to that particular nerve and to other nerves; the spirits are carried from the brain to the muscles which then withdraw the foot from the fire, turn the eyes and the head towards the fire, and also move the hands and the whole body. In conclusion, for Descartes, the body was a machine working inflexibly and deterministically as it was pre-designed, though in humans the body could also take orders from the rational soul which is placed above it (Descartes 1989 [1649]; Descartes 1972 [1664]: 33 – 35; Mayr 1986: 62 – 67).

Descartes created an organo-mechanical hybrid, which to some degree avoided the conflict between the new mechanistic perception and the socio-cultural environment that gradually changed: his social beliefs and values, the religious tradition and the power of the religious establishment did not allow Descartes to totally reduce humans to machines. I'm emphasizing this point since one of the main purposes of this work is to demonstrate how knowledge develops in a gradual and hybrid manner. Moreover, Descartes was also aware of the limitations of the mechanical metaphor due to its deterministic and inflexible features. In Descartes view, the mechanistic order was not entirely compatible with the human mind, and therefore only animals and the human body could be totally reduced by a series of efficient causes. As Mazlish observes (1993: 25 – 26), in *Discourse on the Method* (1850 [1637]) Descartes assigned to reason two qualities that allowed him to discern a human from a machine: (1) the ability to react and to participate in intelligent dialogue (2) as opposed to the machine, reason is universal and is adapted to react flexibly in different situations. It had not occurred to him that a machine could possibly acquire the necessary qualities of an intelligent being:

(1) Theoretically a machine could be designed to produce voices and words (touching a certain part of the machine may produce a cry or even a sentence), but it can never participate in an intelligent dialogue and it can never reply in a flexible manner and according to context:

…but not that it should arrange them variously so as appositely to reply to what is said in its presence, as men of the lowest grade of intellect can do (Descartes 1850 [1637]: 98).

(2) Since the classic machine works in a linear fashion and in accordance with the principles of fragmentation and specialism, Descartes thought that machines could never possess the endless parts needed to deal with different situations:

…whence it must be morally impossible that there should exist in any machine a diversity of organs sufficient to enable it to act in all the occurrences of life, in the way in which our reason enables us to act (Descartes 1850 [1637]: 98).

Perceiving the body as a mechanical clock and transforming bodily functions into mechanical actions became more and more popular in 17th century Europe. In Britain it was the noted philosopher, Tomas Hobbes, a famous rival of Robert Boyle, who already in the 17th century extended the complete reduction of life from animals to humans. Contrary to Descartes, Hobbes was a materialist who did not believe that the soul is an immaterial entity. Hobbes's grand-metaphor was based on interplay between three domains: the body, the machine and the socio-political structure. His famous book, *Leviathan*, begins with the following paragraph:

NATURE (the Art whereby God hath made and governes the World) is by the *Art* of man, as in many other things, so in this also imitated, that it can make an Artificial Animal. For seeing life is but a motion of Limbs, the beginning whereof is in some principall part within; why may we not say, that all *Automata* (Engines that move themselves by springs and wheeles as doth a watch) have an artificiall life? For what is the *Heart*, but a *Spring*; and the *Nerves*, but so many *Strings*; and the *Joynts*, but so many *Wheeles*, giving motion to the whole Body, such as was intended by the Artificer? (Hobbes 1904 [1651]; xviii).

In the following sentences of the same paragraph Hobbes explains that society or the state is a great *Artificial Man* serving as an extension which protects and defends the natural man. Hobbes wrote the book during the English civil war and his main concern was to demonstrate the importance of an absolute sovereign who maintains the social order and protect the citizens. Sovereignty, according to Hobbes, is the artificial soul which is giving life and motion to the artificial body, i.e. to the state or common wealth. Government officials are the artificial joints of the state. Reward and punishment are the nerves of the state by which the sovereign moves every joint and every part of the state. The wealth of the citizens is the strength of the state. The aim or the business of the state is the safety of its citizens. Counselors are the memory of the state. Equity and laws are the reason and will of the state. Concord is the health of the state. Sedition is the sickness of state, and finally civil war is the death of the state (Hobbes 1904 [1651]: xviii, 124, 343).

Descartes mechanical philosophy became popular among the European educated public at the end of the 17th century, but there were many objections to the identification of animals as emotionless mechanical automata, especially in Britain. Similarly, despite the prominence of Hobbes, he was still in the minority among his contemporaries. The majority of British scholars rejected his denial of free will and the complete reduction of humans and animals to deterministic automata. In general, the objections did not include a denial of the mechanical features of the body, but rather a rejection of the complete reduction of life to mechanics, at least in relation to the human body. Prominent intellectuals of the mechanical age expressed the tension and the fear from the new world they helped to create. The French mathematician and philosopher Blaise Pascal wrote that he cannot forgive Descartes for his mechanical interpretation of nature. Yet, at the same time, and similar to Descartes, he wrote that humans are automata no less than souls. The Jewish-Dutch philosopher Baruch Spinoza often used the image of the automaton with negative connotations to describe “brainless people”. Similar to Pascal, the German mathematician and philosopher G.W. Leibniz, who lived between the 17th and 18th centuries, referred to the mechanical philosophy as an intellectual phase he had passed in his early years, but at the same time he still used mechanical ideas, models and images, in addition to the practical construction of automata. Leibniz distinguished the soul from the body as the Cartesians did. He even argued that there is no interaction between the two: both, he explained, operate in harmony and coordination as two deterministic automata separately designed by God. According to Leibniz, then: “living bodies are even in the smallest of their parts machines *ad infinitum*” (Mayr 1986: 67 – 72, 104; Rabinbach 1990: 64).

We encounter again and again the tension between old traditions, religious and social values and between the new mechanical environment, science and philosophy. The Cartesian solution was to withdraw to the notion of God and to the separation of mind and soul from the body, though even the mental or spiritual world became more mechanistic. In 1663, Robert Boyle, the British natural philosopher and one of the founding fathers of modern science, wrote that the “human body itself seems to be but an engine, wherein almost, if not more than almost, all the actions common to men with other animals are performed mechanically” (Keller 2000: 324). Yet, according to Mayr, Boyle’s view was more complicated. In Britain the rejection of the total identification of animals with machines was more determined than in the continent: in general the *animal↔machine* metaphor was accepted in the continent and only when the *man↔machine* metaphor was made explicit the opposition was raised, while in Britain the ideas of Descartes raised an intense opposition from the first moment. Again, Mayr's examples do not demonstrate that there was a rejection of the mechanical metaphor or the mechanistic order, but rather an objection to the radical version of mechanism. On the spiritual dimension, the Cartesian assertion that animals are no more than conscienceless and emotionless mechanical automata was rejected. Boyle himself thought that compared to the mechanical automaton, e.g. the mechanical clock, the body is a unique kind of mechanism and of a higher order. According to his view, the living body, or the living engine, is the product of a divine engineering which is more sophisticated than human engineering. Despite his objection to the concept of soul, Boyle believed that animals are intelligent beings even if they represent a lower degree of beings. Thus animals, like humans, are not exactly mechanical clocks but bodies directed by intelligence, or conscious beings which are able to observe, judge, and to freely make a decision (Mayr 1986: 90 – 92).

To a certain degree, Boyle and many other contemporaries, who were still under the influence of the organic tradition, recognized the limitations of the mechanical metaphor. In addition, Boyle, like Leibniz and other contemporaries who adopted the *animal↔machine* metaphor, explained the complexity and design of the body through a divine intervention. Traditional values of Christianity, along with chemical philosophy, played a major role in his resistance to the complete reduction of the body as suggested by Descartes. According to the Cartesian approach, God created the mechanical laws of the universe, and after the universe was set in motion it began working through them. Boyle also believed in a God who did not tend to interfere with nature, except in cases of pure miracles or in order to preserve matter and motion in the universe. Nevertheless, as a representing figure of the 17th century, he accepted the presence of divine final causes in natural philosophy. Similarly, Leibniz combined teleology and mechanism. He argued that since the body is a “hydraulic, pneumatic, and pyrobolic machine”, the best method to explain its activity is to reveal its ends as designed by the artificer and to understand how its parts serve those purposes. Thus, Leibniz and traditional Christian scientists and philosophers who studied the efficient causes of the body and promoted the mechanistic order, e.g. the French Cartesian philosopher Bernard Fontenelle and the French scientist Rene de Réaumur, argued that the design of the *body↔machine* must be explained through pre-existence, i.e. through an organo-mechanical solution. Notice, however, that to some degree even the notion of God in the views of conservative Christian mechanists became mechanistic: as the French philosopher Nicolas Malebranche defined it, God acts in a “simple, uniform, and constant” manner and his will is subject to “eternal and necessary” law of order (Roger 1997: 177 – 204).

Most mechanists of the first phase created organo-mechanical hybrids, rather than proposing a full mechanistic account of the *body↔machine* in all its aspects. The English philosopher and physician John Locke was among them. Locke’s mechanical philosophy promoted the distinction between primary and secondary qualities. Moreover, McLuhan portrays Locke as one of the main developers of visual space in print culture. In Locke’s view, space and time are abstract, homogeneous, uniform containers, as manifested in the idea of “pure space” (Locke 1849 [1690]; McLuhan and McLuhan 1988: 24 – 27). Nevertheless, Locke’s version of the *body↔machine* was actually an organo-mechanical hybrid. Based on a mixture of moral and experiential considerations, Locke argued that in some respects the *body↔machine* differs from mechanical automata. First, consciousness, morality and freedom cannot be attributed to mechanical automata. For Locke, “denying freedom to mankind” was equivalent to “making men no other than bare machines”. Similarly, he believed that at least some species of animals have a low degree of consciousness and reason, and therefore they are not “bare machines”. Furthermore, during the first mechanistic phase two of the main problems of the *body↔machine* metaphor were the lack of an internal power source and an organizing force in mechanical automata (Locke 1849 [1690]: 31, 94, 219). Locke defined these experiential problems of the mechanical metaphor as follows:

The case is not so much different in brutes, but that any one may hence see what makes an animal, and continues it the same. Something we have like this in machines, and may serve to illustrate it. For example: What is a watch? It is plain it is nothing but a fit organization or construction of parts to a certain end, which, when a sufficient force is added to it, it is capable to attain. If we would suppose this machine one continued body, all whose organized parts were repaired, increased, or diminished, by a constant addition or separation of insensible parts, with one common life, we should have something very much like the body of an animal, with this difference, - that in an animal the fitness of the organization, and the motion wherein life consists, begin together, the motion coming from within; but in machines the force coming sensibly from without, is often away when the organ is in order, and well fitted to receive it (Locke 1849 [1690]: 219).

In conclusion, the objection raised in 17th century Europe was specifically related to the complete reduction of life to the machine. The mechanical approach became dominant at the expense of the organic tradition, but not completely. This situation was articulated by organo-mechanical hybrids. As Des Chene puts it:

… there was, among practitioners of the new science, a quite general agreement that much of what goes on in animals and plants can be explained mechanistically - without the reduction of animal souls to configurations of res extensa (Des Chene 2005: 248).[60]

Des Chene, for example, reviews the works of the Italian physiologist Giovanni Alfonso Borelli and the French physician and intellectual Claude Perrault. These practitioners implemented the mechanical approach (e.g., the principle of the lever, springs etc.) in the study of bodily functions and especially in relation to the function of the muscles and bones, but at the same time they rejected the reduction of the animal soul to mechanical forces. According to their view, the soul explained animal motion. On the other hand, the French philosopher Pierre Sylvain Régis completely adopted the Cartesian view in regard to animals. In his version of animal physiology one could not find a place for the soul and animal motion was explained by a physical cause - the fermentation of blood in the heart. But, in general, many of the earlier mechanists retained main elements of the organic perception even with regards to animals. Similar to Boyle, they also believed that the mechanical metaphor was far from perfect. Metaphors have an experiential basis. Their acceptance or rejection is not based on a simple, objective process of matching, but on a process that depends on the techno-cultural ground and on subjective judgment and values. At the same time, the process is not arbitrary because it depends on interplay with sense experience and on instrumental success. Thus, potential limitations of the mechanical explanation were identified and explored by scientists and intellectuals. Perrault declared that contrary to "the sentiments of the new sect" not every aspect which is related to animals can be explained by mechanical laws. Both Leibniz and Fontenelle promoted the mechanistic order, but in 1695 Fontenelle was accused by Leibniz of being one of the "moderns" who reduced nature to the simple level of artificial automata. Leibniz was referring to a text of Fontenelle from 1686. Yet, in 1733 Fontenelle himself seemed to be in agreement with Leibniz regarding this issue. He argued that unlike simple mechanical automata, the living body is a complex machine that could not be entirely explained by the known laws of mechanics (Des Chene 2005; Roger 1997: 177 – 180).

Since the 17th century intellectuals and practitioners from different schools promoted the mechanistic program. The French scholar and Catholic priest Pierre Gassendi was among them. Gassendi was an atomist and a soft mechanist who believed that human souls are directly created by God. In addition, he promoted the theory of pre-existence: according to Gassendi, in the beginning of the universe God created and scattered on earth the germs which are responsible for the phenomenon of spontaneous generations. Yet, Gassendi also promoted the view that inheritance and embryonic development take place by the motion and action of atoms in the seed. The new scientific mentality in the academies and the schools of Descartes, Gassendi, Perrault and the Scottish-French physician Daniel Duncan had contributed to the acceptance of empiricism and mechanism in physiology especially after 1670. But still many problems appeared, and as always the new metaphorical approach was not flawless. For instance, the heart could be explained as a pump and the organs as levers, but the existence of the spirits that explain muscular contraction and the beating of the heart could not be empirically confirmed by observation. Additionally, Aristotelians and other traditional physicians and scholars did not entirely disappear during the scientific revolution of the 17th century. Many physicians in the late 17th century and in the early 18th century were still faithful to the old traditions. In 1695, for instance, the French physician Jean Bernier included Descartes as one of the enemies of medicine. In 1718 Pierre Hunauld, physician-professor of the faculty of medicine in Angers, criticized the "vain and ambitious curiosity that philosophy has introduced into the practice of medicine". He was skeptical about the possibility that the understanding of "the mechanics of anatomy" could actually contribute to the practice of medicine. Similarly, the French philosopher Pierre Bayle did not detect any advantage in the practice of Cartesian doctors over the practice of their colleagues, and so forth. Surgery benefited from the progress of anatomy, but in the other fields of medicine the utilities of basic research which was directed by the new approaches were felt only in the mid and late 18th century (Roger 1997: 108 – 137).

The mechanization of life sciences was trans-paradigmatic. Cartesians, or anti-Cartesians, Gassendists, iatrochemists and eclectics were all promoting the mechanistic order. Between the end of the 17th century and the beginning of the 18th century, the power of mechanism rapidly ascended. The new trend was supported by eminent philosophers who represented the *modern* spirit, like Leibniz, Fontenelle and Malebranche. According to Roger, the new trend was accepted by most researchers in anatomy, physiology and chemistry with the exception of mystical chemists, outdated Galenists and the forerunners of vitalism (Roger 1997: 167 – 168, 233 – 235). I want to emphasize that most advocates of *mechanism* during the first mechanistic phase still retained elements of the organic perception. Furthermore, the *vitalists,* as we will see below, promoted a softer mechanistic view. Yet, prominent vitalists significantly contributed to the development of the mechanistic approach and to the appearance of the second mechanistic phase.

- The eminent Dutch physician Herman Boerhaave (1668-1738) was leading the new mechanistic trend. He was the most distinguished medical researcher and the senior authority in the medical establishment of the first half of the 18th century. The *Institutes* of Boerhaave, which was published in 1707, became a canonical text of the first mechanistic phase. Following many other researchers in anatomy, Boerhaave perceived the body as a combination of solid parts that contain fluids and have the functions of *instruments*. According to this view, the instruments of the *body↔machine* include *pillars, props, cross-beams, fences, coverings, axes, wedges, levers* and *pullies, cords, presses* or *bellows, sieves, pipes, conduits, receivers,* etc. The functions of these *instruments* "are all performed by *mechanical Laws*, and by them only are intelligible" (Boerhaave 1766 [1708], vol. 1: 80 – 95).

The thorax and the windpipe are bellows that take air into a large cavity and push it through a narrow opening. The cranium is a hard helmet or a fence that protects the soft brain from external pressure. The smallest blood vessels, and also the glands, are sieves that selectively transfer substances and particles through small holes. The long bones are levers, etc. Boerhaave stressed that the organs of the body do not only resemble mechanical instruments, but they are also governed by the general laws of mechanics. Fragmentation or reductionism was an explicit principle in the mechanistic program of Boerhaave. He claimed that the life of each part, e.g. the heart, is different from the life of other parts, e.g. the hair or the nails. Thus, before we can understand life "as an aggregate or a whole" we have to analyze "every single part of which the body is composed". Boerhaave identified the heart as the center of activity in the body. The activity of the heart is an efficient cause whose existence produces life: when the movement of the heart fails, life ends. He described the activity of the body as a linear chain of causes in which the *instruments* or the organs are "intermediate Causes, by which the first Cause produces its ultimate Effect". For example, in the action of hammering a nail into the wall a command from the mind excites the first material cause that appears as a motion in the sensorium or origin of the nerves. The second cause is an influx of the nervous fluid into the muscle that activates the arm. The third cause is the hammer that strikes the nail, and the ultimate effect is the penetration of the nail into the wall. Nevertheless, Boerhaave reserved his position. The body, after all, is a complicated machine: to function properly as a machine its separate and distinct parts must be well ordered in relation to one another and each part has to be in its place. For example, noted Boerhaave, everyone agrees that the heart is the *primary Machine* from which life and the motion of the blood arise, but the action of the heart depends on the action of the muscles, the blood, and the nervous fluid from the brain. Moreover, the blood propels to the brain through the action of the heart. Thus, following Hippocrates, Boerhaave admitted that there is circularity of causes and effects in the body. Yet, practically he continued to analyze and decompose the body through the mechanistic perception (Boerhaave 1766 [1708], vol. 1: 82 – 84; 92 – 95)

The Digestive system was an exemplar for the mechanical action of the body. Boerhaave thought that the study of the digestive system could shed light on the activity of the entire body, since all solid and fluid parts of the body are formed from the aliments that we digest. In fact, we inherent from our parents only a small particle, and this particle is turned into a mature body through nutrition. Boerhaave and many other physiologists from the first mechanistic phase defined digestion as a process of trituration. They saw the digestive system as a grinding machine which is aided by chemical processes. In the first part of the process solid food is modified in the mouth through cutting and mastication and by forming a mixture with air particles and saliva. The mechanical grinding of food in the mouth produces small particles with a larger surface area and facilitates the digestion of food. The saliva assists the process of digestion by a chemical modification of the food, by dissolving the saline parts of the food, by making the food softer, and by exciting fermentation and intestine motion. In the closed, warm and moistly stomach the mixture of food, air and saliva begins to ferment or putrefy, according to the properties of the food. The stomach contains several humors that dissolve food. It acts upon food by the contraction of its muscular coat, and it is also affected by external forces and pressure of the aorta, diaphragm and abdominal muscles. The decomposition of food continues in the intestine (Boerhaave 1766 [1708], vol. 1: 95 – 96, 119 – 263)

Boerhaave combined mechanism with chemicalism and identified chemical action as a mechanical play of corpuscles. It is important to note that modern chemistry was influenced by the mechanistic foundations of corpuscular physics, and therefore it is not easy to distinguish between the “mechanists” who studied life and the “mechanico-chemists”. For instance, in 1685 Charles Drelincourt, a professor of medicine at Leiden and the son of the theologian Charles Drelincourt the Elder, explained the phenomena of fertilization and embryonic formation as a product of the action of numerous “acido-saline” atoms from the male, which move like the particles described by Descartes. Similarly, in 1686 Duncan declared that life should be explained in terms of mechanics and chemistry. This trend also characterized Cartesian like Heinrich Herfelt and Joseph Besse (Roger 1997: 167 – 168, 233 – 235).

- I would like to give an example of the rear view mirror phenomenon exactly in this context.

The medical theory of Boerhaave synthesized iatro-mechanism and iatro-chemistry, but even a devoted mechanist like him could not have escaped the old organic perception, the traditional worldview and its concepts. While Boerhaave was trying to promote a full mechanistic explanation of nature, his view still referred to traditional chemical thought, and thus he squeezed the mechanical outlook into the organic view:

> [There is] between each particle of gold and each particle of royal water a virtue through which they love each other, unite with each other, and cleave to each other reciprocally (Boerhaave cited in Roger 1997: 372).

This small example from Boerhaave is not an exceptional phenomenon, but rather the norm. Like most 18th century mechanists, Boerhaave was a conservative Christian who adopted the organo-mechanical solution of pre-existence to the problem of generation. Conservative Christian mechanists who belonged to the first phase believed that (a) the body is a machine (b) only an intelligent artificer can generate machines. Although nature is entirely mechanical, the mechanical laws by themselves cannot account for the development and organization of the *body↔machine*. Therefore the conservative Christian mechanists developed the theory of pre-existence. According to this theory, the rudiments of all future embryos were created by God and afterwards the embryos develop to an adult form by mechanical enlargement and unfolding. Over time the mechanistic perception became part of the *common sense*, and therefore one can find rear view mirrors in an entirely different direction: contemporary biologists deal with the mechanistic tradition and many of them have been trying to squeeze the new electronic perception into the old mechanistic outlook, i.e. to discuss the mechanistic order using the new terms of cybernetics and computerized systems.

The Swiss physiologist Albrecht von Haller (1708-1777) was the most distinguished student of Boerhaave and his successor in the leadership of medical and physiological establishment. Similar to the Boerhaave, Haller represented the Christian mechanists of the first phase: he believed that the body was an integral part of the mechanistic universe and that the existence of the *body↔machine* can be explained only through pre-existence. Yet Haller did not think that the *body↔machine* can be reduced to the mechanical laws of physics. In this sense he emphasized the autonomy of the life sciences, but at the same time he reduced the physiology of the *body↔machine* to the principles of the mechanistic order. The *body↔machine*, according to the theory of Haller, is characterized by sensibility and irritability. Sensation is produced by the action of the nerves and the brain. Organs that contain more nerve fibers than others are more sensitive, for instance the eyes are more sensitive than the viscera. Irritability is the power to produce muscular contractions and movements of body parts. In general, irritability depends on the activity of nerves, but Haller's experiments confirmed that sensibility and irritability are two separate powers. Hence parts of the *body↔machine* can be irritated and move even in a dead body, i.e. when feeling is lost and the activity of the nerves stops: in a state of death physical irritations can still produce motions in different parts of the automaton, for instance the heart in a dead body can contract as a result of heat, vapors, poisons impelled flatus, watery liquors, wax, blood and electric sparks (Haller 1966 [1747], vol. 1: 58 – 60, 214 – 243, vol. 2: 207).

Through fragmentation and reduction Haller and his colleagues reconstructed the body as coordinated chains of efficient causes. The body had become a mechanical automaton and the implications were significant. If the body works as a mechanical clock, then it is comprised of different separable parts which are functionally equivalent to springs, pendulums, cogwheels etc. As McLuhan emphasized, the characterizing aphorism of the mechanical age was "A place for everything and everything in its place". Under this metaphoric perception, the body was analyzed and reduced into parts and elements, each having specialized, distinct function, although the parts are mechanically connected to each other by chains of efficient causes. Gradually, this new approach had begun to reshape all aspects of the *body↔machine* in physiology and medicine, adaptation and evolution, heredity and embryology. Haller, for example, significantly contributed to the fragmentation of diseases: under the new mechanistic approach, he identified diseases with lesions, i.e. with specific malfunctions in distinct parts of the *body↔machine* (see Haller 1756).

❖ ***The Radical Materialists***

A more radical current of mechanists appeared during the 18th century. French thinkers of the enlightenment, such as Denis Diderot and Julian Offray de La Mettrie, extended the *man↔machine* metaphor. The radical materialists not only denied the existence of spiritual souls, but unlike the noted Christian mechanists from the 18th century (e.g., Boerhaave, Haller, Réaumur, Spallanzani and Bonnet) they also claimed that the design and organization of the *body↔machine* could be explained by the mechanistic laws of nature. We will later see that the teleological design and organization of the *body↔machine* was gradually replaced by the mechanistic framework. As radical materialists, Diderot and his colleagues promoted the mechanistic order and broke away from the religious outlook as well as from traditional hierarchies and systems of classification. In 1749 Diderot was imprisoned due to the publication of *Letter on the Blind* in which he rejected the argument from design or the idea that the perfect design of the *body↔machine*s can only be explained as an act of a supreme artificer. Together with Jean le Rond d'Alembert, Diderot edited the famous and revolutionary *Encyclopédie* (*Encyclopedia, or a systematic dictionary of the sciences, arts, and crafts*). The first volume was published in 1751. Montesquieu, Voltaire, Jean Jacques Rousseau, Anne Turgot, Baron d'Holbach and other noted scholars of the enlightenment wrote for the encyclopedia. Traditional, religious and medieval hierarchies were violated. In the *Encyclopedia* religion was no longer the highest authority of morality and knowledge. Theology had become a branch of philosophy. Diderot and his colleagues were accused of promoting materialism, anti-religious, anti-royal and anti-moral views, which intended to destroy the bonds of society and the authority of the old regime. In order to satisfy the Jesuits and the Catholic Church, the first volumes of the *Encyclopedia* were officially banned by a decree of the king's council in 1752, but practically the decree did not to forbid Diderot and his associates to continue the work. The authors of the Encyclopedia had to censor themselves, but they also outwitted the official censors. Lamoignon de Malesherbes, the minister who was in charge on the book trade and later an advisor to King Louis XVI, believed in the values of enlightenment and specifically in the freedom of the press. He protected and helped the *encyclopédistes* behind the scenes. Over the years the political relations between the state and the church, and even the caprices of the King's mistress or a minister's mistress, influenced the work of the philosophers, but despite the difficulties created by the old establishment the *Encyclopedia* had a great success and it became more and more popular (Furbank 1992: 47 – 64, 72 – 96; Morley 1914, vol. 1: 117 – 247; Hankins 1985: 163 – 170).

Diderot was born at Langres to a family that had a successful business for manufacturing knives. His father was considered to be a master cutler. Diderot was trained by his father and he visited other workshops to learn more about the industry. The mechanistic order which is found in Diderot's *Pictorial Encyclopedia of Trades and Industry* is practically the same order which helped him to analyze and construct the new body. Fragmentation, analytic approach, division of labor, specialization of functions, sequentially of efficient causes and standardization were the basic characteristics of the industrial order, as described by Diderot. He demonstrated and internalized these characteristics in various fields: agriculture and rural arts, the art of war, iron foundry and forge, extractive industries, metal working, glass, masonry and carpentry, textiles, paper and printing, leather, gold, silver, jewelry, fashion and miscellaneous trades (Diderot 1959 [1763]).

- Science was a key element in the development of the industrial environment, and scientists were part of the industrial society. Not surprisingly, then, the characteristics of the industrial order redesigned the body through modern science.

Although Diderot was attracted to the idea of freedom, under the mechanistic outlook he chose to believe in determinism. He did not believe in providential God and his faith moved from deism to atheism. For him the universe and the body were machines. Thus, according to his view, the mechanical laws assure the lawfulness and determinism of the universe. Even on the moral level strict casual laws of pleasure and pain guide the *body↔machine* (Furbank 1992: 24, 435 – 438, 446, 469 – 470). The idea of soul, according to Diderot, is an expression of ignorance in respect to the way the mechanism of the body works:

Consider man, the automaton, as a walking clock where the heart represents the main spring, and the parts contained in his chest the other principal pieces of the movement. Imagine in his head a bell equipped with little hammers linked to an infinite number of strings that end at all points of the body (Diderot cited in Mayr 1986: 78).

Animal and Machines - What difference between a watch that feels and lives, and a watch of gold, iron silver and copper? ... The peasant who sees a watch move and who, unable to understand the mechanism, puts a spirit into the hand, is neither more nor less foolish than our spiritualists (Diderot cited in Mayr 1986: 78 -79).

One of the most important manifests of the radical materialists was the well known book of La Mettrie, *L' Homme Machine,* or *Man a Machine*, that was published in 1747 (La Mettrie 1961 [1748]). La Mettrie studied natural philosophy and medicine. In 1733 he came to the University of Leiden, Holland, to continue his medical studies under the guidance of Boerhaave. He also translated the works of Boerhaave. The influence of the Newtonian movement in 18th century Europe was enormous and the belief in Newtonian mechanics peaked. The medical sphere in general, and Boerhaave and his students in particular, were greatly influenced by this movement. La Mettrie himself was a member of an idealist movement that combined monarchic absolutism with mechanical and deterministic thinking. The movement was led by the Prussian king Frederick II, "the Great", who was the patron of La Mettrie. La Mettrie not only rejected the idea of the spiritual soul, but he was also secular and atheist. According to his view, "the soul is but a principle of motion or a material and sensible part of the brain, which can be regarded, without fear of errors, as the main spring of the whole machine" (La Mettrie 1961 [1748]: 3 – 9; 122 – 128, 135; Mayr 1986: 79, 107; Roger 1997: part III).

There was another aspect that distinguished La Mettrie's thought from the Cartesian thought. While Descartes had denied the existence of animal consciousness, animal intelligence and animal feelings, La Mettrie used observations similar to those of Descartes and reached the opposite conclusions. Each human can sense directly only his own consciousness and feelings. Still we ascribe similar qualities to other people by observing their responses and by relying on their words. Therefore we can also rely on animals' responses and reactions to conclude that they have consciousness and feelings (La Mettrie 1961 [1748]: 114 – 118; Mazlish 1993: 29). Unlike Descartes, La Mettrie thought that the transition from animals to man is not “violent”. According to La Mettrie’s theory, there is a possibility that some day man will be able to teach a language to apes which are the closest animals to man. Man only has a “few more wheels, a few more springs than in the most perfect animals”. A personal testimony of La Mettrie sheds light on the metaphorical thinking. In his eulogy on La Mettrie, Frederick the Great told that in 1742 La Mettrie accompanied the Duke of Gramont to a war. During the war La Mettrie was infected with fever. According to this story, which illustrates the work of the metaphorical imagination, in that event La Mettrie saw thought as “a consequence of the organization of the machine” and the so called “soul” as something which depends on the springs of the machine. He finally “found only mechanism where others had supposed an essence superior to matter.” After his ideas were printed, La Mettrie was blamed for heresy and he was persecuted by the theologians. As a result, he had to flee from France to Holland and from there to the court of Frederick the Great (La Mettrie 1961 [1748]: 5 – 9; 100 – 104, 128, 135, 140 – 141).[61]

L' Homme Machine opens with a critique on Descartes, Leibniz and John Locke who still held the belief in a spiritual soul which is separated from the empirical realm of the material body. According to La Mettrie, only physicians who empirically investigated the body have the authority to uncover the mechanism of the body, but the theologians have no such right. Like Galileo before him, La Mettrie concluded that the Holy Scriptures should be understood and interpreted according to the study of nature and not the other way around (La Mettrie 1961 [1748]: 85 – 89). He argued that “man is a machine”, a “complicated” machine that “winds its own springs” through nourishment. At this point the problem of self propulsion arises. We will later see how the mechanistic approach solved this problem with the aid of the *body↔engine* metaphor. For La Mettrie, material food, and its effects, was the key for solving the self propulsion problem. Like the ancients, La Mettrie described the effects of food on human feelings, characters and behaviors: from the necessity of food to keep the machine running, through the joy a meal can give to a sad heart, and to the savagery of the English who eat red-bloody meat like fierce animals do. He therefore wondered if one can locate the seat of the soul in the stomach. La Mettrie's *man↔machine* was also characterized by a certain amount of inherent determinism. According to La Mettrie, there are "thousand" factors that are inherited and transmitted from parents to children and determine human behavior. Prime examples are children of criminals and the mentally ill who inherit the behavior patterns and the criminal activities of their parents (e.g. thievery and cannibalism), although some of them were raised by honest people and not by their own parents. La Mettrie sympathized with their condition, since they do their crimes involuntarily and unconsciously. Another level of determinism which bounds the *man↔machine* is that of sensations. The "will", contended La Mettrie, is actually an effect of sensations: according to the principle of pleasure and pain, different types of sensations bound the *man↔machine* to will or not to will, to love or to hate. Similar to Descartes, La Mettrie also adopted the notion of animal spirits that guide the nervous activity and limit the will of the organic automaton (La Mettrie 1961 [1748]: 93 – 95, 118 – 120, 148).[62]

The Cartesians believed that the human soul is located in the brain and from there it guides the movements of the body. Since animals do not have souls, only the brain guides the movements of their body. Conversely, La Mettrie provided a list of experiments and observations which, in his opinion, proves that there is no need to invoke the *soul* (an "empty word" signifying the brain) in order to explain the movements of the body. Each part and each fiber of the body can make mechanical, involuntary movements even in the absence of the brain. For example, a frog's heart can produce motions for an hour or more after it has been removed from the body, especially in warm conditions. La Mettrie also referred to Harvey who had made similar observations on toads, and to a case reported by Francis Bacon in which a convicted man was cut down alive and when his heart was thrown into hot water it leaped several times (two feet high in the first time) until it stopped. Other examples provided by La Mettrie: muscles separated from the body contract when they are stimulated; when a rooster's head is cut off its body continues to run until it falls, and then the muscles keeps their movement for a while. The innate force of the body, claimed La Mettrie, is found in the organization of the *body↔machine*. The "springs of the human machine" operate "in a purely mechanical way". Regular, involuntary movements characterize the body and its parts. The body shrinks back when it is struck with terror at the sight of danger, the pores of the skin close in winter etc. La Mettrie does not elaborate how these phenomena are explained in "a purely mechanical way", but as the translator of the book Gertrude Bussey notes, La Mettrie's account is probably very similar to that of Descartes: when moving the hands quickly towards the eyes the "machinery of the body" is arranged so that the movement of the hand excites another movement in the brain "which controls the animal spirits in the muscles that close the eyelids". Since the organo-mechanical hybrid of Descartes included the belief in God, the design of the *body↔machine* was easily explained in a mechanical-teleological framework. La Mettrie was secular. He discussed whether the universe and life were created by God or by the laws of nature, and (implicitly) ruled in favor of the second alternative. Yet he did not propose a clear mechanism by which the mechanical universe could have generated the *body↔machine* (La Mettrie 1961 [1748]: 122 – 132, 198; Descartes 1989 [1649]: 26).

In order to disprove the Cartesian dualistic view, and to promote his materialistic view, La Mettrie emphasized the ability to excite movements in different parts of the body, even in the absence of the so called "soul" or the brain. But on the next page he calls all these movements and activities of the body (the shrinking back of the body, the closing of the pores of the skin, etc.), "little subordinate forces" for which no special explanation should be given by him, since they are all animated by the most important force which is located "in the brain at the origin of the nerves". From this location the force controls the rest of the body. To clarify that he was still speaking about a material brain and not about a spiritual soul, La Mettrie stated that "the brain has its muscles for thinking, as the legs have muscles for walking". The physical effects of the mind on the body, through the action of feelings, pleasure, passions and thoughts, are expressed in a portrait of Alexander Pope, which La Mettrie described as the Voltaire of the English. The efforts and energy of Pope's remarkable mechanical brain are imprinted on the structure and texture of his countenance: his eyes protrude from their sockets, his eyebrows are lifted up due to the efforts of the forehead's muscles, and his whole body shares the effects of the exhausting work of the brain. We do not need the idea of the soul, wrote La Mettrie. It is experientially evident that thought is part of the brain and that it leads to a casual chain which affects the body:

> In fact, if what thinks in my brain is not a part of this organ and therefore of the whole body, why does my blood boil, and the fever of my mind pass into my veins, when lying quietly in bed, I am forming the plan of some work or carrying on an abstract calculation?... why should we regard as double what is manifestly one being? (La Mettrie 1961 [1748]: 133)

The human body is a mechanical watch, concluded La Mettrie. When the wheel of the seconds stop the wheel of the minutes keeps rotating, and when they both stop other wheels, such as the quarter-hour wheel, keep rotating. In the same way, when few blood vessels are not working the movement of the blood in other parts of the *man↔machine* continues as long as the strength of the heart, the mainspring of the machine, is not destroyed (La Mettrie 1961 [1748]: 141 – 142).

Another prominent representative of the radical materialistic movement was the French-German intellectual Baron d'Holbach, an associate of Diderot and La Mettrie. He published his famous book, *The System of Nature*, in 1770. D'Holbach had to use a pseudonym and he had to send his works to Amsterdam in order to publish them. *The System of Nature* was published under the pseudonym "M. Mirabaud". In this book d'Holbach summarized his materialistic and atheistic outlook. Again, it is the mechanistic perception that guided d'Holbach to reject the idea of a spiritual soul. D'Holbach compared the dead body to a broken clock in which the mechanical design was lost. When a clock is shivered into a thousand pieces it loses its ability to work and it cannot tell the hour. In the same way the soul cannot think and feel after death. Moreover, he claimed, to explain the survival of the soul after death through the almighty power of God is to support an "absurdity" by "gratuitous hypothesis". D'Holbach declared that he is proud to be a machine. Nature herself "is a vast machine of which the human species is but a very feeble spring", and in fact nature and her products are good and noble. Accordingly, the moral man is a machine whose springs are adapted to be useful to his fellow men and to fulfill their expectation (D'Holbach 1836 [1770]: 112, 119).

❖ *Vitalism as an Organo-Mechanical Hybrid*

During the 18th century industrial society was in its infancy. As an integral part of the industrial world, the perception of scientists and intellectuals developed in a gradual and hybrid manner. Old traditions and values, religious beliefs and social institutions were weakened and changed, but they did not disappear right away. These aspects, combined with the anomalies of the mechanical metaphor, delayed the process of mechanization in the life sciences. In this section I want to start reviewing the relations between vitalism and the first mechanistic phase. Vitalism was a popular approach in the 18th century and in the beginning of the 19th century. The vitalistic theories were based on the formation of hybrids between the mechanical and the organic. Usually the vitalists held a soft mechanistic view, according to which the body is a machine, or a mechanical automaton, endowed with vital, teleological organizing powers. Furthermore, I will later show how the prominent vitalists significantly contributed to the development of the mechanical metaphor and to the appearance of the second mechanistic phase. Vitalism was rooted in the traditional organic perception and it did not suddenly appear in the 18th century: as a response to the rise of the new sciences, the aim of the vitalistic approach was to reconcile the traditional organic outlook with the mechanistic program. The English anatomist and physician William Harvey, who worked in the first half of the 17th century, already combined the organic perception with the empirical-mechanical approach of modern science. Harvey partially adopted the new mechanistic order, but he still held an Aristotelian view. He described the circulation of blood as a mechanical process, and at the same time he described the generation of the body as a process that primarily depends on teleological, vital forces (see Harvey 1847).

In general, the vitalists accepted the assertions that nature is mechanical and that the body works according to mechanical principles. Nonetheless they claimed that the living body depends on the existence of vital or teleological organizing forces which are beyond the laws of physics and chemistry. Descartes was able to prevent the complete reduction of humans to machines using the dualistic solution. For many other scientists and intellectuals who took part in the first mechanistic phase the vital forces did the same job.[63] The earlier and stronger version of vitalism was based on a spiritual, non-material force, but fewer and fewer scientists accepted this view. Even the noted German physician Georg Ernst Stahl, who represented the stronger version of vitalism in early 18th century, admitted that the body combines mechanical laws and functions with an immaterial organizing force. Moreover, even vitalists who claimed that the laws of physics and chemistry are irrelevant to the functioning of the body, e.g. Xavier Bichat, accepted the mechanistic order. Therefore we have to make a distinction between the general mechanistic order, as I have defined it, and the particular the laws of physics and chemistry that govern inorganic nature and machines. In some cases the term *vitalism* refers to views which were essentially mechanistic without accepting the simple reduction of the body through mechanical laws: these views are defined as vitalistic mainly because they emphasized the autonomy of life sciences. One of my aims, then, is to examine how much the vitalistic approaches retained residues of the organic perception.

The first mechanistic phase consumed the organic perception in a hybrid manner. Over time vitalism had become more mechanistic. The vitalistic approach specifically had to respond to the instrumental successes and failures of the mechanical metaphor and to its interrelations with the empirical data. One has to remember every metaphor or theory has flaws. For example, the automatons of Vaucanson and Droz had demonstrated the mechanical principles by which the *body↔machine* works, but vitalists noticed that unlike the organic body these automatons did not have an internal power source. Furthermore, mechanical automatons are built by artificers and they cannot develop according to the known mechanical laws. Thus in addition to the old tradition, culture, institutions and religious faith, vitalism also drew its strength from the experiential failures of the mechanical metaphor. Mechanists and radical materialists had tried to provide explanations for the flaws of the mechanical metaphor, but the decision whether these explanations were convincing or not depended on the complex interaction of the metaphor with empirical data, the techno-cultural environment, and an entire system of knowledge, values and beliefs as well as the perception of each scientist.

I will begin to examine the vitalistic approach and its connection to the first mechanistic phase through the work of the German physician and physiologist Johann Blumenbach (1752-1840). Blumenbach was one of the most influential scientists at the end of the 18^{th} and his work had a great impact on the study of life in the first decades of the 19^{th} century. In the following chapters I will further analyze the connection between vitalism and mechanism using other versions and traditions of vitalism. The term *vitalism* is used in this discussion in a broad sense and it denotes aspects of the body which cannot be reduced either to mechanical-chemical terms or to the characteristics of the mechanistic order. Under the influence of the mechanical sciences, the vital force that Blumenbach introduced was a material, non-spiritual force, and yet it was much more than just a mechanical force. Teleology and vital principles were mainly evoked by Blumenbach and others in order to explain problematic aspects which did not give in easily to the mechanical metaphor: the organization of the *body↔machine*, embryonic development, adaptation to circumstances, the appearance of life and transformism.

Blumenbach's work marked the shift from pre-existence to epigenesis. Epigenesis asserted that the embryo takes form and develops only after conception. The rival theory, pre-existence, was supported by the conservative Christian mechanists, who asserted that the miniature embryo pre-exists in the semen or eggs of the ancestors since the act of creation (i.e., the rudiments of the body are organized as a machine; after conception the *body↔machine* merely grows by mechanical enlargement and unfolding). The Newtonian values were explicit in Blumenbach's approach. He tried to find the mechanical forces of life which would be equivalent to the Newtonian forces. Eventually he came up with the idea of the "formative force" that combined the mechanical with the teleological. In short, the formative force was an organo-mechanical hybrid (Blumenbach 1825 [1779]: 11 – 20; Blumenbach 1817 [1787]: 333 – 338).

Blumenbach's theory of epigenesis was first published in 1781 (entitled *Über den Bildungstrieb and das Zeugungsgeschäfte*, or *On the Formative Drive and Matters of Reproduction*). In the beginning of *A Manual of the Elements of Natural History*, Blumenbach examined the classification of bodies into the categories of *natural* and *artificial*. The natural category comprises all the bodies which are not man made, and the artificial category comprises all the bodies which are designed and produced by man. At this point Blumenbach added two reservations. First, hybrids like mules, or the process of artificial selection, and even the *moulded skull* of the Carib, blur the distinction between natural and artificial bodies. Secondly, in many cases the natural and the artificial closely resemble each other, and thus it is difficult to make a clear distinction between the classes. However, Blumenbach did not deny the existence of these categories. In addition, he distinguished between *inorganic* bodies and *organized* bodies. This distinction is manifested in the three kingdoms: minerals, plants and animals. Minerals are inorganic bodies and they are governed by the simple laws of physics. Their origin and growth depend on aggregation and on the addition of homogenous particles from the outside. Therefore mechanical and chemical forces, such as attraction and affinity, can account for the dynamics of minerals. Blumenbach rejected "the favourite metaphor of gradation" and the view that there are no kingdoms and sharp divisions in nature. He argued that there is a fundamental difference between minerals and organized bodies: minerals are characterized only by inorganic forces, while organized living beings, i.e. plants and animals, are also characterized by a vital force (Blumenbach 1825 [1779]: 1 – 6).

Blumenbach was among the many scientists and philosophers who were deeply influenced by Newton. He struggled with the values of the mechanistic order, while trying to fit the study of life to the Newtonian ideal. Pre-existence was rejected by him for two main reasons: (a) violating the values of the mechanical sciences (b) the inability of the theory to account for empirical data. To explain his first reservation from pre-existence, Blumenbach quoted Newton's first rule of "reasoning in philosophy" - the *vera causa* principle. The empirical arguments of Blumenbach against pre-existence were not new. According to the popular version of pre-existence, the pre-formed germ is found in the female. Yet, the offspring usually has intermediate characters and in many cases they resemble the characters of the father more then the characters of the mother. Thus, even the supporters of pre-existence accepted the idea that the formative power in the male semen can modify the pre-existing germ and not just excite it. Blumenbach preferred the theory of epigenesis, which asserted that the seminal matter is unorganized, but has the potential to become organized "under certain necessary circumstances". Epigenesis, he proclaimed, is "far more consonant with” the vera causa principle and with the empirical observations (Blumenbach 1825 [1779]: 8 – 11).

- Blumenbach frequently used images and phrases that belong to the grand technological metaphor: “the animal machine”, “chemical laboratory of the human machine”, etc (Blumenbach 1865 [1795]: 193, 197, 208). Nonetheless, he thought that the experiential ground of the mechanistic framework was lacking in some important aspects. As a representing figure of the first mechanistic phase, he solved the anomalies of the mechanical metaphor by introducing an organo-mechanical hybrid - the formative force (the *Nisus Formativus* or *Bildungstrieb*), which combined the organic with the mechanical:

This *impulse* is distinguished from all purely mechanical *formative powers* (such as that which produces crystallizations, &c. in the mineral kingdom), by its capability of moulding the varied kinds of organizable seminal matter by an infinite number of modifications into forms corresponding to, and equally numerous with the endless differences in the purposes which organized bodies and their parts are destined to fulfil. The combination of the mechanical principle with this, which is susceptible of modifications subservient to particular objects, operates, first, in producing the *progressive formation* from the time of conception*;* second, the support of the structure thus formed, by *nutrition* during life; and, lastly, as far as is possible, repairs, by the process of *reproduction,* the accidental injuries it may experience (Blumenbach 1825 [1779]: 11).

I describe the formative force as partially *organic* not because Blumenbach defined it as a “vital power” which is exclusive to living beings, but because he used it in order to prevent the complete reduction of the body through the characteristics of the mechanistic order. In the second note to this passage, Blumenbach clearly emphasized that the body is directed by organo-mechanical forces. According to his view, the combination of the mechanical principle and the teleological principle is evident in numerous cases of comparative anatomy. This combination serves as the foundation for the doctrine of the formative force and it explains the unique characteristics of the living body: generation and development of the organized *body↔machine*, self-maintenance through nutrition, and reparation or regeneration. Blumenbach felt the tension between the formative force and the values of the mechanistic order, and thus he clarified again that the phrase *vital power* explains nothing by itself and it only designates a peculiar power that combines the mechanical principle with the principle which allows modification. In other words, he provided an explicit definition of vitalism as soft mechanism or as an organo-mechanical hybrid. The reason that Blumenbach introduced the new concept of *nisus formativus* was to distinguish this hybrid force of generation - which unites the "PHYSICO-MECHANICAL, with the purely TELEOLOGICAL" - from the *plastic force* of the ancients (and the *plastic force* of the English naturalist John Needham) and also from the *essential force* of the German physiologist Caspar Wolff. Blumenbach believed that the ability of living beings to become organized to develop, to regenerate, to preserve and to repair themselves verifies "the superiority of the machines constructed by the Creator over the most perfect productions of human art". Living beings are mechanical, but at the same time they are more than mechanical, simply because man made automatons do not possess the ability to repair themselves, to regenerate parts that were destroyed, and to procreate (Blumenbach 1825 [1779]: 11 – 20; Blumenbach 1817 [1787]: 333 – 338).

Blumenbach claimed that like other natural powers (e.g. gravitation), the cause of this unique vital power is unknown, but we can still study its effects by empirical means and reduce these effects to general principles. The formative force produces and preserves species and characters (e.g. sexual differences), by acting in a determinate way on the materials which it modifies and organizes. Nonetheless, the activity of the formative force may be interrupted by the circumstances and the result will be the appearance of different characters, abnormal forms and monstrosities. Moreover, there is a similarity between monstrosities and there are regular kinds of monstrosities. Therefore, their appearance must be regulated by certain laws. Blumenbach noted that one can see much more monstrosities in cultivated plants and domesticated animals than in plants and animals under natural circumstances. For Blumenbach and the supporters of epigenesis this was another piece of evidence against the theory of pre-existence. Blumenbach used another example to demonstrate the impact of environmental conditions on the generation of the body: cold climate interferes with the growth of organized bodies, and thus in cold regions animals, plants and even people (the Greenlanders and the Laplanders) tend to be smaller and in many cases they are also characterized by white color (Blumenbach 1825 [1779]: 12 – 20).

In *The institutions of Physiology*, Blumenbach pointed out that the hair seemed to him "most truly electrical". He also accepted galvanic apparatus and "electrical machines" as models for the action of the nerves. Regarding the connection between the electric fluid and the nerves, Blumenbach provided a reference to his student Alexander von Humboldt. Yet, he emphasized that models which are based on man made automatons may be misleading when applied to the "living machine" or the "human machine". For instance, according to Blumenbach, the circulation of blood is not merely governed by the same mechanical laws that govern the movement of liquids in a hydraulic machine. This form of argument represented the common vitalistic or soft mechanistic approach of the first phase. Regarding the problem of generation, Blumenbach adopted the old view that made a connection between generation and nutrition. He gave the credit for describing the process of nutrition as a continued generation to George Ent, an English physician and anatomist who lived in the 17th century. In this context he emphasized again that the characteristics of generation and nutrition clearly demonstrate that the organized body suppresses all man-made machines. Indeed, the known forces of physics, mechanics and chemistry participate in the action of the body, but the vital powers are the ones that make the difference between an organized body and an inorganic body. Vital powers, for example, can resist chemical affinities that induce putrefaction. Similarly the muscles can resist the force of gravity only when they are alive. It should be noted that there is a great difference between the powers that belong to the organic order and other unique powers that the vitalists ascribed to living beings. Not all the powers which Blumenbach defined as *vital* are also organic in the sense that I've used so far. For example, Blumenbach included among the vital powers not just the teleo-mechanical power of generation, but also other "peculiar powers", such as Haller's force of irritability which is a peculiar power of the muscles. Blumenbach himself distinguished the power of generation from all other vital powers (Blumenbach 1817 [1787]: 16 – 28, 60, 112, 127, 243, 335).

We can see, then, that in Blumenbach's mind, the mechanical metaphor was essential and at the same time unsatisfying, because it encountered significant experiential limitations. Therefore he argued that only a teleo-mechanical solution can settle the problems. When Blumenbach constructed his theory he thought of two instances in particular. First, he had in his mind an experiment in which he cut off arms of a polyp and observed the regeneration of the arms. In the second case he observed the healing process of a patient with an injury in his knee. From the regeneration of the arms and the flesh Blumenbach proceeded to the innate formative force that enables living beings to procreate, to develop by nutrition, to repair and to regenerate. The empirical evidence, he claimed, shows that the formative force peaks after fertilization, and when the living being grows old the force is diminished. The formative force is part of living matter and at the same time it organizes living matter and generates the body (Look 2006).

Blumenbach and Kant had been an influence on many scientists who adopted the teleo-mechanical approach. Kant was a soft mechanist. He was ambivalent about vitalism and sympathetic towards the organo-mechanical solution of Blumenbach. According to Kant, "No one has rendered more valuable services to" the theory of epigenesis than Blumenbach. He further claimed that "to suppose that crude matter, obeying mechanical laws, was originally its own architect, that life could have sprung up from the nature of what is void of life, and matter have spontaneously adopted the form of a self-maintaining purposiveness, he [Blumenbach] justly declares to be contrary to reason." At the end of this passage Kant describes Blumenbach's alternative, i.e. the *formative force*/*impulse* (Kant 2007 [1790]: 253; Blumenbach 1825 [1779]: 11). This force is distinguished from the purely mechanical formative forces which are found in nature, e.g. the force that produces crystallization:

> But at the same time he [Blumenbach] leaves to the mechanism of nature, in its subordination to this inscrutable *principle* of a primordial *organization*, an indeterminable yet also unmistakable function. The capacity of matter here required he terms—in contradistinction to the simply mechanical *formative force* universally residing in it—in the case of an organized body a *formative impulse*, standing, so to speak, under the higher guidance and direction of the above principle (Kant 2007 [1790]: 253).

Kant developed his view on the body in the last decades of the 18th century under the influence of Blumenbach and the French mathematician and philosopher Pierre Maupertuis. Maupertuis was a leading exponent of the Newtonian worldview. Among other things, he developed an organ-mechanical theory of epigenesis. Additionally he had contributed to the idea of mechanical transformism of species, an idea which paved the way for the theory of evolution. Following Leibniz and Maupertuis, Kant criticized Newton because he had deviated from the physical-mechanical framework and used a divine intervention in his explanation for the orbits of the planets. Kant's approach to the question of life also aspired to be mechanistic and Newtonian, but to a large extent he identified the limitations of the mechanical framework. Since Kant was influenced by Blumenbach's doctrine of the *formative force*, his explanation to the phenomena of life flirted with the vitalistic solution. The context in which Kant developed his ideas was the debate on the development of the *body↔machine* between the two organo-mechanical paradigms, pre-existence and epigenesis. Influenced by Blumenbach, he finally adopted epigenesis around 1787 (Blumenbach 1817 [1787]; Blumenbach 1825 [1779]; Kant 2007 [1790]: 253; Zammito 2006; Maupertuis 1966 [1745]).

In 1790, Kant published the *Critique of Judgment*, in which he addressed the *Critique of Teleological Judgment* in relation to nature and living beings (Kant 2007 [1790]: Part II). The discussion is based on a distinction between *relative* and *intrinsic* purposiveness of nature. Kant explained that the relative purposiveness of nature is its utility for living beings in general and its advantages for humans in particular: the river and the mud it carries are important for the growth of plants; a sandy soil which was carried by the sea works for the benefit of pine trees; fruits, vegetables and grass are used by animals and humans for their survival, and they are also used for making "foolish" designs, e.g. using colored earths and the juices of plants to paint the face or using feathers of birds to decorate clothes. According to Kant, these instances cannot be considered as the intrinsic purposiveness of nature itself, unless we assume that humans and other living beings were destined to live on earth, i.e. that they are the final cause of nature (then, and only then, their needs would have to be an integral part of the purposiveness of nature). But the assumption that things in nature are directed for the benefit of living creatures is based on an arbitrary judgment. Relative purposiveness in nature is only an *external*, contingent purposiveness, an "advantageousness of a thing for other things" and not something which inherently defines the natural thing. Note that this is the point at which the view of Kant departed from the old organic, religious views, although he did not come to the same mechanistic conclusion which Darwin made in the 19th century (Kant 2007 [1790]: 194 – 197).

In addition to their relative and practical purposes, living beings are the only products of nature which can be defined as natural purposes. Kant maintained that a thing may be defined as a *natural purpose* "if it is both *cause and effect of itself*". As a mechanist Kant could not have accepted this organic view as an objective truth, but he still recognized its value. In the following pages I'll try to clarify his position. First, according to a familiar natural law, the tree perpetuates and produces itself *generically* (i.e. producing a tree of the same genus) through generation or reproduction. The tree is the cause and the effect of reproduction. Secondly, the tree also produces itself as an *individual* by the act of growth which "is here to be understood in a sense that makes it entirely different from any increase according to mechanical laws, and renders it equivalent, though under another name, to generation". Although the tree uses inanimate matter as a raw material, the tree "bestows upon it a specifically distinctive quality which the mechanism of nature outside it cannot supply". Thirdly, the tree generates and maintains itself as a whole: each part of the tree reciprocally depends on the other parts. For instance, leaves are the products of the tree, but they also support the tree and they are vital to its existence. Moreover, the tree can recover from injury in a flexible manner, and if one of its parts is defected the remaining parts of the tree will take the place of the defected part in the self healing process of the tree. (Kant 2007 [1790]: 199 – 200).

In the following sections of the *Critique of Judgment*, Kant redefines natural purposes as organized beings, and now the explanatory power of the mechanistic order is clearly called into question. Note that in the early days of industrial society the mechanical clock symbolized the ideal order in the universe, and thus the hidden assumption of Kant was similar to the hidden assumption of Descartes: a complex artificial mechanism cannot be more than a mechanical automaton which is based on fragmented, linear and standard series of efficient causes. The anomalies of the mechanical metaphor enabled Kant to define the limitations of the mechanistic order with regards to living beings. If Descartes found an incompatibility only between the mechanical automaton and the human mind, Kant also found an incompatibility between the automaton and the plasticity and self organizing abilities of living beings.

According to this view, efficient causes alone cannot account for self organizing beings. Efficient causes work in a linear fashion: the effects serve as causes for other effects down the casual chain, but not upstream. In other words, reciprocal and simultaneous regulation of causes and effects is beyond the mechanistic order: “The things that as effects presuppose others as their causes cannot themselves in turn be also causes of the latter.” On the other hand, purposes or final causes are based on reciprocity and circularity: “the thing that for the moment is designated effect deserves none the less, if we take the series regressively, to be called the cause of the thing of which it was said to be the effect”. Regarding intentional actions, the house, for example, is the cause of money received as rent, but in the first place the will for that money was the cause of building the house. Each part of the self organizing being exists not just through the special arrangement of parts, but as a part of a whole in which all parts are reciprocally combined and serve as cause and effect for each other’s form. According to Kant, this can never be the case with artificial instruments. The wheel in the watch can only be the effective cause of the movement of other parts, but it cannot be the effective cause of the production of other wheels and the complete watch cannot make other watches. Moreover, the watch cannot produce replacements for missing parts and it cannot fix or regenerate itself. Conversely, a self organizing living being has self preservation abilities which work in varying conditions. Therefore, a self organizing living being is “not a mere machine” with moving parts. Beyond the *motive power*, living beings possess a *formative power* that enables self propagation (as Blumenbach explained). Living beings are something more than mere artifacts because they have the abilities of the artificer who maintains, fixes and replicates the artifacts (Kant 2007 [1790]: 200 – 202).

Kant adopted the values of the mechanical sciences. He argued that nature must be explained in materialistic terms. According to this view, the concept of soul cannot solve the problem of self organization and self preservation, since it presupposes the existence of an external *artificer* to nature which in itself does not explain or contribute anything to the study of nature. Similarly, Kant argued that the concept of God cannot help to explain the purposiveness in nature. The fragmentation and specialization of knowledge was explicit in the *Critique of Judgment*. Kant wrote that “Every science is a system in its own right… a separate and independent building”. Hence theology and natural sciences, or metaphysics and physics, should be separated and their boundaries should not be overlapped. The question whether or not natural purposes are *designed* is a metaphysical question and therefore physics cannot address this question. The natural sciences can only relate to natural causes and natural purposes which are revealed by empirical laws, but not to supernatural causes or divine purposes of nature which were designed by a supreme architect. Teleology itself is not an *intelligent being*, but an *unavoidable mode of judging* which assists the mechanical study in the life sciences (Kant 2007 [1790]: 203, 209 – 212).

Kant accepted the mechanistic program as the right approach to the study of the body, but at the same time he did not ignore the vitalistic reservations. For Kant, "*an organized natural product is one in which every part is reciprocally both end and means*. In such a product nothing is in vain, without an end, or to be ascribed to a blind mechanism of nature." This conviction, argued Kant, is based on observations (as we have seen before, he relied on the work of Blumenbach), but it is also based on an a-*priori principle* which "may be one that is merely regulative, and it may be that the ends in question only reside in the idea of the person judging and not in any efficient cause whatever." The tension between the mechanical and teleological principles of generation is solved once we recognize that they "are merely principles of reflective judgement" which "tell us nothing definite as to the origin of the things in their own intrinsic nature." Nevertheless, due to the constitution of our mind "we are unable to conceive the origin in the case of beings of this kind otherwise than in the light of final causes": the phenomena that characterize the living body must be explained "on mechanical lines", but at the same time we have to be aware of the limitations of our subjective perception that interprets and unites the phenomena and laws of the living body through final causes. The functions of organs, like the skin, the hair and the bones, might be explained by mechanical laws, but the formation and modification of organs and parts, and their organization as a whole, "must always be judged teleologically". Thus one can study and interpret the efficient causes in the living body only under the assumption that they are teleologically organized. In conclusion Kant was a soft mechanist who argued that due to constitution of the human mind we will never be able to circumvent the teleological judgment. For this reason he recognized the importance of the vitalistic approach although he did not believe that teleological forces exist in nature (Kant 2007 [1790]: 204 – 205, 210 – 211, 257 – 258). Unlike the more radical mechanists of the first phase, he thought that the complete reduction of living beings to mechanical principles is probably impossible:

> It is, I mean, quite certain that we can never get a sufficient knowledge of organized beings and their inner possibility, much less get an explanation of them, by looking merely to mechanical principles of nature. Indeed, so certain is it, that we may confidently assert that it is absurd for human beings even to entertain any thought of so doing or to hope that maybe another Newton may some day arise, to make intelligible to us even the genesis of but a blade of grass from natural laws that no design has ordered (Kant 2007 [1790]: 227 – 228).

The hybrid development of the life sciences was manifested in the work of the disciples of Blumenbach and Kant. Timothy Lenoir (1989) uses the terms “teleomechanism” and “vital materialism” to describe the approach of German scientists who were influenced by Blumenbach and Kant during the early decades of the 19th century. These distinguished scientists were mechanists, but they still evoked teleological forces to explain the organization and the maintenance of the *body↔machine*. The teleo-mechanists believed that the teleological organization of the body cannot be reduced to the physical and chemical laws of the inorganic world. Yet they emphasized that the teleological framework only unites the mechanical forces of the body, without contradicting them or violating the laws of nature. Among the distinguished teleo-mechanists, Lenoir counts German colleagues and students of Blumenbach and Georg Lichtenberg, for example, Gottfried Treviranus (who coined the term *biology* with Lamarck at the beginning of the 19th century), Johann Reil (who coined the term *psychiatry*), Carl Kielmeyer and Johann Meckel. The younger generation which was influenced by this research tradition included Karl von Baer, Johannes Müller, Carl Bergmann and Rudolf Leuckart. In my opinion, these scientists were in between the first mechanistic phase and the second mechanistic phase. Later, the students of Müller significantly contributed to the development and to the predominance of the second mechanistic phase. Moreover, even the generation of Müller, von Baer and their colleagues accepted the new theory of the cell, which in the late 1830s became the main paradigm of the second mechanistic phase. Yet, unlike his students, Müller and the vital materialists of his generation did not entirely dispose of the ideas of the first phase: as we will see in one of the following chapters, in their versions of the cell theory the vital materialists combined teleological elements.

Robert Richards (2000; 1998) raises objections against the analysis of Lenoir. While Lenoir emphasizes the teleological aspects in Kant's approach, Richards emphasizes the mechanistic aspects. Richards accepts the claim that Kant was highly influenced by the ideas of Blumenbach. In fact, both Kant and Blumenbach thought that they reached a common understanding. However, according to Richards, they did not promote the same outlook and they even misunderstood one another. Kant interpreted the formative force in a narrow sense: a generation of an organized body out of an organized body (and yet he still accepted the theory of epigenesis). Blumenbach, on the other hand, interpreted the formative force as a power that produces an organized body from an unorganized homogenous mass. Moreover, Richards argues that as a mechanist Kant actually did not accept the existence of teleological force in nature. In Kant's view, the formative force was only a heuristic concept designed to help the naturalist in finding the mechanical causes of the body (to find the efficient causes or how the end is achieved). Conversely, in Blumenbach's view, the formative force was a real teleo-mechanical force. Kant, as Richards portrays him, perceived the formative force as a subjective tool that enables to reflect on the body and to study the body *as if* it was working in a purposeful manner. Nevertheless, Kant also believed that the life sciences will never be able to circumvent the teleological judgment. Richards notes that (a) Blumenbach and Goethe did not understand the ideas of Kant (b) Kielmeyer and Friedrich Schelling developed ideas that departed from the original intensions of Kan (c) the early Reil rejected Kant's holistic and teleological view of the body.

- ➢ The theoretical or paradigmatic differences between Kant, Blumenbach and their followers are less relevant to the current discussion. The emphasis, I think, is that all the theories and research programs of the vital materialists manifested an organo-mechanical approach that became more mechanistic through time.

The ideas of Kielmeyer and other vital materialists are reviewed in the following chapters, but let's take the work of Reil as an example of the organo-mechanical approach. In his early work Reil promoted an approach which was based on mechanical fragmentation. He perceived the body through two main metaphors that transformed the body into a mechanical automaton and into a republic. Perceiving the body as a modern nation-state became prevalent in 19th century industrial society, and we will encounter this phenomenon again, for example, in the work of Rudolf Virchow who was influenced by Reil. According to republic metaphor, the body parts are individuals connected by chains of efficient causes:

> …each part forms itself and maintains itself through its own energy; its connection with the other parts is only the external determination whereby its force can be effective… The animal body is like a large republic, which consists of many parts. These parts, of course, stand in a determinate relationship with one another and they contribute to the maintenance of the whole. But each part operates through its own force and possesses its own perfections, deficiencies, and failures independently of the other branches of the body (Reil cited in Richards 1998: 710).

According to Richards, Reil explained that even if some parts lose their function, e.g. muscle groups, sense organs or faculties of the brain, the rest of the body can continue to function properly. He saw the body parts as citizens in a republic: each works on its own, although it is connected to the other citizens that together constitute the republic. The metaphor of the republic became popular after the 1795 crisis in Prussia: the king was forced to accept neutrality by the French and the liberals revolted against the old regime. In 1795 Reil presented a rather strict mechanistic view. The life force, as Reil defined it, comprised casual chains of chemical reactions. Moreover, Reil did not accept the teleological aspects of Blumenbach's formative force. He described the processes of assimilation, growth and reproduction as the attraction of food to relevant body parts, in which the matter is chemically modified through a process resembling crystallization of inorganic matter (Richards 1998: 708 – 711).

Although the rather strict mechanistic ideas of Reil influenced leading scientists of the mid 19th century (especially Virchow), between 1795 and 1807 Reil himself abandoned the more radical approach. He now clearly endorsed a synthesis of the mechanical and the teleological. Reil began to see the development of the embryo in the uterus as a purposeful operation. The uterus, he claimed, is not simply stretched after conception, but undergoes a complex modification which includes an interaction with other parts of the body for the purpose of generating, maintaining and nurturing the fetus. This goal is achieved by transforming the uterus from hard, amdorphous white substance into a soft, reddish, vascular and fibrous structure. Similarly the process of birth is a complex, purposeful transportation of the fetus from the womb to the outside. In his experimental analysis of embryology Reil was under the influence of romanticism, the Naturphilosophie and especially the philosophy of Schelling. He now accepted Blumenbach's formative force which he rejected before because it entailed teleology and even intelligence. He perceived the formative force as the "striving of the ideal", i.e. as the force that materializes Schelling's universal ideal. Thus embryonic development is explained by the formative force and the formative force expresses the metaphysical foundation of the universe. According to Reil, "the idea entered the arena of the mechanical principle… the dead have been resurrected to life; the machine of the heavenly bodies has been animated", through the philosophy of Schelling. Schelling's idea of polarity was central to the work of Reil, who identified the formative force as responsible on the array of stars that stretches from one pole to another, as well as on the development of the embryo in the uterus. According this view, the polar forces of expansion and contraction govern the dynamics of the uterus after conception: the body of the uterus expands in order to accommodate the fetus, while the neck of the uterus contracts in order to hold the fetus in the uterus. Reil compared the axis of the uterus to a magnetic line pole. Before birth the polar forces gradually reverse: in order to discharge the infant from the uterus, the body of the uterus contracts and the neck of the uterus expands. The whole process, claimed Reil, is a harmonious combination of mechanical and vital forces. Under the same organo-mechanical approach, Reil studied the efficient causes of pregnancy and birth. For example, he showed that birth contractions occur not only due to the muscles in the abdomen and diaphragm, but also due to development of new muscles in the uterus itself (the muscles of the uterus work in coordination with the muscles of the abdomen and diaphragm). During the experiment he dissected pregnant, near-term rabbits. When he stimulated the uterus using a galvanic apparatus, the uterus contracted and the fetuses were discharged from the uterus (Richards 1998: 728 – 736).

6

The Second Mechanistic Phase and the Development of the Industrialized Body

In this chapter I want to identify a more advanced phase, the second mechanistic phase, that reinforced the *body↔machine* metaphor and the mechanistic program in the life sciences. The second phase drew strength from the development of the industrial society and the appearance of modern chemistry at the last decades of the 18th century. I would like to claim that despite the differences between the two phases, the industrial-chemical phase efficiently applied and reinforced the same characteristics of the mechanistic order, as I have defined them before: fragmentation (i.e., specialization and reductionism), actions which are based on chains of efficient causes, standardization and even determinism. The new phase was fruitful in articulating and elaborating the basic perception that characterized earlier mechanical theories, but the theories of the new phase achieved a much greater instrumental success. Paradigmatically speaking, conversions and revolutions had taken place between the first mechanistic phase and the second. Nonetheless, using a low resolution analysis I will reveal the continuation of fundamental patterns and historical trends between the phases, namely the increase of mechanization and the vanishing of the organic perception. In this respect, the low resolution analysis enables us to see the forest more than the trees.

The metaphorical thinking did not disappear during the development of the second mechanistic phase. On the contrary, the *body↔machine* metaphor was brought up to date and the body was transformed into a laboratory, an engine, a factory, an industrial-capitalist business etc. These developments manifested the productivity and creativeness of the metaphorical thinking: new generations of scientists continued to explore the basic assumptions, the implications and the empirical boundaries of the *body↔machine* metaphor, to deepen its instrumental successes and to discover new aspects of the body, despite the inevitable appearance of experiential failures within the industrial-chemical framework. In comparison with abstract *modernist* approaches, e.g. naïve realism or positivism, the metaphorical approach which I present in this thesis is able to better deal with the following aspects of scientific development: (a) the *extra-scientific* impact of techno-cultural environments on scientific theories and on the assumptions and expectations of scientists (b) the dynamic of scientific theories throughout history, or in other words, the appearance of contradicting theories that can partially explain a certain subject and the appearance of anomalies and deficiencies which undermine the validity of these theories until they collapse and are replaced by new theories. Metaphorical frameworks cannot provide *stable literal truths*, but they can provide *relative truths* that depend on the experiential basis of the metaphor and on the techno-cultural context. As we will see below, the mechanistic metaphor encountered many problems and many mechanists admitted that the reduction of the body to the laws of physics and chemistry is impossible. Moreover, even if we try to partially reduce biology to physics and chemistry, metaphors will still not disappear because natural sciences are as metaphoric as all other fields of human knowledge. Throughout modern history the *body↔machine* continued to change according to the new developments in the techno-cultural environment. When the electro-cybernetic environment developed in the 20th century, the mechanistic approach was undermined and the *body↔machine* took a new form. The new electronic environment even revived, in a new form, *organic* characteristics, such as holism and teleology. Thus, from a historical perspective, the industrialized body was a manifestation of a techno-cultural order that is slowly fading away.

❖ *The New Chemical Outlook as a Precursor of the Second Mechanistic Phase*

In this section I will examine the mechanistic basis of the new chemical approach. This approach was a precursor of the second mechanistic phase that gradually emerged from the first phase. In the following section I will examine the industrial basis of the second mechanistic phase.

During the second half of the 18th century a new chemical outlook began to replace earlier mechanical models, such as the Boerhaavian solids and fluids. The earlier models were unsuccessful in explaining the complexity of phenomena. For instance, the mechanical models of the digestive system were replaced by chemical models that focused on the gastric juice. Yet, the emphasis in this section will not be on the relative success of the new chemical models and the failures of earlier mechanical models, but on the order or the medium to which they belong. Although the theories of the new age were not *mechanical* in a narrow sense, they were *mechanistic* in the broader sense which I've defined before. The characteristics of the mechanistic order united the mechanical and the chemical. Thus Descartes saw the chemical as part of the mechanical. For him, and for many after him, chemical action was based on the same basic principles of corpuscular physics: "…food is digested in the stomach of this machine by the force of certain liquids which, gliding among the food particles, separate, shake, and heat them just as common water does the particles of quicklime, or aqua fortis those of metals" (Descartes 1972 [1664]: 5 – 6).

As we have seen before, Boerhaave, another prominent advocate of the first phase, believed in the theory of trituration as an explanation to the process of digestion, and yet had no problem to combine the mechanical approach with chemical theories because he identified chemical action as a mechanical play of corpuscles. Modern chemistry was influenced by the mechanistic foundations of corpuscular physics and therefore it is not easy to find the boundaries between the *mechanists* (or the iatro-mechanical approach) and the *mechanico-chemists* (or the iatro-chemical approach).

The theories of the second mechanistic phase reinforced the basic perceptions and characteristics of the first phase. Wilhelm Roux, a leading German embryologist who represented the mechanistic biology of the end of the 19th century, explicitly articulated this position. Following Spinoza and Kant, Roux claimed that "every phenomenon underlying causality" should be defined as a *mechanical phenomenon* and the study of these phenomena should be called *mechanics*. Moreover, "physics and chemistry reduce all phenomena, even those which appear to be most diverse, *e.g*., magnetic, electrical, optical and chemical phenomena, to movement of parts, or attempt such a reduction." Therefore, according to Roux, the older and more restricted sense of the concept of *mechanics* "as the casual doctrine of the movements of masses, has been extended to coincide with the philosophical concept of mechanism, comprising as it does all causally conditioned phenomena" (Roux 1894: 108).

I would like to reveal the increase in the power of the mechanistic order in all different forms and definitions. Indeed, the replacement of earlier mechanical models with the chemical models articulated a paradigm shift, but the characteristics that I've defined before will help us to identify the reinforcement of the mechanistic order in its new form. During the last decades of the 18th century researchers such as Spallanzani and Lavoisier laid the foundations of the industrial-chemical phase, and through the 19th century the second phase matured and became dominant. Since the limitations of the older mechanical models were exposed in the study of the digestive system, I will begin to clarify my claims through the work of the fathers of gastric physiology.

In each era some of the main insights in the life sciences were based on the dominant techno-cultural environment that defined the era. During the second half of the 18th century physiologists and chemists replaced the dominant Boerhaavian model that referred to the digestive system as a *grinding machine*, with newer models that referred to the digestive system as a *chemical laboratory*. In 1833 William Beaumont, a surgeon in the U.S. Army, published his book, *Experiments and Observations on the Gastric Juice and the Physiology of Digestion* (Beaumont 1838), which was based on the experiments he made since 1825. Beaumont traced the origins of his experiments on the digestive system to the doctrine and work of the Italian physiologist Lazzaro Spallanzani (Beaumont 1838: 2, 64 – 73, 82). The new theory that explained the digestive action as a chemical process of the gastric juice was developed by the

French scientist Rene de Réaumur around 1750 and afterwards by Spallanzani in the last decades of the 18th century.

- Before we get to Beaumont and the 19th century, I would like to review the roots of the chemical approach in order to expose (a) the connection of the chemical approach to the mechanistic program, in the broad sense which I've defined before and not in the narrow sense which may be defined as the reduction of the *body↔machine* to the mechanical laws of physics (b) the gradual development from the first mechanistic phase to the second.

The work of the Flemish physiologist Jean Baptiste van Helmont and the Dutch physiologist Franciscus Sylvius, during the 17th century, was the progenitor of the chemical approach to the study of the digestive system. They suggested a theory of fermentation as an explanation for digestion, and Sylvius also stressed the importance of saliva which is swallowed with the food in the process of fermentation. Two other physiologists from the 17th century, the Italians Santorio Sanctorius and Giovanni Borelli, developed a different paradigm which was based on a mechanical approach. Borelli, who explained the actions of the body in mechanical terms, saw the stomach as a grinding machine (the theory of trituration). His followers even denied the role of chemical reactions in the process in digestion (Horsman 1996: 106). During the 18th century Boerhaave's mechanical model to the digestive system became dominant. According to Spallanzani, "The opinion that prevails chiefly in the schools or Europe is that advanced by Boerhaave, who has in truth done nothing but reconcile the opinions that had been proposed at different times before him." Boerhaave saw the digestive system as a grinding machine which is aided by chemical processes. At first the food is ground and masticated in the mouth while forming a mixture with air particles and saliva. The saliva helps to modify the chemical composition of the food, to dissolve the saline parts of the food, to soften the food, and to excite fermentation and intestine motion. The fermentation or putrefaction of the mixture of food, air and saliva in the warmth and moist of the stomach depends on the properties of the food. In addition, the stomach secretes several humors that dissolve food. Finally the firmer textures of food are crushed by the triturating power of the stomach. This power depends on the action of the muscular coat of the stomach and on the pressure of the aorta, diaphragm and abdominal muscles (Boerhaave 1766 [1708], vol. 1: 95 – 96, 119 – 263; Spallanzani 1784: 234 – 236).

During the second half of the 18^{th} century Réaumur and Spallanzani developed the chemical theory of the digestive system. First let us examine the general framework of their work. Both Réaumur and Spallanzani were distinguished physiologists and conservative Christian mechanists whose approach represented the first mechanistic phase. Like the majority of mechanists in the 18^{th} century they believed in the theory of pre-existence. Their approach was based on the assertion that the physiology of the *body↔machine* is entirely mechanistic, while the *design* of the *body↔machine* is beyond the forces of nature. According to this view, the *body↔machines* were designed by the Divine Artificer as miniature germs that develop to an adult form by mechanical enlargement and unfolding. Réaumur found *mechanisms* everywhere in the *body↔machine*. For instance, in metamorphosis of certain caterpillars the chrysalis uses spines or hooks as “stops, like the ones used in so many machines to block escapement.” Similarly “the insects’ probosces…are machines analogous to our pumps.” According to Réaumur, no other *mechanism* is more simple and ingenious as the mechanism of the beetle’s elytra. Réaumur supported father Joseph de Lignac who wrote anonymous letters against the radical materialists in general and against Georges Buffon’s mechanistic theory of epigenesis in particular. De Lignac saw the work of Buffon as an anti-Christian work. He claimed that nature cannot create by itself “an intelligent and free machine”. This machine did not necessarily work as inanimate machines. Mechanists like Haller and Spallanzani believed in the autonomy of the life sciences and thus they claimed that the *body↔machine* is characterized by other laws besides the mechanical laws. Nonetheless, as mechanists they tried to reduce the physiology of the *body↔machine* to the principles of the mechanistic order (fragmentation, efficient causes etc.). In his work on the circulation of the blood, Spallanzani wrote, for example, that he supports “the sage maxim of Haller, respecting the caution with which we ought to apply mechanical principles to the animated system; for, in fact, if the animal machine be strictly subject to Hydraulic laws, why do they not produce the same effects in the vascular system as in common tubes. Whilst, however, we acknowledge that these laws must exert an influence upon the phenomena of the circulation, we contend that their power is counterbalanced by opposite causes, inherent in the sanguiferous system.” Spallanzani, who was a catholic priest, participated in the debate between the supporters of pre-existence and the supporters of epigenesis. In a series of experiments he tried to expose the flaws of the epigenetic theory of John Needham and Buffon (Roger 1997: 180 – 204, 301 – 318, 475 – 493, 509 – 515; Spallanzani 1769; Spallanzani 1801: 257, 260, 265).

The program of Réaumur and Spallanzani concerning the *body↔machine* extended beyond pure scientific research. Both had contributed to the mechanization of life for industrial purposes. Around 1750 Réaumur developed the “artificial mother”, that is, the modern hatching device for chickens which was modeled on ancient Egyptian incubators. Réaumur’s artificial mother was based on a wood-heated cylindrical *stove* and on a thermometer he developed. Practically since the end of the 18th century the *animal↔machine* became part of the industrial world. The life of chickens was modified, standardized and adapted to increase the production of eggs. Milking cows had the same fate. During the second half of the 18th century Spallanzani became the pioneer of mechanical fertilization, thanks to his observations and experiments on the generation of animals. Spallanzani was the first researcher who succeeded in fertilizing frog eggs in vitro. He then invented the technique of mechanical fertilization. Using a small syringe he was able to fertilize a female dog. “I have no difficulty in believing”, he wrote, “that we shall be able to give birth to some large animals without the concurrence of the two sexes, provided we have recourse to the simple mechanical device employed by me.” During the 19th century Spallanzani’s technique was improved and in the 20th century mechanical fertilization became indispensable for breeding and for the mass production of animals. Breeding and selection were used to increase the weight of animals for the food industry, i.e. to increase animal products and the production of meat. Already in the mid 19th century animals were assimilated by the industrial process: as Mazlish describes it, they “were placed on an assembly line, skinned, cleaned, and cut into pieces by a standardized procedure, and then packaged for mass consumption” (Giedion 1948: 97, 135 – 136, 209 – 256; Pinto-Correia 1998: 183 – 210; Mazlish 1993: 63 – 64). In addition, during the 19th century the French microbiologist Louis Pasteur was able to harness the bacteria to the industrial production, and in the 20th century the industrial science created *biotechnology*. Through biotechnology, the breeding technique was improved, production increased as well as the variety of products in the food industry, medicine etc.

Réaumur and Spallanzani began to develop a new technique, *artificial digestion*, which simulated the digestive process (Spallanzani 1784). The new technique reconstructed in the laboratory a physiological function which was separated and taken out of the living body as a fragment. The acceptance of artificial digestion and similar laboratory techniques by the scientific community was not obvious. As the French physiologist Claude Bernard observed, vitalists, and even soft mechanists like the French naturalist Georges Cuvier, had raised objections to the new type of techniques: "Cuvier said that experimentation was not applicable to living beings, since it separated organized parts which should remain united" (Bernard 1957 [1865]: 89).

In the experiments that he conducted Réaumur fed a kite with perforated metal tubes that contained pieces of meat. The meat and the tubes were wrapped with thread and thus only fluids contacted the food. After the bird regurgitated the metal tubes, Réaumur found that the meat was reduced to a fraction of its original size and it became soft and grayish. In other experiments Réaumur put sponges inside metal tubes. After the bird regurgitated the tubes, Réaumur squeezed the gastric juice out of the sponges. He concluded that the juice is acidic and that it can dissolve food, although he was unable to produce an artificial digestion in vitro, i.e. to dissolve the meat in a tube which was maintained at near body temperature and contained gastric juice. Following Réaumur, Spallanzani experimented on animals and on himself. For example, he tied sponges to strings and swallowed them. By pulling the sponges out of the stomach he obtained samples of the gastric juice. Spallanzani concluded that "In general these juices produce their effects out of the body…" He also showed that in artificial digestion heat accelerated the dissolving of food by the gastric juice, that food did not putrefy in the juice and that fermentation was not involved in the process (Spallanzani 1784: especially 8 – 11, 50, 58, 85, 94, 97, 234, 256 – 260; Horsman 1996: 106 – 109; Holmes 1974: 141 – 145).

The mechanistic approach that Spallanzani and others represented was different from the earlier mechanical approach. Spallanzani believed that the body works not as a classical automaton but as a more sophisticated machine. Nevertheless, the new *body↔machine* still worked according to the mechanistic principles: fragmentation efficient causes etc. Spallanzani accused Boerhaave that his ideas on the gastric juice "were indeterminate and unsettled". According to his interpretation, Boerhaave believed that the gastric juice acts on the food "like a simple diluent, like water heated to the same degree". Spallanzani, on the other hand, contended that the gastric juice works effectively "as a real solvent" that can dissolve "the hardest and most tenacious" substances. Moreover, he rejected the theory of trituration and the idea that the digestive system works as a grinding machine: first the metal tubes used in the experiments protected the food from the so called triturating power of the muscles, and yet the food was dissolved; secondly, Spallanzani did not find direct evidence which confirm the grinding hypothesis, for instance, he observed the stomach of a dog during the time of digestion, but he did not detect motions that can break down food. Spallanzani concluded that "the gastric fluid… is the efficient cause of digestion independently of any triturating power", although he did not exclude the juices of the intestines "from their share" (Spallanzani 1784: 8 – 11, 115, 179 – 180, 199, 211, 216, 227, 234 – 237).

Beaumont was proud to announce that, unlike former theories (Concoction, Putrefaction, Trituration, Fermentation and Maceration), Spallanzani's new theory of Chemical Solution was based on scientific examination and experiment. The new doctrine asserted that digestion is an act of a chemical solvent - the gastric juice. But even after Spallanzani its mode of operation and its specific effects remained unknown. Modern chemistry follows the mechanical principle of fragmentation: in order to solve a complex problem, or to study, investigate, understand and control a process or a subject matter, the first thing that one has to do is to break the problem or process into pieces. In the case of chemistry one had to analyze matter into the characteristics of its atomic components. The gastric juice in itself was a fragment which was abstracted from the living body and now it was also subject to chemical analysis. Spallanzani and the Tyrolean physician and chemist Giovanni Scopoli analyzed the gastric juice. They concluded that the gastric juice is not acid or alkaline, but neutral. Scopoli discovered that the gastric fluid contains water, a soapy gelatinous animal substance, sal ammoniac and an earthy matter which exists in all animal fluids. Spallanzani concluded the experiments he made claiming that the gastric juice is a neutral solvent which can digest and dissolve organic matter inside the stomach and outside. He clarified that animal matters do not putrefy in the stomach, but are dissolved by the solvent with the aid of heat. Nonetheless, he admitted that he was unable to discover the specific “principle” by which the gastric fluid works (Spallanzani 1784: 265 – 293; Beaumont 1838: 64 – 73).

The mechanistic doctrine of Spallanzani was in conflict with vitalism. For example, the British surgeon John Hunter conducted during the 18th century experiments similar to those of Spallanzani, but Hunter was a vitalist (i.e. a soft mechanist) who rejected the complete reduction of the body into mechanical and chemical terms. He therefore strongly criticized Spallanzani’s attempts to reduce the gastric process to the action of a chemical solvent which is not directed by a vital principle. In Hunter’s view, the “living principle” preserves animal substances and prevents their dissolution by other natural forces. For example, “if the living principle was not capable of preserving animal substances from undergoing that process, the stomach itself would be digested.” As long as the stomach possesses the living principle, it is capable of resisting the digestive powers which it contains, while in the dead body the stomach itself may be partially digested by the remains of these powers. Hunter admitted that the gastric juice is the solvent which dissolves the food in the stomach, but he emphasized that “although this menstruum is capable of acting independently of the stomach, yet it is obliged to that viscus for its continuance” (Hunter 1784: 295 – 302; Horsman 1996: 107). Nonetheless, as I will later demonstrate, Hunter was not immune to the impact of the mechanistic metaphor, quite the contrary. He saw the body as a machine which is activated by the vital principle. Under the mechanistic perception of Hunter, even the vital principle was broken down, and from a holistic force it became a fragmented force that exists independently in every part of the *body↔machine* (Hunter 1835 [1787], vol. 1: 219 – 223, 241 – 246, 272 – 273). Vitalists, then, had the same reservations about mechanical and chemical explanations, since both types of explanation were based on the characteristics of the mechanistic order. The vitalists did not believe that the *body↔machine* can be totally reduced to the mechanical and chemical laws which govern inorganic materials. They emphasized the autonomy of the study of life, and in fact many mechanists agreed with then on this particular issue.

The reduction of the digestive system, then, was based on the analytic methods of chemistry. Scopoli, the chemist who analyzed the gastric juice for Spallanzani, worked in a tradition which was rooted in the 16th century. Herbalists and chemists in that period tried to decompose animal and vegetable matters into their constituent substances. Yet during the 17th century it became clear that the old methods of distillations were not very effective. Alternatively, by the early 18th century, more and more practitioners began to use water and alcohol, and afterwards ether, as solvents. New techniques of chemical analysis elaborated and perfected the fragmentation of the body. Materials were decomposed into their constituent substances through reactions with alkalis, alkaline earths, metals and acids. At the beginning of the 19th century chemists, like the Swedish chemist Jöns Berzelius, systematically analyzed different body fluids and tissues using these techniques. Berzelius and his colleagues produced standard sequences of operations that enabled them to do so efficiently (Holmes 1974: 145 – 149).

Already in the 18th century prominent scientists such as Blumenbach defined the body as a *chemical laboratory*. Berzelius adopted and worked according to this metaphoric perception. In 1806 he wrote that “there is no special force exclusively the property of living matter which may be called a vital force or force-for-life, rather, this force arises from the conflict of numerous other [forces] and organic nature possesses no laws other than those of inorganic nature.” Practically his work was based on fragmentation and chemical analysis, but later he admitted that the reduction of the organic to the inorganic has significant limitations. He thus emphasized the autonomy of the life sciences and recognized the existence of the vital force: “The elements seem to obey, in living bodies, other laws than those in dead bodies, or bodies not endued with life… and we attribute it to a power of a peculiar nature, belonging only to living bodies—the vital power.” Berzelius assumed that this peculiar force, which cannot be reduced to the qualities of inorganic elements (e.g. gravity, impenetrability and electric polarity), controls the development and organization of the *body↔machine* (Blumenbach 1865 [1795]: 197, 208; Tiedemann 1834: 8, 29, 184 – 185; Coleman 1979: 147 – 148).

During the 1820s the German physiologist Friedrich Tiedemann and the German chemist Leopold Gmelin elaborated the work of Spallanzani on the gastric juice.

Following Berzelius and others, Tiedemann perceived the body as a *chemical laboratory*. In *A Systematic Treatise on Comparative Physiology* he gave this metaphor a vitalistic interpretation:

> A living body, considered as an object of chemical examination, is, as Berzelius expresses it, a laboratory in which many chemical operations are going on, finally designed to produce all the phenomena the collection of which we designate by the name of life, and to keep the laboratory itself in such a state as that it may be developed, as it were, from an atom to the highest perfection it is capable of attaining, after which it retrogrades, and is at last destroyed. It cannot be refuted that life is accompanied by continual changes in its composition. These changes, however, differ, as to their causes and effects, from the chemical operations that take place in lifeless bodies. As I have previously remarked, chemistry may possibly dissolve the organic combinations and their elements, but it is impossible for it to reproduce them from the latter. What, therefore, in living bodies, retains the elementary matters in the organic combinations necessary to the continuance of their existence, and determines the particular changes of composition which accompany life, is a specific power, altogether different from the chemical affinities acting in inorganic bodies (Tiedemann 1834: 184 – 185).

Yet, in practice, vitalists like Tiedemann promoted the physiological study through the mechanistic approach and they prepared the ground for the predominance of the second mechanistic phase. The work of Tiedemann and Gmelin did not focus on artificial digestion in vitro, although they claimed to confirm the observations of Spallanzani. Instead, Tiedemann and Gmelin focused on the analysis of the digestive juices. In addition to the stomach, they studied the small intestines and the secretion of bile, the pancreatic juice, and the glands of the intestinal wall. By opening the stomachs of laboratory animals, they found that the gastric juice appears in the stomach after eating. Their conclusion was that the gastric juice appears due to a mechanical or chemical stimulation. Tiedemann and Gmelin decomposed the digestive juices as far as they could. First they used solvents, i.e. water, alcohol, acetic acid and ether. Then they tested each of the separated substances with standard sequence of reagents, such as chlorine, mineral acids, metallic salts, lead acetate, copper sulfate, mercurous nitrate and silver nitrate and litmus. In their experiments Tiedemann and Gmelin identified, for example, the presence of osmazome and “salivary matter” in the gastric juice of dogs and horses. Also, they concluded that the gastric juice contains free acid. In the gastric juice of horses they detected hydrochloric acid and evidence for the presence of butyric acid and acetic acid. In another set of experiments Tiedemann and Gmelin studied the chemical transformation of digested food. They demonstrated, for instance, the conversion of starch to sugar in the digestive system of dogs. This specific chemical transformation was demonstrated in vitro in the laboratory of the Russian chemist Gottlieb Kirchhoff almost a decade earlier. Following the work Tiedemann and Gmelin, and the works of Johann Eberle, Johannes Müller, and one of his noted students Theodor Schwann, the pepsin theory developed. As described in the following chapter, Schwann was one of the fathers of cell theory and one of the radical mechanists who shaped the second mechanistic phase. In the early 1830s Eberle isolated the mucus which covers the content of the stomach during digestion. Using the mucus he was able to produce artificial digestion of fibrin, coagulated albumin and casein. Müller and Schwann continued the work of Eberle. They confirmed that albumin is decomposed into osmazome, salivary matter and "animal matter". By 1836 Schwann extracted from the mucus the "active principle" of digestion, the *pepsin*. This digestive agent was characterized by Schwann as a catalyst. Later the pepsin was identified as an enzyme (Holmes 1974: 149 – 178).

In their joint work Tiedemann and Gmelin did not refer of to vital principles. Nevertheless, they admitted that digestion is a vital process that cannot be explained in terms of chemical analysis alone, since the stomach has to respond to stimuli by secreting gastric juice and work together with other systems of the body. For instance, the digestive process and the secretion of the gastric juice are under the influence of nervous action. Thus the digestive system should also be studied in respect to its connections with other organs or in respect to the inner organization of the body (Holmes 1974: 156 – 157). Generally, Tiedemann believed in the autonomy of the life sciences. For example, according to Tiedemann's theory, nutrition, or the assimilation of proper materials by different organs and tissues, does not depend on simple secretion, juxtaposition and the laws of aggregation, but on the specific activity of each organ or tissue, the unification of the organ and the entire body, and the existence of proper external and essential conditions of life. Thus "the act of nutrition, properly speaking, consists — an act which is altogether different from every mechanical, chemical, and physical effect, such as they are seen in lifeless or inorganic bodies" (Tiedemann 1834: 178 – 179). Tiedemann added:

> The operation of primary existence, of formation, growth, and nutrition, by which living bodies are distinguished from all natural productions not endued with life, and from all artificial products, are not the simple physical, mechanical, or chemical effects, such as are observed in lifeless bodies. The act of origination, formation, and nutrition consists neither in a precipitation, according to laws of gravity, of the organic molecules contained in the fecundated generative liquid and in the nutritive fluid, nor in mechanical attraction of these particles, nor, lastly, in a simple chemical affinity and combination, as in crystallizing inorganic matters. All the attempts of the iatro-mechanicians and iatro-chemists to reach this point have failed, and it is well ascertained that such ideas are both unsatisfactory and erroneous. We are therefore under the necessity of regarding them as effects sui generis, as vital manifestations, founded on a power proper to, and inherent in, organic bodies (Tiedemann 1834: 183 – 184).

Thus the following characters depend on the vital force: nutrition, maintenance, reproduction, fetal development and organization. Tiedemann mentions in this context the ideas of physicians and physiologists, such as Galen, Harvey, Stahl, Caspar Wolff and Blumenbach. He admitted that the vital force remained an "occult quality" and claimed that his predecessors were not able to explain its existence, its mode of action and its different manifestations (sometimes as a plastic principle, sometimes as a motor principle and sometimes as a sensitive principle). Additionally, some physiologists defined the vital principle as an immaterial force, while others defined it as a result of a specific combination of materials from which the body is made, i.e. a combination of the mechanical and chemical forces of these materials. Finally, others suggested that the vital force is simply oxygen or electricity. According to Tiedemann, it was the Scottish physician John Brown who at the end of the 18th century saw more clearly than his predecessors the dependence of the living body on the action of external conditions. Yet Tiedemann rejected Brown's theory as well, since "He degraded living bodies to the rank of simple machines that are put into action by external influences, and denied them all internal principle of spontaneous determination." Tiedemann himself defined the different types of vital activities, e.g. excitability and organic contractibility, as organic reactions to external agents that act either mechanically or chemically: "The action produced in an organized body by an external object, or excitation, is a vital act consisting in the reaction of the living body against the mechanical or chemical impression which is thereby arrested…we do not admit that they [the organic movements] are the immediate effects of mechanical or chemical impression, but that they are ever those of the powers of the organism, which the external impression only induces to become active" (Tiedemann 1834: 11 – 12, 29, 184 – 194, 362 – 411).

Tiedemann was a soft vitalist, but the groundbreaking work of Tiedemann and Gmelin on the digestive system demonstrates (a) that *vitalism* became more and more mechanistic through time and (b) that prominent vitalists were among the pioneers of the mechanistic program. We will see it again in the following chapters. The metaphor of the *chemical laboratory* became much more mechanistic by the prominent representatives of the second mechanistic phase, e.g., Schwann.

The dispute over the validity of the gastric juice theory was decided through the experiments of Beaumont on the subject of *artificial digestion*. Beaumont can be seen as one of the forerunners of the second mechanistic phase. On the one hand, he was committed to the industrial-chemical program and he rejected the vitalistic view. On the other hand, his view was also very different from the view of the Christian mechanists who influenced him - Réaumur and Spallanzani: we should keep in mind that pre-existence theory which was supported by most mechanists during the 18th century disappeared at the end of that century.

At the preface to his book, Beaumont wrote that if the reader finds inconsistencies in the book it is since "the human machine is endowed with a vitality which modifies its movements in different states of the system, and probably produces some diversity of effects from the same causes" (Beaumont 1838: 2). Yet, Beaumont was not endorsing physiological vitalism or denying the mechanistic order of the body. He rather wanted to emphasize the autonomy and complexity of the physiological research as compared to the laws of the inorganic world. The mechanistic motivation and values were so rooted in Beaumont's view that when he reviewed, for example, several possible explanations for the sensation of hunger he offhandedly disqualified the "foresight of the vital principle" as a legitimate kind of explanation: it "means any thing, every thing, or nothing", it contributes "nothing to the promotion of science" and it consist of "mere sounds and words" which only reveal "their author's ignorance" (Beaumont 1838: 45). Beaumont considered seriously only mechanical/mechanistic explanations to the sensation of hunger. Accordingly, his hypothesis was based on the mechanistic order. He suggested that the repletion of the gastric juice affects the distention of the vessels which secrete the gastric juice and the result is the sensation of hunger. Different degrees or states of distention determine the intensity of the sensation of hunger: the sensation will be more acute as the distention of the vessels increases. As one can see, this mechanical explanation is based on efficient causes, and following the mechanical principle of fragmentation the sensation of hunger becomes a regional effect only: unlike the "foresight of the vital principle" the hunger sensation is not considered to be a result of holistic forces or holistic states of the body. An "established fact", emphasized Beaumont, support this hypothesis: "the internal sensations referred to different organs… are caused by some modified action or condition of the parts in the tissues of the organ itself" (Beaumont 1838: 47 – 48).

Beaumont was among the scientists who tried to extract and analyze samples of the gastric juice in the most purified state. He had sent the sample of the gastric juice to Prof. Dunglison who analyzed it with the help of Prof Emmett. In Feb. 1833, Dunglison reported to Beaumont that the sample contained: free muriatic (hydrochloric) and acetic acid, phosphates and muriates (a chloride compound), with bases of potassa (potassium hydroxide), soda, magnesia (magnesium oxide), lime, and an animal matter soluble in cold water but insoluble in hot. Today the approach of Beaumont and others may seem obvious, but Beaumont had to defend Dunglison from the possibility that he would be accused of distorting the results of the experiments in favor of the theory which they support – the chemical theory of the gastric juice. In general, concluded Beaumont, various examinations had shown that the gastric juice contains free muriatic acid combined with acetic acid and some salts, and when the science of chemistry advances further, the exact chemical combination of the gastric juice and the exact chemical process by which it works will be determined. The action of the gastric juice is "*purely chemical*" (Beaumont 1838: 2, 65 – 75).

Alexis St. Martin, one of Beaumont's patients, was the subject of his experiments. St. Martin, a French Canadian who worked for an American company, was accidentally injured by a gunshot on 1822. He had recovered with the help of Beaumont, but a perforation in his stomach remained. Beaumont's experiments on the digestive system of St. Martin began on May 1825 and in his book he describes the experiments which were made until 1833. During the experiments Beaumont inserted small pieces of food tied to a silk string into St. Martin's stomach through the perforation. The food was removed from the stomach periodically to determine the rate of digestion. Beaumont could also measure the temperature of the stomach through the perforation and extract samples of gastric juice mixed with some mucus. In one of the experiments he made, Beaumont put a boiled salted beef in a vial with the sample of the gastric juice, corked the vial and put it in a pot filled with water. He kept the pot at the same temperature that he measured in St. Martin's stomach - 100ºF. In Forty minutes the surface of the meat was digested, until the meat was completely digested in a few hours. The effect of the "artificial digestion" in the vial was similar to the effect of the observed digestion in St. Martin's stomach (with little or no difference in their appearance), although the meat was digested more rapidly in the stomach. By agitating the vial the digested surface was removed and the remainder of the meat was digested more rapidly. In a second series of experiments from 1929, Beaumont showed, for example, that the temperature of the stomach is affected by the atmosphere: a dry atmosphere increases the temperature and a humid atmosphere decreases the temperature. He also showed that in the absence of food the gastric juice was not accumulated in the stomach. When small pieces of bread were introduced to the inner surface of the stomach, the gastric juice slowly began to accumulate and the bread dissolved. Beaumont continued to sample and to observe the action of the gastric juice after St. Martin ate different kinds of food and he continued the experiments on the artificial digestion of food using a vial with samples of the gastric juice, in the right range of temperatures and with frequent agitation (Beaumont 1838: 7 – 23, 117 – 291).

The mechanistic metaphor was far from perfect. When Beaumont wrote that "the human machine is endowed with a vitality which modifies its movements in different states of the system, and probably produces some diversity of effects from the same causes", he meant that fragmentation and standardization have limitations. Yet, as a mechanist who represented the second phase, he did not turn to vitalism. In general, Beaumont succeeded in abstracting the process of the gastric juice through the model of artificial digestion, but he also acknowledged that the casual chain in the body can affect the gastric process. For example, he hypothesized that the yellow bile he found in St. Martin's stomach in several occasions is the result of a "violent anger". According to Beaumont, bile is usually considered to be foreign to the stomach and a negative side effect of a disease, unless it appeared under peculiar circumstances of diet (to assist the digestion of oily food). The presence of bile in the stomach alters the homogenous quality of chyme and disturbs its exit to the duodenum (Beaumont 1838: 2, 148 – 149).

In conclusion, Beaumont introduced food directly into the stomach, and experimented on extractions of the gastric juice outside the stomach, in order to show that digestion is a chemical process and the gastric juice is a chemical solvent. As a follower of Spallanzani, Beaumont applied the mechanistic order in physiology and reduced the digestive process to a series of efficient causes, and while denying the need of vital-holistic forces to explain the digestive process, the action of the gastric juice was separated by Beaumont from the operation of the whole body through the model of artificial digestion. Moreover, the juice was chemically analyzed with the prospective target of explaining the physiological process by the qualities and actions of its atomic components. Beaumont, for example, tried to artificially synthesize the gastric juice by mixing muriatic and acetic acids reduced in water, but the results were not satisfying: the beef steak did not dissolve in the artificial mixture as it dissolved in the vial with the gastric juice. Yet, Beaumont thought that the advances in chemistry would enable science to determine the exact chemical combination of the gastric juice (Beaumont 1838: 236 – 237).

- Spallanzani and Beaumont's technique of "artificial digestion" was based on fragmentation, specialization, efficient causes and standardization. The vial with the gastric juice was working successfully, as a little *factory* (If I may use a metaphor which had become widespread in modern biology) specialized in chemical processing of organic materials. Beaumont and his colleagues used the industrial program and employed the same techniques of the industrial world. The Spallanzanian in vitro experiment of *artificial digestion* symbolized that the industrial–chemical phase was taking over the science of physiology. This does not mean that the *body↔machine* metaphor and the reductionist approach were flawless. As Beaumont himself admitted, the *body↔machine* did not always behave according to the principles of fragmentation and standardization.

In the following section I examine the strong connections between the industrial world and the physiology that characterized the second mechanistic phase. The students of Johannes Müller had an important role in shaping the biology of the second mechanistic phase that matured and became dominant around the 1840s.

❖ *The Triumph of the Body↔Engine Paradigm*

The mechanical imitations of the organic body, which were designed by Vaucanson and Droz during the 18th century, were very impressive. Yet they were lacking an internal power source and were activated by an external force. This flaw in the *body↔machine* metaphor was noticed by physiologists who supported the vitalist view at the end of the 18th century. For example, the French physiologist Paul Joseph Barthez mocked the lifelessness of these mechanical imitations because they were lacking the power to produce self propulsion or “a self motive power” (Rabinbach 1990: 52). A solution to this problem was already available in the 18th century. The chemical analysis of life developed thanks to Antoine Lavoisier, the father of modern chemistry, who made the operationally defined chemical elements accessible to systematic study through a theory of oxidation (combustion). During the 1780s Lavoisier began to explore the body as a steam engine, i.e., as combustion mechanism producing physiological work equivalent to the work of the machine. Lavoisier’s view became dominant during the 19th century. Through the engine metaphor the focus of the new program was on the respiration and oxidation processes. In the process of respiration the body takes oxygen from the air and produces CO_2, just as in the combustion process. According to the industrial model of Lavoisier, the respiration process is the internal power source that produces heat and power for the operation and movement of the *body↔machine*. In this study he collaborated with the French mathematician Pierre Laplace, one of the most distinguished advocates of the *world↔machine* metaphor and the Newtonian model of the universe (Coleman 1979: 119 – 130).[64]

Lavoisier's work was part of a large program of the industrial society. Schaffer argues that as a representative of the enlightenment Lavoisier saw both the body and society as automatons (the *body↔machine* and the *political↔machine*). The physiological and social aspects of labor converged under the mechanistic analysis of Lavoisier. As a French patriot, Lavoisier helped the National Assembly to analyze and reform the political economy of the modern state and he developed a technique for measuring the mechanical worth of intellectual labor. Lavoisier's work included an analysis of the balance of profit and loss in the national agrarian economy and a calculation of air consumption and mechanical effects of the body in intellectual and manual labor. In the laboratory, wrote Lavoisier, natural philosophers can "exercise patriotic functions". Similar involvement in political economy had led his close colleague, the French physicist and engineer Charles Coulomb, to analyze and measure the effects of labor and the amount of fatigue in field experiments (Schaffer 1999: 128, 134 – 135, 147 – 148, 158 – 159).

During the 19th century the metaphor of the *body↔machine* continued to update, to develop and to gain power, in compliance with new developments in the techno-cultural environment. The Steam engine, one of the most important and most influential manifestations of the industrial era, was an important milestone in this development. A central paradigm in the life sciences was founded on the *body↔engine* metaphor: physiologists had begun to perceive and examine the body as a "converting energy" machine. The motivating power of the body became an engine, i.e. an internal power source that converts fuel into heat and heat into mechanical work. In the mid 19th century German scientists like Justus von Liebig, Hermann Von Helmholtz and Julius Mayer made the *body↔engine* metaphor dominant. The respiration process was identified with the law of conservation of energy. As an integral part of the mechanical universe, the organism was entirely controlled by matter, energy, physical and chemical processes. The soft mechanistic view that characterized many theories of the first phase was gradually replaced by a strong mechanistic view and by a reductionist approach. By the mid 19th century, the second phase matured and the strong mechanistic view became dominant (Liebig 1846: 39 – 46, 176 – 177; Helmholtz 1962 [1862]: 186 – 222; Rabinbach 1990; Coleman 1979: chap. VI; Lenoir 1989: 197 – 215).

Liebig was one of the founding fathers of biochemistry. The industrial orientation of his work was clear. He was named the "father of the fertilizer industry". His studies demonstrated the importance of nitrogen in the nutrition of plants and they contributed to the formulation of the "the law of the minimum" (the law which determines that the growth of plants is depended on the limiting factor, i.e. on the least available resource). Leibig was also deeply involved in the livestock industry. He developed the technique for processing meat extracts (made from beef), and together with the engineer George Giebert he founded the *Liebig's Extract of Meat Company*. For him, scientific agriculture was "the true foundation of all trade and industry" (Liebig 1843: vii). Leibig described the industrial *body↔machine* in his book *Animal Chemistry*, which was first published in 1842. He argued that different machines and phenomena, e.g. the steam engine, the galvanic apparatus, the solution of metal in an acid and the fast rubbing of two solid bodies together, demonstrate that heat, force and motion are equivalent and convertible. Heat, force and motion are never lost, but take another form. On the one hand heat can produce force and motion, and on the other hand force and motion can produce heat. For example, the steam engine can produce different kinds of motions by the fire that heats the boiler. The steam-vessels consume oxygen and fuel, and emit carbonic acid and water, and soot or smoke. In the process of combustion, the ship's engine produces heat, mechanical power and motion. Carpenters, blacksmiths and other workers maintain the ship. Liebig came to a conclusion that "A rude image of the organism, in many of its relations, may be found in the great sea-going steam-vessels". Like the motive power of the steam-vessel, the ultimate cause of the vital force is a chemical process of combustion, a process which involves oxygen and food, respiration and digestion. The *body↔engine* consumes oxygen and food and produces heat, power and motion (in the process food particles turn into oxidized products). The job of the physiologist is to study these processes and to study the characteristics of the *carpenters* and *blacksmiths* that work in the living body and the relationships between them (Liebig 1846: 39 – 46, 176 – 177).

Hermann Von Helmholtz, an eminent German physiologist and a student of Johannes Müller, was one of the main representatives of the strong mechanistic approach. He was among the scientists who contributed to the formulation of the law of conservation of energy, or as he called it the law of conservation of force. This law emerged on the experiential basis of the industrial revolution. New developments in the field of engineering, especially the invention of the steam engine, had created a new environment and scientists recognized that heat, energy, and mechanical work, are convertible.[65] Helmholtz defined the law as follows: "…*the quantity of force which can be brought into action in the whole of Nature is unchangeable*." On July 1847 Helmholtz promised during a lecture the triumph of the new principle of energy. For him, and for other materialist scientists, a materialistic science cannot separate the forces of nature from their materials: on the one hand, matter could be comprehended only through its forces, and on the other hand forces could not be made from nothingness. Energy, according to Helmholtz, explains the qualities and dynamics of matter. Additionally, energy cannot be diminished in nature: it is conserved and transformed constantly. In this view, engines and organisms are part of a cosmic energy chain: they consume energy from the cosmic storehouse, and using an internal conversion mechanism they are able to convert energy to mechanical force which motivates their organs and parts to move and to function. The body/engine loses the energy, but the energy returns back to the endless reservoir of nature and from there the body/engine can further consume. In the materialistic universe of Helmholtz there was no essential difference between mechanical work produced by nature, humans and machines: the energy source is the same source, the energy is the same energy, and the conversion of energy is carried out under the same laws (Rabinbach 1990: 52 – 54; Helmholtz 1962 [1862]: 188). I think, then, that the second order simulacra of the industrial age, as described by Baudrillard (see chapter 3), are clearly manifested by the equivalence between the body and the engine (the prosthesis of the body):

> The new technology of the industrial age thus produced a new image of the body whose "origins lie in labor power." The body is not simply analogous to, but essentially identical with a thermodynamic machine: "The animal body therefore does not differ from the steam engine as regards the manner in which it obtains heat and force, but does differ from it in the purpose for, and manner in which the force gained is employed." Helmholtz did not denote the living creature to the machine; he transposed the character of an energy-converting machine, to the body, indeed to the universe. The metaphor of the machine rather than the machine itself - the automata - is anthropomorphized (Rabinbach 1990, citing Helmholtz: 61).

So, according to Helmholtz, the same principle applies both to the hand and to the machine: an equivalent *moving force* is required in their actions. Machines produce a variety of actions and movements, from the actions of powerful steam-hammers and rolling-mills to spinning and weaving of fabrics. All mechanical actions in nature and the machine can be quantified and measured by the *quantity of force* or the *amount of work*. Different motions in the machine are transferred from one set of rolling wheels to another at varying velocities, and they are also transferred from wheels to the up-and-down motions of piston-rods, hammers, stamps and vice versa. Since the body works as a machine, its actions can be quantified in the same manner. For instance, the moving force of the hand is found in the muscles that receive orders from the brain through the nerves. Different degrees of muscular exertion are needed for different actions, e.g. the use of a hammer by the blacksmith or the use of a violin by the violinist. In fact, the degrees of muscular exertion correspond to the degrees of the moving force in machines. Hence muscular exertion can be measured through the amount of work. Moreover, in both the body and the machine the "expenditure of force" leads to *exhaustion* or *fatigue*. The exhaustion's degree depends on the exertion's degree and its duration. According to Helmholtz, the function of the muscles is a complex application of this principle. The simplest application of the principle is based on the usage of gravity as a moving force, e.g. clocks driven by weight according to the law of gravity. In clocks the weight is attached to a spring wrapped around a pulley, and the pulley is attached to the first toothed wheel of the clock. When the weight drops according to the law of gravity, the clockwork is set in motion. The weight sinks until it stops, and consequently the entire mechanism stops. Now the moving force is in a state of fatigue: the gravity of the weight is not lost, but it cannot move the clockwork. When the moving force of the arm winds up the clock, the weight is lifted again and its working capacity is recharged. Helmholtz's entire explanation of the law of conservation of energy was based on machines and followed by illustrations of high-pressure engines, water wheels, pulleys, levers, crab-winches, spindles, equipment for measuring the forces of heated gases (a specific apparatus built by Henri Regnault, a student of Liebig) galvanic apparatus, magneto-electrical machines and a telegraph (Helmholtz 1962 [1862]: 188 – 192).

Many other important aspects, besides the motor paradigm, were involved in the construction of the industrial body and in the following chapters I will review some of them, e.g. the cell theory which was developed by the students of Müller and the impact of the mechanistic perception on pathology. The best known example of the industrial influence on the biological perception is the explicit connection between Darwin's theory of evolution and the socio-economic theories of industrial society. Already at the end of the 1820s the eminent French zoologist Henri Milne-Edwards developed the idea of the *division of physiological labour*, following the work of Adam Smith. His ideas had influenced Darwin and in return the ideas of Darwin influenced prominent physiologists like Michael Foster. The myogenic theory of Foster and the Cambridge School of Physiology depended very much on the idea of the division of labor. According to this view, the heart muscle cells that control the heartbeat are autonomous and they work independently of the nervous system (Milne-Edwards 1863: 189 – 193; Darwin 1872: 74, 89, 97; Geison 1978: 337 – 355)

The body in the industrial age became a factory, an industrial city and an economic-capitalist system. In the second half of the 19th century the Scottish biologist Patrick Gedds perceived and defined the body as an economic system which is based on "capital", "income" and "expenditure". As a biological "business" the body can make a profit, lose or be balanced. These three states are possible as long as the expenses are not too high. When the body makes a profit, anabolic reactions take place (chemical reactions on the cellular level of energy conservation). When the body consumes and loses, catabolic reactions take place (chemical reactions on the cellular level of spending and releasing energy for action). Gedds also claimed that women tend to be more anabolic and men tend to be more catabolic. Under the influence of the capitalist outlook, diseases were perceived as problems that appear due to the limited amount of energy in the body which suffers from reckless expenditure. Additional new characteristics were added to the body which became an industrial city, e.g. factories that produce vital materials and "police stations" that protect the body from micro-organisms. Electricity had begun to play a major role in the construction of the body as an industrial city. Electric technologies provided new models for understanding the nervous system. Biologists, such as T. H. Huxley, and intellectuals, such as Ralf Emerson, defined the telegraph as an extension of the nervous system. This view became widely accepted at the last decades of the 19th century. The French philosopher Henry Bergson described the activity of the brain as a "central telephonic exchange" and the American clergyman and educator Frederick

Gates also saw the nervous system as an array of telephone cables. Additionally, according to Carolyn de la Pena, by the end of the 19th many practitioners in the US began to see the body as an "electrical machine". Actually, as Laura Otis notes, the relations between neurophysiology and electricity could be traced to the origins of these two research fields. Physiologists such as the noted students of Müller, Helmholtz and Emil Dubois Reymond, had close relations with electric engineers and the influence was reciprocal (Martin 1987: 32 – 34; 36 - 37; Sontag 1978: 61 – 62; Emerson 1968 [1870]: 161; Gere 2004: 358; Pena 2003: 98; Otis 2002). In 1851 Reymond declared:

> …the wonder of our time, electrical telegraphy, was long ago modeled in the animal machine. But the similarity between the two apparatus, the nervous system and the electric telegraph, has a much deeper foundation. It is more than similarity; it is a kinship between the two, an agreement not merely of the effects, but also perhaps of the causes (in Otis 2002: 105).

Reymond's metaphorical assertion is not arbitrary at all. Yet he was probably not aware of the full complexity of the metaphoric interaction between the body and the machine. For example, he was not aware that future electronic technology would not necessarily serve only as a model for the nervous system or that his models are metaphoric. On the other hand, he was certainly aware that society creates and uses technological environments as extensions of the body. Similarly, in 1858 another noted student of Müller, Rudolf Virchow, proclaimed that "the same kind of electrical process takes place in the nerve as in the telegraph line or the storm cloud". The studies of Reymond, argued Helmholtz, demonstrate that all kinds of nerves produce the same electro-motor actions and work according to the same mechanical, electrical, chemical and thermometric laws. Helmholtz and others saw the nerve fibers as telegraphic wires that connect different stations in the country/body. One of the stations was the eye that was defined as a camera obscura. These were not just empty words. Descartes and the mechanists of the previous centuries made the camera obscura a concrete model of the eye. For instance, according to the illustrations and explanations of Helmholtz, the blackened chamber of the natural camera obscura is the sclerotic coat, "the white of the eye". Unlike its artificial analogous the blackened chamber of the eye is globular and not cubical, and it is not made out of wood, but of thick, strong, white substance. The commercial telegraph foreshadowed the new electronic environment and the post-industrial age. However, mechanists, like Reymond, Helmholtz and Virchow still rode the industrial wave (Virchow 1958 [1858]: 107; Helmholtz 1962 [1868]: 97 – 99, 119 – 121).

- Print culture and industrial society promoted the trends of fragmentation and specialization, the appearance of the new mechanistic mentality, the rule of efficient causes, the values of detachment and objectivity and the establishment of modern scientific communities. A new social order was created. The modern nation-state was based on homogenous citizenship of individuals, on urbanization, standardization, and the separation of powers. Theocracy was abolished and the power of the Church was separated from the power of the state. The mechanistic approach in the life sciences thrived in the social atmosphere of industrial society.

Historically speaking one can identify a gradual decrease in cleric supervision and a gradual increase in academic freedom all over Western Europe. Descartes emphasized in his work that the human mind can only be explained through a dualist view which assumes the existence of a spiritual soul. Nonetheless, in 17th century France it was not sufficient: Descartes was still under threat of the inquisition and had to live and work in the protestant Netherlands. In 18th century Europe one can detect the rise of radical materialism and atheism, but still the social climate was not tolerant of these views or of complete reductionism: Diderot was arrested and imprisoned after he published *Letter on the Blind*; the celebrated Encyclopedia, of Diderot, d'Alembert and the intellectuals of the enlightenment, was officially banned at the beginning, and afterwards it was written under the threat of censorship; La Mettrie had to escape from France to Leyden and from there to the court of Frederick II; d'Holbach had to publish anonymously; and Droz, who created human-like mechanical automata, was arrested by the inquisition in suspicion of practicing in "black art". In the social atmosphere of the 19th century these dangers diminished and became irrelevant. Rudolf Virchow, a distinguished representative of the new scientific establishment, the father of cellular pathology and member of the Prussian parliament, summarized the new situation plainly. Under the protection granted by the institutions of industrial society, he declared in 1858, at the beginning of his lecture *On the Mechanistic Interpretation of Life*:

…I have the cheerful conviction that in Germany the Church will not again succeed in presiding as the arbiter of Science (Virchow 1958 [1858]: 102).

His noted student, Ernst Haeckel, who was one of the main advocates of the Darwinian Theory in the 19th century, identified in human history a "clerical selection" that leads to a decay of culture, education, morality and science. The most obvious example, he claimed, is Spain in which the power of the Catholic Church increased during the middle ages. Consequently the Inquisition appeared in Spain and the scientific education and activity declined. Similarly, during a lecture he gave in 1854, Helmholtz reviewed the development of 18th century automata, and from the standpoint of a mid 19th century scientist he spoke sympathetically about the encounter of Droz with the Spanish inquisition. On the other hand, in 18th century Prussia, where Frederick II ruled, the power of the Church began to diminish: academicians surely did not have complete freedom from the religious establishment, but they were already state employees and their loyalty was given to the state and not to the religious establishment. The intellectual milieu of Frederick the Great included men of the French enlightenment like Voltaire and d'Alembert, and he appointed the prominent mechanist Pierre Maupertuis president of the Prussian Academy of Sciences. Since the 1760's Catholic princes began to promote reforms in Catholic universities: the control in many of these universities was transferred from the Jesuits and the Church to the state bureaucracy. Additionally, the new bureaucratic and administrative establishment of the modern state had tried to force the academy to contribute to the industrial development and to focus on practical and technological problems that were related to industrial applications. Nevertheless, Prussia and France were lagging behind England in combining academy and science with industrial development, technological innovations, division of labor and mass production (e.g. with regards to machinery application in the textile industry or the use of steam). Nevertheless, the bureaucratic efforts in Prussia to combine science and industry finally became successful and fruitful in the 19th century (Haeckel 1914 [1868], vol. 1: 177 – 178; Rabinbach 1990: 57; Johnson 1975: esp. 232 – 237; MacDonogh 2001; McClelland 1980: 72 – 79).

Carl Vogt, a distinguished student of Liebig who contributed to cell theory and to the Darwinian Theory, reflected in the preface to his book, *Lectures on Man* (1864), on the days when science was not free from the supervision of the religious establishment. Vogt participated in the project of the *Useful-Knowledge Society* that offered popular lectures to the general public in Switzerland and especially in Neuchâtel. The main issues discussed by the lecturers were natural sciences, the history of Switzerland, political economy and social life. Vogt attributed the success of this organization to the decline of the clerical establishment. Ironically, as Vogt noted, in places where there were no spacious rooms the lectures were delivered in churches. Before Neuchâtel became a Swiss canton it was a Prussian principality. In that age an entirely different social order supervised and dictated the boundaries intellectual activity:

It is very probable that, in that happy period when a Prussian general, with a few knights of the red eagle governed the country, the lamentations of those, who condemn every result of science which does not agree with the ancient Jewish lawbook, would have prevailed and suppressed this society (Vogt 1864: 1).

As a young student, Vogt had to escape from Germany in 1835, due to his involvement in the activity of the radical political movement of the students at Giessen. Later Vogt became one of the leading figures in the movement of the scientific materialists which had a great impact on the general public in Germany during the second half of the 19th century. Together with Jacob Moleschott and Ludwig Büchner, he endorsed a republican, materialistic and anti-religious view. Scientifically, Vogt and the scientific materialists promoted a strict mechanistic approach in biology which was an integral part of the second mechanistic phase. Vogt contributed to cell theory and Darwinism, and Moleschott and Büchner to physiology. Their social and scientific views were intertwined with each other. As Vogt explained, the advancement and achievements of the materialistic science contributed to the inevitable downfall of the Christian state (Gregory 1977: especially 55, 192 – 197; Vogt 1864; Lenoir 1989: 134 – 140)

In his 1877 inauguration speech as the new rector of the *Frederick William University of Berlin*, Helmholtz noted that due to political, social and international developments, the number of students increased, new social needs and problems appeared and the sciences became "more and more specialized and divided". The title of the lecture was: *On Academic Freedom in German Universities.* Helmholtz believed that the academic freedom was one of the main reasons behind the prosperity, honor, and international status of German universities. Indeed, the nation-state and the separation of powers, as envisioned by Montesquieu who applied the principles of the mechanical thought to society, provided a support to the prosperity and diffusion of the ultra-mechanistic ideas of Helmholtz and his colleagues. In the past, claimed Helmholtz, political and religious establishments "allowed themselves to encroach" on the academy, but now political freedom in the new republic facilitates the liberty of teaching in the universities. In fact, "The same spirit which overthrew the yoke of the Church of Rome, also organised the German Universities." As a result, for instance, professors can teach radical materialistic hypotheses which are based on the theory of Darwin. Helmholtz proudly announced that the liberty of teaching is much greater in German universities than in English and French universities (Helmholtz 1884: 237 – 265).

In France the official victory of reductionism and materialism over the residues of the vitalistic position was made possible in the 1870s after the establishment of the third republic. Under the authority and influence of the new national regime, French scientists were no longer committed to the outlook dictated by the Catholic Church, but rather to an opposite worldview (Barnes, Bloor and Henry 1996: 136). If in Germany Helmholtz's approach represented the triumph of reductionism, in France it was the approach of the physiologist Étienne-Jules Marey. In his book from 1873, *Animal Mechanism*, Marey described the close similarity of modern machines and "animal machines". Like Helmholtz he believed that it is more than a mere analogy: both the body and the industrial engine work according to the same physical laws and both convert energy with heat and mechanical work. In Marey's view, the only difference between the two types of mechanisms was the greater efficiency of non-organic machines compared to organic machines which suffer from fatigue. Many French physiologists, who were influenced by the eminent physiologist Claude Bernard, did not accept the radical view of Marey. Bernard believed in a soft mechanistic approach. During the 1860s he described the deficiencies of the mechanical metaphor and emphasized the autonomy of biological research. According to Bernard, the basis of life is chemical and physical, and therefore the organic and inorganic worlds share common characteristics. However, he added, the complexity and unique features of the organism cannot be studied using chemistry and physics alone: the experimental method of life sciences requires terms, laws and research tools of its own. Moreover, unlike man-made machines, the qualities and functions of the *body↔machine* depend on the complex environment in which it exists (Rabinbach 1990: 66, 90 – 92; Bernard 1957 [1865]).

As a soft mechanist Bernard proclaimed that the living machine must be analyzed like a “crude machine whose parts also have their role to play in a whole.” He urged biologists to “transfer physiological functions as much as possible outside the organism” and analyze them as separate fragments according to the model of artificial digestion. Nevertheless Bernard emphasized that we must always “draw our final conclusion” about a physiological function “in relation to its effects in the whole” (Bernard 1957 [1865]: 69 – 71, 89, 93). Bernard summarized his ideas on the *body↔machine* as follows:

In fact, a created organism is a machine which necessarily works by virtue of the physico-chemical properties of its constituent elements… we call properties vital which we have not yet been able to reduce to physico-chemical terms; but in that we shall doubtless succeed some day. So that what distinguishes a living machine is not the nature of its physico-chemical properties, complex as they may be, but rather the creation of the machine which develops under our eyes in conditions proper to itself and according to a definite ideas which expresses the living being’s nature and the very essence of life (Bernard 1957 [1865]: 93).

The electronic technologies which developed during the 20th century are characterized by totality and systemic approach, implosion, flexibility, feedback etc. These new technologies can react in a flexible manner and adapt themselves to complex environments. The ideas of Bernard on the *internal milieu,* which did not make a significant impact during the 19th century, became very important in the electro-cybernetic biology of the 20th century, via the theory of homeostasis and feedback.

Techno-cultural environments, as well as human knowledge, develop in a hybrid manner. The metaphoric body in 20th century science continued to develop according to this pattern. On the one hand, the industrialization process in Western societies increased dramatically around the end of the 19th century and at the beginning of the 20th century. On the other hand, the electronic environment appeared and the post-industrial age began to develop. McLuhan argued that the interaction between the electronic world and the mechanical world "is the peculiar drama of the twentieth century" and in my opinion this assertion is true in respect to biology. Today the electro-mechanistic hybrids dominate biology. Thus the metaphors of the industrial age have not disappeared: they have been merged with the electro-cybernetic metaphors. Nonetheless, we can identify in today's biology the growing strength of the electronic perception and a decline of the power of the mechanistic perception. Today the mechanistic perception plays a similar role which the organic perception played before: the mechanistic perception gradually loses its power and becomes subordinate to the electronic alternative, as part of the transformations that occur in the techno-cultural environment.

7

The Spell of Fragmentation: Pathology and Cell Theory

In this chapter I will examine the development of the *body↔machine* metaphor through pathology and cell theory. One of the main manifestations of the mechanistic program in the life sciences was the analysis of the body on the tissue level and on the cellular level. As I have described before, traditional organic medicine was based on holistic humoralism, the metaphor of the *macrocosm↔microcosm*, animism and mysticism. With the development of the new mechanical sciences at the 17th century, new alternatives gained strength and undermined the traditional organic perception. Again we will be able to identify historical patterns that lead from the development of the first mechanistic phase to the triumph of the second mechanistic phase. I will show that there was no clear paradigmatic boundary between "mechanists" and "vitalists", but rather a dialogue between the two positions. The main vitalistic programs in pathology were actually a collection of soft mechanistic approaches that adopted the principle of fragmentation. Moreover, eminent vitalists, who took part in the practices of industrial society, became the pioneers of the mechanistic approach in pathology, and actually they prepared the ground for the triumph of the paradigms which represented the second mechanistic phase. Xavier Bichat and his school are the most distinguished representatives of this trend. The second mechanistic phase reached a peak with the development of Cell theory and cellular pathology.

The shift from the organic perception to the mechanistic perception created the basic framework that allowed the development of the new pathological program. Indeed, the shift from the pathology of the living to the pathology of the dead also contributed to the development of the new program, although medical researchers quickly returned to the mechanistic analysis of the living body via the technique of percussion and especially via the stethoscope. The question is what were the new pathologists looking for in the corpses and what were their basic assumptions and expectations? As we saw in the previous chapters, holistic forces in physiology gave way to the metaphor of the *body↔machine* and to the mechanical fragmentation. The fragmentation of diseases was one of the major implications of the mechanical metaphor and the mechanistic-reductionist approach in physiology: if physiological processes are not based on holistic forces, but on mechanistic forces and distinct mechanisms within the *body↔machine*, then the malfunctions and diseases of this machine are located in specific mechanisms. We will see, for example, that, according to the tissue doctrine of Bichat, the differences between the characteristics of different tissues establish the differences between their diseases (Bichat 1813 [1799]: 127).

Let us review the manifestations of the first mechanistic phase in the medical outlook. During the 17th century the traditional humoral view was challenged and modified due to the appearance of the first mechanistic phase. In addition to iatro-mechanical approaches, new iatro-chemical approaches appeared as well, but as discussed before, the iatro-chemical approaches also became more and more mechanistic with time. The basics of the new mechanistic approach were already present in the 16th century. One can see it, for example, in the work the French royal surgeon, Ambroise Paré (1510-1590). Paré illustrated and designed mechanical limbs which work through gears and levers. In practice, as well, he produced mechanical prostheses for patients' limbs. Through the metaphoric construction of the body as a machine, practitioners like Paré had begun to perceive diseases as mechanical malfunctions of the *body↔machine*. Autopsies served them not only to study anatomy, but also to apply the principle of fragmentation and the reductionist approach in the study of pathological phenomena. Due to their mechanistic expectations, Paré and his colleagues tried to identify and locate specific malfunctions in specific parts of the machine. In one of the cases described by Paré he and other senior French physicians dissected the body of Isabeau Rolant. They found the pancreas and mesentery hard and extremely enlarged (weighing 10.5 pounds). The area contained many abscesses with different types of cysts. The patient was healthy until two months before she died. Paré estimated that the tumor developed slowly over eight or more years. The tumor compressed the bladder and caused difficulty in urination. Additionally, the tumor pressed the bowel and the diaphragm and caused difficulties in bowel movements and in breathing. In general the entire lower abdomen was found in an abnormal state (Paré 1960 [1578 and circa 1563]: 12 – 14, 99).

Let us briefly examine two other cases. A young woman who suffered from white menses came to Paris to be examined. After a few days she developed great pain in the side of her body and a fever. The doctors who examined her concluded that she suffers from pleurisy (inflammation of the covering of the lungs) and peripneumonia (pneumonia - inflammation of the lungs). One of the doctors claimed that the patient might die due to the passage of materials from the lungs to the brain and that the indications for it will be the appearance of headache and itching of the head. The next day the patient started to suffer from pain and itching of the head and died after a few hours. About five days later Paré and his colleagues dissected the body of a priest who died from pleurisy and peripneumonia and suffered from a headache. They wanted to confirm the above mentioned prognosis (the passage of materials from the lungs to the brain). During the autopsy they found that the space between the pia matter and the brain was filled with pus (Paré 1960: 107).

Following the mechanical philosophies of Descartes, Galileo, Gassendi and others new medical views appeared. By the 1660s the iatro-mechanical approach became an established theory in medicine, and the publication of Newton's *Principia* in 1687 further reinforced the mechanistic trend among physiologists and physicians. Italy was one of the centers in which the iatro-mechanical approach developed. Through the dialogue between physicians, mechanists and mathematicians, especially under the impact of Galileo's mechanics, the body had become a hydraulic machine. Among the scholars who contributed to these developments was Giovanni Alfonso Borelli, an Italian physiologist, mechanist and mathematician which we have encountered before. Borelli was connected to other distinguished figures in the movements of iatro-mechanism: the physicians Marcello Malpighi (the father of microscopic anatomy) and Lorenzo Bellini. In 1661 Malpighi published an iatro-mechanical account of the lung, in 1662 Bellini published an iatro-mechanical account of the kidneys and in 1680 a famous study of Borelli on the mechanics of muscular motion was published. Many works, which analyzed the body with the aid of mechanical, mathematical and geometric models, appeared in this age all over Europe. One of the main problems which the mechanical metaphor encountered was how to explain the peculiar power source that generates the movements of the living machine and its parts. As described before, with the development of the second mechanistic phase the engine metaphor became dominant, but during the first phase organo-mechanical explanations were still common, e.g. a vital principle or the soul. Some iatro-mechanists still used the concept of the soul in a Cartesian fashion. For example, Borelli used the unconscious act of the soul as an explanation for mental and emotional influences on the movement of the heart. During the first four decades of the 18th century, the German physician Friedrich Hoffmann represented the iatro-mechanical approach along with Boerhaave. As a Cartesian physician, Hoffmann believed that the body is entirely mechanical and therefore medicine should adopt a mathematical method and physico-mechanical principles. For instance, the production of bodily humors was explained by Hoffmann as the result of a mechanical process of filtration. Even the soul was mechanized through Hoffmann's view: in addition to thought and reason, claimed Hoffmann, God gave the soul mechanical powers to activate the movements of the *body↔machine* (Haigh 1984: 20 – 24).

Hoffmann's work was published at 1695 and had a great influence, but in 1707 Boerhaave published the *Institutes* and eventually he became the undisputed authority of the iatro-mechanical approach. Boerhaave was the leading figure in the medical establishment and the most distinguished representative of the first mechanistic phase in the field of medicine. In the 1760s the physician William Cullen claimed that for his own good and for the good of the University of Edinburgh he was warned not to dispute the approach of Boerhaave. The influence of Boerhaave was felt in North America as well, and students came from America to study under him. Boerhaave defined the body as a mechanical automaton or as a set of mechanical automata. As we saw in chapter 5, he divided the *body↔machine* into parts that seemed to him as pipes, levers, presses and bellows, pillars, fences, wedges, axes etc. Basically, he argued, the body is an *assemblage* of small elastic solids which form a mechanical structure, and the heart is the main spring of motion and life. Moreover, the life of each part, e.g. the heart, is different from the life of other parts, e.g. the hair or the nails. Indeed, under the lead of Boerhaave, iatro-mechanism had successfully broken down and analyzed the functions of specific body parts, e.g. muscle contraction, blood flow and glandular filtration. The iatro-mechanists tried to demonstrate that all body parts work according to the general laws of mechanics (Boerhaave 1766 [1708], vol. 1: 7, 80 – 95; Haigh 1984: 24 – 26).

Albrecht von Haller was the most distinguished student of Boerhaave and one of the main authorities in 18th century medicine and physiology. Although he argued that the "animal machine" is not reducible to the simple laws of physics, he emphasized that "animal mechanics" is equivalent to physics, i.e. the laws of animal mechanics operate in the same manner as the laws of physics. In chapter 5 we saw that he defined two fundamental forces: the force of irritability (the contraction effect of muscle fibers and semen in response to a physical irritation), and the force of sensibility (the ability of the nerves to feel or sense). The physiological forces employed in Haller's theory were inspired by the Newtonian physics. Haller explained that irritability and sensibility are similar to the law of gravity: their actions and effects are evident by observation and can be measured, although their exact nature is unknown. Irritability and sensibility are unique forces which appear in the body, and yet Haller insisted that they are mechanical forces and not vital. Irritation, for example, is an automatic reaction which can be produced even in the dead body and without sensation, e.g. contraction of the heart in a dead body as a result of heat, vapors, poisons impelled flatus, watery liquors, wax, blood and electric sparks (Haller 1966 [1747], vol. 1: 58 – 60, 214 – 243; Roe 1981: 96 – 102).

Boerhaave, Haller and the iatro-mechanists rejected the existence of holistic-essential forces and broke the physiology of the *body↔machine* into specific mechanisms which work according to mechanical forces. If physiological processes are based on mechanical forces and fragmentation, then the diseases of the *body↔machine* are mechanical malfunctions which are located in specific fragments of the machine. A new mechanistic perception of diseases became dominant, as inferred from the work of Haller. The imbalance of holistic, vital forces in the body had given way to fragmentation and to the reductionist approach. Under the assumption that diseases are lesions and malfunctions in specific parts of the *body↔machine*, Haller's program was to analyze specific sets of lesions inside different organs. In his book, *Pathological Observations* (1756) Haller summarized his findings which were based on the dissections of corpses. Let us take, for example, the diseases of the neck. Aneurysm of the carotid artery is a local bulge of the artery that supplies blood to the head and the neck. Haller examined a man who suffered from suffocations and quick pulse and was unable to work. During an operation performed on the patient Haller found the lesion which he identified as the disease: a white tumor spreading from the ear through the lower jaw and to the clavicle. The patient had died during the dangerous operation and Haller dissected the body. He described the tumor as membranous, cellular, spongy, adhering to the skin and more than twice as large as a feast. A large quantity of coagulated blood was found in the aneurysm. Other diseases and abnormalities were analyzed by Haller in the same way, for example, wryneck – a condition in which the head is considerably inclined to one side. Physicians located the problem in the mastoid muscles of the neck. Haller dissected a body with an inclined neck and argued that in this specific case the cause of the wryneck is a hard fibrous tumor located near the middle of the mastoid muscle. Above and below the tumor the muscle seemed quite normal. In cases of pleurisy Haller identified the "seat" of the disease at the bottom of the lungs, "in that part of the lungs which is contiguous to the diaphragm". In other words, the disease was reduced to the abscess he found which was "full of a white, yellow, and well concocted pus". The new medicine began to identify the lesion as the seat and cause of the disease (Haller 1756: 6 – 10, 22 – 24)

- The mechanistic solution is primarily based on fragmentation, division of labor and on a reductionist analysis. Accordingly, the mechanical automaton is built from fragments, i.e. from the linear arrangement of distinct parts. Each part in the mechanical automaton fulfills a special function and all parts of the automaton are arranged as a series of efficient causes. Hence, malfunctions are located in specific parts or connections of the machine. This mechanistic perception transformed the study of diseases.

The new mechanistic mentality of the 17th and 18th centuries brought about the decline of Galenic humoralism and the rise of iatro-mechanical and iatro-chemical approaches. Modern medicine had gradually detached from organic and holistic approaches. The new pathological approach made use of autopsies in order to define diseases as specific malfunctions and lesions located in specific parts of the body.

During the second half of the 18th century the foundations of the second mechanistic phase were laid through a systematic analysis which was based on the pathological approach. Under the new mechanistic perception, the Italian anatomist Giovanni Morgagni (1682-1771) systematically tried to locate diseases in specific parts of *body↔machine*. Morgagni was educated in the mechanistic tradition of Malpighi. His teacher was Antonio Valsalva, a distinguished student of Malpighi. Among the colleagues who influenced Morgagni one can find Boerhaave and Haller. The classic work of Morgagni, *The Seats and Causes of Diseases*, was a published in 1761 (Morgagni 1983 [1761]). This work summarized decades of work from the beginning of the 18th century and even before that. One of Morgagni's sources was the *Sepulchretum* – an important work of the Swiss physician Théophile Bonet from 1679. In the preface to his book Morgagni gave a credit to Bonet. He defined him as the first physician who combined various sources in order to produce a methodological analysis of diseases through autopsies. The roots of pathological anatomy, then, were already found in the 17th century. Despite the importance of Bonet's work, Morgagni found it to be inaccurate, full of inconsistencies and occasionally unreliable. Therefore he warned the readers to make careful use in the work of Bonet via the methods of the 18th century. Morgagni's book was based on the observations of his teacher Valsalva, on the observations of Morgagni himself and on the observations of Morgagni's friends (Morgagni 1983 [1761], vol. 1: xv – xxi)

As a forerunner of the mechanistic perception in medicine, Morgagni helped to replace humoral pathology with anatomical pathology. Through his work diseases became kinds of specific lesions located in specific organs. His book is divided into parts and chapters, according to the relevant lesions found in different organs and regions of the body, e.g. diseases of the head, diseases of the thorax and diseases of the belly. Let us take diseases of the head as an example. Through autopsies Morgagni found a common phenomenon to all cases of maniac and melancholic persons: unusual hardness of the cerebrum or at least hardness of the medullar substance of its hemispheres. Boerhaave and others also confirmed these observations. In such cases, claimed Morgagni, there was nothing more interesting and important than the hardness of the cerebrum. Haller added that the brains of old men are relatively harder and attributed to this phenomenon the weakness of memory and understanding. Yet, Morgagni made clear that one should not relate to this phenomenon as the only possible cause of mental disorders. Moreover, the hardness of the cerebrum can also be an effect of other causes and it can also be found in persons who were not mentally ill. Morgagni came to a conclusion that based on the empirical evidence mental disorders cannot be attributed solely or chiefly to the hardness of the cerebrum. Nevertheless his perception was clear: diseases are lesions located inside the organs. In simpler cases than the pathology of mental illnesses Morgagni was more decisive. Together with Valsalva, for example, he confirmed that in apoplexy an injury in one hemisphere of the brain may lead to paralysis on the other side of the body (Morgagni 1983 [1761], vol. 1: 24 – 41, 144 – 162).

Tumors fitted very well to the view of Morgagni who saw diseases as specific lesions which are connected to malfunctions in vital organs, e.g. tumors in the liver, in the spleen or in both. Let us examine one of the many cases described by Valsalva and Morgagni. A sixty years old woman had a tumor in the umbilical region. She suffered from severe pain in the region of the back due to the weight of the tumor and she had difficulty in urinating. The tumor was as large as a uterus of a pregnant woman and it increased everyday. Morgagni noted that there is a connection between the two cases: in the later part of pregnancy there is a difficulty in urinating due to the enlargement of the uterus, and as it seems the same difficulty appears due to the bulk of the tumor. Through the autopsy Valsalva analyzed the *body↔machine* of the deceased. His aim was to locate the mechanical failures that led to her death. He found that the basis of the tumor was located in the center of the mesentery - the membrane which connects the intestines to the back wall of the abdominal cavity. The tumor reached the colon and the adipose membrane of the right kidney. A large quantity of sand particles was found in the right kidney and the renal pelvis was greatly dilated. In part, claimed Morgagni, the symptoms of severe pain and the difficulty in urinating were related to the malfunction of the kidney. The sandy concretions in the kidney and the weight of the tumor disturbed the function of the kidney and especially the function of the adipose membrane that surrounds the kidney. The ureter tubes that carry the urine from the renal pelvis to the bladder were frequently compressed and therefore the secretion of the urine was obstructed (Morgagni 1983 [1761], vol. 2: 182 – 211, 364 – 365)

Let us examine the vitalistic approach in 18th century medicine. The iatro-mechanical approach did not satisfy Georg Ernst Stahl, one of the main representatives of the vitalistic view. At the end of the 17th century he was invited by Hoffmann (the mechanist) to work at Halle. Despite the differences between the theoretical views of Hoffmann and Stahl, Elizabeth Haigh claims that it is not easy to define them, and in many cases they were more about emphasis than substance. Stahl's main writings were published between 1706 and 1708. On the one hand, Stahl admitted that the body is "a mechanical structure". On the other hand, he argued that the organization and conservation powers of the body cannot be reduced through mechanical analysis. He defended the old medical tradition, claiming that the iatro-chemical approach did not contribute to medicine. Alternatively he utilized the notion of spiritual soul in order to explain the purposefulness of the body. Thus, according to Stahl, the mechanical principles and the mechanical activities of the body always remain under the guidance of the soul (Haigh 1984: 26 – 28; Roger 1997: 343 – 345; Ceglia 2006: 280 – 281).

Stahl was in opposition to the iatro-mechanist approach and the impact of his work was very limited. Eventually, during the first half of the 18th century, a school of vitalists, who were influenced by Stahl, was established in France (in the University of Montpellier). Francois de Sauvages was one of the founding fathers of the school of Montpellier. He studied under iatro-mechanists and always admitted that medicine must be based on mechanics and mathematics, but he also thought that the iatro-mechanical approach of the first phase was not sufficient. In a work he wrote for the French government de Sauvages clearly applied the mechanistic approach. He explained the appearance of rabies symptoms as follows. The rabid venom contains volatile alkaline particles that coagulate the blood. As a result the heartbeats slow down, the quantity and velocity of blood are reduced, the temperature declines and muscles suffer from lassitude. The activity of the nervous system, on the other hand, is enhanced by the effect of the rabid venom. Similarly, de Sauvages' description of later stages of the disease was also mechanistic. Yet de Sauvages endorsed a modified version of iatro-mechanism and we can see it in the way in which he explained the action of drugs on the body. Drugs, as well as food and poison, are digested in a mechanical manner: they are broken down into parts or molecules, and in general they act according to "mechanical principles such as mass, velocity, the structures of the parts, calibre size and so on." However, there is a difference between a "pure" machine and an "animated" machine: due to the special characteristics of the living motor, small quantities of drugs can generate in the body great forces. De Sauvages argued that while the mobile body is purely mechanical, just like plants and hydraulic machines, the soul function as the living motor. When the machine metaphor encountered experiential problems, which according to de Sauvages' view could not have been solved in mechanical terms, he turned to the traditional solution. But unlike Stahl, who was committed to the holistic approach, de Sauvages used the notion of the soul (as a living motor) more carefully (Haigh 1984: 28 – 31).

One of de Sauvages' distinguished students was Théophile de Bordeu, who criticized Boerhaave and the iatro-mechanism. Bordeu associated with Diderot and d'Alembert and his views were introduced into the Encyclopedia. He tried to demonstrate that the simple models of the first mechanistic phase were inadequate. For instance, glands, according to his study, are much more than complicated sieves with selective pores, although no one can ignore the mechanical aspects of glandular activity, as analyzed by researchers such as Malpighi, Morgagni and Boerhaave. Bordeu noted that Boerhaave's theory on the activity of glands was generally accepted in the mid 18th century. Boerhaave explained that the manufacture of glandular humors from blood depend on many factors, and mainly on the different arteries and their relation with the heart, the velocity of blood in the arteries, the propelling forces acting on the humors, the characteristics of the humoral passages, the degrees of absorption or exhalation of the fluids, etc. The glands themselves are activated by compression, for instance, in the act of chewing salivary juices are excreted or pressed out of the glands due to the movement of the jaw and the action of muscles around the glands. Bordeu had some problems with this theory. He demonstrated that compression cannot explain the process of secretion from glands. According to the theory of Bordeu, all vital activities, including glandular secretion and excretion of humors, are based on unique vital forces of *sensibility* and *irritability* which cannot be reduced to simple mechanical forces. Each organ possesses a sensing ability working through the nervous fibers. The sensing ability is adapted to the particular function of each organ, and it leads to irritation and movement of the organ. In illness the sensing ability even directs the action of remedies. Finally, according to Bordeu, the spiritual, rational soul takes part in the control over conscious functions and it affects organs through emotions. Nevertheless, the signs of fragmentation were also apparent in the vitalistic theory of Bordeu. According to this view, the body as an integrated unit is “a collection of several organs which live in their own way” and “the sum of all the particular lives”. The activity of the body is supervised by three centers: the brain, the heart and the stomach. Note that the concepts of sensibility and irritability were also accepted by the more mechanistically minded scholars of the 18th century, like Haller, Diderot and La Mettrie. Materialists, like La Mettrie, even used these concepts in order to show that the concept of soul is not needed even in relation to the mind. In fact it was Haller who contributed more than anyone else to the development of these concepts in his studies on the function of nerves and muscles. He demonstrated that even short time after death an irritation of a nerve can excite convulsions in the muscle to which it is attached. Moreover, he demonstrated that muscles can contract in response to other irritations, even when the body dies, and the activity of the nerves is destroyed and sensibility is lost. Thus, according to Haller, the ability to contract resides in the muscle itself and it is separated from sensibility (Haigh 1984: 31 – 37, 47 – 65; Haller 1966 [1747], vol. 1: 58 – 60, 214 – 215, 234 – 235).

Eventually the school of Montpellier tended to the views of Paul Barthez- the Newtonian vitalist, and not to the views of Bordeu despite his influence on the medical world. Barthez was a closed friend of d’Alembert and shared his admiration for Newton. Following Newton he searched for a vital force that would be able to account for various physiological phenomena, just as the force of gravitation explained different physical phenomena. Barthez believed that the spiritual, rational soul is related to willpower, and he therefore distinguished between the soul and the vital force that controls involuntary physiological actions. Furthermore, he tended to believe that the vital force is a material one. This vital force contains a sensitive element and a motor element and it cannot be reduced to simpler forces of nature. Through sensibility and irritability of parts the vital force can account for all the phenomena of life. In general the vital force is responsible for the unity of the body and for the complex connections between its different parts, and it does so through the travel of sympathies in the nervous pathways. The simplest vital force is found in plants, while animals have a more complicated vital force and humans have the most complicated vital force (Haigh 1984: 37 – 42). Indeed, the iatro-mechanical theories of Hoffmann, Boerhaave and others were challenged during the first phase by vitalists such as de Bordeu or Barthez, who favored soft mechanism. Yet, I would later show that the pathological approach endorsed by the new vitalists, Xavier Bichat, Jean Corvisart Rene Laennec and their colleagues, only reinforced the mechanistic approach. In practice the new vitalists were the pioneers of the second mechanistic phase.

Let us examine the medical situation in England after the age of William Harvey. From the 1660s to the 1730s English medical theory was under the rule of iatro-mechanism. According to Theodore Brown, the physiologists of the *Royal Society*, the medical writers of the *Royal College of Physicians*, and almost every distinguished physiologist like Stephen Hales, tried to apply in physiology the principles of mechanical philosophy. Iatro-mechanism comprised a wide variety of approaches. Some of them were based on the Cartesian philosophy and others on the Newtonian philosophy. The Newtonian physiology declined in the 1730s. By the 1750s and 1760s the mechanical philosophy lost its power and by the 1770s vitalism dominated English medicine and physiology. Brown describes English vitalism as an anti-mechanistic current which was led by John Hunter (1728-1793). The maintenance of body heat, for instance, was explained by Hunter using a vital power which “seems to be a property in an animal while alive”. Like the irritated muscle of Haller, the power that generates heat in higher animals responds to stimuli: according to Hunter, the power is exerted when the body is under cold conditions and it preserves a standard body heat. Therefore Hunter defined this force as a power of resistance. Hunter’s experimental physiology developed under the influence of Haller’s work. Now, on the one hand, this piece of information is not surprising because Haller was the leading physiologist in mid 18th century Europe and he influenced mechanists as well as vitalists. On the other hand, Haller was a mechanist, and Brown, like many other historians, identifies a sharp epistemic break between vitalism and iatro-mechanism (Brown 1981; 1974).

- According to Brown, Hunter’s “physiology denied the possibility of mechanistic explanations” (Brown 1974: 181). Conversely, I would like to claim that although Hunter did not accept the models of iatro-mechanism he was a soft mechanist himself. The vitalistic outlook, as represented by Hunter

> and his disciples, was based on an organo-mechanical perception that promoted fragmentation. The decline of iatro-mechanical theories of the first mechanistic phase did not involve the disappearance of the mechanistic order. In fact, the vitalism of John Hunter and his school was part of the mechanistic approach.

Hunter was one of the most distinguished vitalists in the field of medicine before the age of Bichat. In the previous chapter we encountered the vitalistic reservations of Hunter to the attempts of Spallanzani to reduce the gastric process through the action of a chemical solvent. Hunter refused to believe that the process is not directed by the vital principle. Nevertheless, the mechanical metaphor was rooted in his mind to such an extent that even the vital principle did not avoid fragmentation. In *Lectures on the Principles of Surgery* (Hunter 1835 [1787], vol. 1), Hunter presented a typical organo-mechanical outlook which was shared by many vitalists. He declared that mechanics are "introduced into the [animal] machine for many purposes", but the vital principle itself is not mechanical at all. Furthermore, all the mechanical and chemical causes of the body work under the vital principle. In Hunter's view, the materials of the body are organized in a mechanical manner "like the component parts of a machine". Yet, even a machine with perfect organization is still a dead mechanism. For this reason one cannot find differences with respect to the mechanical organization of the dead body and the living body. The vital principle is the power source that gives life to the dead mechanism of the material body. It is found in "every individual particle" of the body, just as gravity is found in every particle in the universe, and its basic property is self-preservation. Hunter rejected the comparison of the vital principle to the spring of a watch. The power in the spring is the cause of the first movement from which all other causes and movements in the watch are generated. On the other hand, the vital principle exists and functions independently in every part of the body. Even when the action of one part is the cause of an action in another, the process is always performed by stimulating the vital principle which is found in the other part. So, ironically, Hunter was a vitalist who thought that fragmentation characterizes the *body↔machine* more than it characterizes the mechanical clock. Let us continue with his analogy. Clocks and other mechanical automatons are composed of special parts which perform different kinds of actions. Some machines are more complicated than others, and they are composed of a large number of parts, but eventually all parts of the machine are combined for achieving a certain effect or a certain result. For instance, the ultimate effect of a clock is to show the correct time. Similarly, animal machines are divided between the less complicated and the more complicated. Secondly, the actions and effects of different parts in the animal machine, like the kidneys or the liver, "appear complete in themselves". Finally, all parts in the animal machines are combined to achieve the ultimate effect of preserving the species (Hunter 1835 [1787], vol. 1: 219 – 223, 241 – 246, 272 – 273).

According to the theory of Hunter, a linear series of standard actions was responsible for achieving the ultimate effect:

> To produce the ultimate effect in any machine, there must be a succession of actions, one naturally arising out of another, each part taking on the action peculiar to itself; the preceding action being always the stimulus to the next succeeding one; and thus the parts go on acting in regular succession until the ultimate effect is produced, and then the whole is at rest until stimulated into action again (Hunter 1835 [1787], vol. 1: 273).

Some of the organs in the *body↔machine*, e.g. the heart and the organs of respiration, are stimulated back into action almost immediately. Other functions, e.g. functions related to hunger and urine, are slowly renewed. We can see, then, that the mechanical metaphor shaped Hunter's view. His work is an early example for the adoption of the fragmentation trend by vitalists who practiced medicine. The implications of the independent function of parts in the *body↔machine* were clear: as opposed to the holistic approach, under the new approach body parts seemed as if they react independently in a state of disease. Hunter defined the concept of disease as a disposition for a malfunction in the *body↔machine*. The malfunction is the immediate effect of the disposition. Malfunctions, or their effects, produce symptoms, and only through symptoms one can locate the cause of the disease. Usually the symptoms are identified as the disease, e.g. sensations of pain, or structural changes of body parts. However, Hunter emphasized that the symptoms of the disease are not the disease itself: the disposition is the cause of the disease and the symptoms are only the effects. In a healthy state the body has a disposition to proper actions: it works "according to the combined laws of the machine". In a state of disease the malfunctions are divided into two main classes. First, there are malfunctions in the natural activity of organs, e.g. spasms of muscles. The remote causes of these malfunctions are the nerves. Secondly, there are malfunctions of the vessels which may involve increased or diminished action. According to Hunter, some diseases are common to all body parts, like inflammations, tumefaction and scirruhs (fibrous, cancerous tumor). Other diseases are peculiar and they depend on malfunctions in the unique activity of certain parts, like involuntary action of voluntary muscles and high or low secretion from glands. Since the natural actions of the liver are very different from those of the lungs, in many cases the malfunctions of the liver and the lungs are different. But the liver and the lungs may also suffer from common inflammation or from the same specific diseases, as scrofula (Hunter 1835 [1787], vol. 1: 299 – 311).[66]

What did Hunter think about locating the diseases? First, peculiar diseases are particular malefactions in certain parts of the *body↔machine*. Secondly, Hunter distinguished between *local* and *constitutional* diseases. Yet, he emphasized that some local diseases result from the constitution and not from the diseased part, and on the other hand a local disease may affect other parts of the body. Constitutional diseases are divided into two classes. When the action of the disease affects all parts of the body we may define the disease as universally constitutional, e.g. different kinds of fever. When the action of the disease is local, although the susceptibility for the disease is found in all parts of the body, we may define the disease as constitutionally local. Scrofula, for example, can affect different body parts, but the actions related to this disease are "always local and independent". Moreover, in Hunter's view, each part of the body copes with diseases on its own: there is a difference, he claimed, in the power of different body parts to resist diseases and to cure "themselves". In many cases it is probably a result of the strength of circulation in different parts of the body. For instance, the strength of circulation in muscles is greater than in the tendons. This may be the reason why muscles have greater power to resist diseases. In conclusion, the roots of fragmentation are already found in the medical view of Hunter, but the following generations of vitalists went much further than Hunter (Hunter 1835 [1787], vol. 1: 305 – 306, 338 – 343).

At the end of the 18^{th} century pathological anatomy became an independent research field. A milestone in this development was a book published by Matthew Baillie, a nephew and a student of John Hunter and his brother William and physician to King

George III. Baillie's book, *The Morbid Anatomy of Some of the Most Important Parts of the Human Body* (Baillie 1986 [1793]), was entirely devoted to a systemic classification of diseases, according to local alterations in anatomical structures. The book is divided into 24 chapters. Each chapter deals with diseases located in different parts of the body: "Diseased Appearances of the Pericardium", "Diseased Appearances of the Heart", "Diseased Appearances in the Cavity of the Thorax", "Diseased Appearances of the Lungs"… and chapters dealing with diseases located in different organs and parts of the abdomen, the brain, etc. Baillie admitted that anatomical alterations do not appear in all diseases, and yet in many diseases the morbid actions produce morbid structures. Morbid actions by themselves cannot be observed, since they occur in the "minute parts" of the body, but the effects of these actions, i.e. the morbid structures, can be examined through autopsies and shed light on the morbid actions (Baillie 1986 [1793]: i – ii).

The study of diseases had evolved through the principle of fragmentation. In both the iatro-mechanical and the vitalistic approaches diseases came to be identified with lesions located in specific parts of the corpse. Baillie describes, for example, specific diseases that attack the pericardium, the membrane that surrounds the heart. The first disease is the inflammation of the pericardium. In this state the membrane is frequently thicker than normal and perhaps also pulpier than normal, due to the increased action of small vessels that transmit substances to the membrane. The second disease is characterized by adhesions of the pericardium to the surface of the heart. In some cases the adhesion is at different spots and in other cases the adhesion is on the entire surface. The evidence, claimed Baillie, shows that adhesions develop as a consequence of previous inflammation. When the pericardium is tightly connected to the surface of the heart the inflammation probably appeared more recently, and when it is loose the inflammation probably appeared earlier. The third disease is characterized by dropsy of the pericardium, i.e. by abnormal accumulation of water in the pericardium. In most cases water accumulates in all the cavities of the thorax and not just in the pericardium, but in some cases it only accumulates in the pericardium. The color of the fluids varies between lighter and darker shades of brown. If the patient also has jaundice the color of the fluids will be yellow. Bailli thought that there are two possible causes for the accumulation of water in the pericardium. First, the small vessels that open into the inner surface of the pericardium may infuse an abnormal quantity of fluids into the cavity of the pericardium, although the vessels of the cavity cannot absorb the large quantity of fluids. The second possibility is that the quantity of the fluids is normal, but the absorption mechanism is flawed due to “a defect in the action of the absorbent vessels”. Finally other diseases may specifically attack the pericardium. For instance, scrofulous tumors, composed of white soft matter with a texture of fresh cheese, rarely appear in the cavity of the pericardium (Baillie 1986 [1793]: 1 – 11)

- ***Mechanistic Vitalism: Fragmentation and the Paris School of Medicine***

18th century anatomists were concerned with descriptive anatomy of organs and the organization of systems of organs. Yet descriptive anatomy was unable to provide a sufficient explanation to the function of the described parts. Toward the 19th century, the tissue doctoring replaced the descriptive anatomy. The trend of locating diseases was further developed by physicians in the hospitals of Paris, who studied the postmortem characteristics of corpses and tried to relate them to the afflictions of the patients. Their goal was to study the disease as a disturbance that appears on the tissue level. In 1798 Philippe Pinel, the spiritual father of the medical school of Paris, proclaimed that medicine should follow the path laid down by the other sciences, that is, to apply a systemic analysis in order to classify and control general or complex phenomena (Coleman 1979: 16 – 34). The modern tissue doctrine was introduced by the 18th century French anatomist and physiologist Xavier Bichat (1771–1802) who was a member of the school of Paris. In *A Treatise on the Membranes* he analyzed the structure of organs and defined twenty-one tissues or membranes, such as mucous and fibrous, without the aid of microscopes. The tissues, he believed, were the active elements of vital organization. If we wish to study a function, he claimed, we should study the relevant organ, but if we wish to study the organ's “properties of life” we should “decompose it” and “analyze [it] with rigor” (Bichat 1813 [1799]; Coleman 1979: 21).

Pay attention to the program of Bichat: “decompose it” and “analyze [it] with rigor”. His tissue doctrine was based on fragmentation, specialization and the division of labor. In this spirit, the holistic approach to diseases was torn apart by Bichat and his colleagues. Was Bichat a mechanist? After all, he suggested following the basic rule of the mechanistic program - the principle of fragmentation. Yet Bichat is labeled as a vitalist. Now, I do not wish to deny that Bichat was a vitalist, but I wish to clarify an important point: Bichat, like most vitalists, developed an organo-mechanical hybrid, and thus the mechanistic aspects that guided his work should not be ignored. He went further than Haller, Morgagni and the previous generation of mechanists in analyzing the body and its diseases. According to Bichat, the organs of the body can be decomposed to the characteristics and functions of twenty one tissues. In other words, diseases can be further analyzed and decomposed below the level of organs: instead of locating and attributing the disease to the complete organ, Bichat contended that one should locate the disease in certain tissues of the organ. The new metaphoric perception identified the disease with lesions in specific tissues almost regardless of the organ in which the tissue is found. Each type of tissue has different characteristics compared to the other types of tissues and it is therefore characterized by different illnesses. For instance, polypi is a group of diseases that only characterizes the mucous membranes. This group of diseases usually appears in mucous membranes that are located near the skin, such as the nose, pharynx and vagina, and not in the internal organs of the body, such as the stomach and intestines. The reason for this, according to Bichat, may be the special texture of the mucous membranes near the skin, or the existence of many more causes of irritation which act on the mucous membranes near the skin (Bichat 1813 [1799]: 74 – 75).

Similarly, in his remarks on the diseases of the fibrous membranes, Bichat wrote:

> Should not, as we have seen, the essential difference between the two classes of the preceding membranes [the mucous and serous membranes], in regard to exterior organization, texture, vital properties, functions, etc., establish one between their diseases? If it be true that the difference of inflammation of the mucous, and of the serous membranes, rests on their diversity of structure, why should not this diversity have the same influence here also, where it is so prominent? (Bichat 1813 [1799]: 127)

Pathological fragmentation, then, was part of the general mechanistic approach that decomposed the *body↔machine* to distinct structures, functions and mechanisms. I would like to stress that there was no clear paradigmatic boundary between the "mechanists" and the "vitalists". On the contrary, there was a dialogue between the two positions and the works of distinguished researchers from both sides had a reciprocal influence. Bichat, for example, explicitly followed the work of prominent mechanistic physiologists, such as Morgagni, Haller and Spallanzani, and in return his work influenced the development of the mechanistic program. The vitalistic aspects in the approach of Bichat developed under the influence of Bordeu and Barthez. In fact, Bichat tried to reconcile the experimental physiology of Haller and Spallanzani with the vitalistic views of de Bordeu, or as he wrote in the preface to *Physiological Researches upon Life and Death*: "In the present state of physiology, it appeared to me the most judicious plan to connect the experimental method of Haller and Spallanzani with the grand and philosophic views of Bordeu." The tissue doctrine of Bichat integrated the works and views of many scientists from the second half of the 18th century, such as Pinel, Haller and John Hunter. In general his doctrine was indebted to the Newtonian methodology, i.e. to the mechanistic analysis which by breaking the object of study to its components achieved an explanation based on "simplicity of causes allied to a multiplicity of effects", as Bichat defined it (Haigh 1984: especially 3, 88, 112, 120; Bichat 1809 [1800]: ix – x; F.G. Boisseau in Bichat 1827: 8). Therefore, Bichat had taken part in the mechanistic discourse and his work had developed on the techno-cultural ground of the industrial age. Bichat, the vitalist, was one of the main promoters of the mechanistic approach in the study of life.

What were the vitalistic elements that characterized the theory of Bichat? Well, Bichat asserted that the living tissues are characterized by the vital forces of *sensibility* and *contractibility*. If the materialists used these notions in order to reject the organic view of the body and the concept of soul, Bichat used them in order to defend the organic view. Similar to his predecessors in the vitalistic tradition, he argued that the distinction between living matter and non-living matter is based on these two notions. Any attempt to further reduce the living body will fail (Bichat 1809 [1800]).

Bichat defined sensibility as the ability to receive an impression, to feel or sense. The stomach, for example, can sense the presence of food and the heart the influx of the blood. Sensibility is divided into (a) organic sensibility which is shared by animals and plants; this form of sensibility includes the phenomena of digestion, circulation, secretion, exhalation, absorption, nutrition etc. (b) animal sensibility which is shared only by animals; this form of sensibility includes sensations and perception, pleasure and pain. In a state of a violent death the difference between the two becomes apparent: animal sensibility is immediately destroyed while organic sensibility remains intact for a longer period of time, e.g. the lymphatics still absorb, muscles feel and can be excited, nails and hair may still be nourished and grow. Organic and animal sensibilities are manifestations of the same power which is present in different degrees. Contraction is the most common mode of motion in animal organs. Contractibility is divided into (a) organic contractibility that depends on the organ itself and is independent of voluntary actions; this form of contractibility includes digestion, circulation, secretion, absorption, nutrition etc. (b) animal contractibility which is controlled by the brain, and depends on the will and on voluntary muscles; this form of contractibility includes locomotion, the voice, general motions of the head, thorax, abdomen etc. In violent death animal contractibility is almost immediately destroyed while organic contractibility proceeds for a longer period of time. Also, in a state of paralysis voluntary motions stop, but the organic motions continue. Organic contractibility depends on organic sensibility, for instance the contraction of the heart is excited by the influx of the blood. Respectively, animal contractibility depends on sensations of external objects. Animal sensibility and contractibility arise from the cerebral nervous system which is responsible to external functions, sensations, locomotion and voice. Organic sensibility and contractibility arise from the nerves of the ganglions which control most organs that are related to internal functions. At this point Bichat thought that perhaps we should not attribute sensibility and contractibility to the organs themselves, but to the cerebral nervous system and to the ganglions which provide the nervous connection to the organs. “It is easy to see”, he summarized, “that the vital properties are reduced to those of feeling and moving” (Bichat 1809 [1800]: 60, 70 – 80).

According to Bichat, the decomposition or fragmentation of the body ends here. Sensibility and contractibility are unique vital forces that cannot be further reduced to the laws of physics and chemistry. Using the experiential deficiencies of the mechanical metaphor, Bichat tried to justify the vitalistic outlook. He claimed that despite the existence of mechanical and chemical functions within the body, the laws of physics and chemistry do not apply to the study of life. The laws of physics are deterministic, uniform, fixed and invariable, while the vital laws as observed in the living body are always varying, unstable and unpredictable. In the living body the slightest causes can produce "thousands different modifications" in an instant. Bichat compared the physical law of attraction to the vital law of feeling: the force of attraction can always be determined in relation to a given body and mass, but the force of sensibility constantly changes even in relation to the same organic part and the same mass. Due to the invariability of physical laws, we can calculate the return of a comet or the resistance of a fluid passing through an inert canal. Nonetheless, Bichat rejected the calculations of Borelli with regards to the force of the muscle, the calculations of the speed of blood or the calculations of Lavoisier with regards to respiration and the quantity of air that enter into the lungs. The irregularity of the vital forces, in response to varying circumstances, prevents the possibility to calculate and standardize the powers of living tissues. Bichat uses another comparison. The "uniformity" of physical phenomena enables us to calculate the behavior of inert fluids. On the other hand, living fluids behave in an entirely different way: they are easily influenced by numerous causes and even by complex causes, such as emotions. Urine, for instance, changes at every instant, after meal or a sleep, in winter or summer etc (Bichat 1809 [1800]: 66 – 70). Therefore:

> Physics and chymistry approximate, because the same laws govern their phenomena; but an immense space separates them from the science of organized bodies, because an enormous difference exists between those laws and that of life. To say that physiology is the physics of animals, is to give but a very imperfect idea of it; I might say with equal propriety that astronomy is the physiology of the stars (Bichat 1809 [1800]: 69).

- If so, unlike most late 18th century vitalists, Bichat still denied the relevance of the laws of physics and chemistry to the study of life. Yet, a belief in the autonomy of the study of life does not contradict the adoption of the mechanistic order. In this sense, even a "radical" vitalist like Bichat still held a soft mechanistic view. Practically he promoted the mechanistic program in a significant manner. Moreover, Bichat was not the only pioneer who believed in vitalism and at the same time contributed to the development of the mechanistic perception.

I find additional support to my claims in the work of Michel Foucault, although I do not accept the sharp epistemic breaks which are found in the historical analysis of Foucault. My analysis is based on hybrid development and rear view mirrors, and as I've previously claimed, the foundations of the systematic-reductionist research in pathological anatomy were already laid in the 16th and 17th centuries, e.g. the work of the surgeon Ambroise Paré and his colleagues or the works of Théophile Bonet and Antonio Valsalva (in this context it should also be noted that Foucault focused on *medicine* and not on *surgeons*). In any case, Foucault notes that many historians, like P. Rayer in 1818, argued that pathological anatomy generated and manifested the appearance of a new, revolutionary medicine. Pathological anatomy provided new methods of analysis and clinical examination. It also promoted the union of medicine and surgery and the reorganization of the schools and hospitals. According to this narrative, religion, morality and prejudice had prevented medicine from discovering the plain scientific truth. The revolution occurred after the resistance to dissection of corpses was slowly removed: thanks to the movement of Enlightenment scientists no longer had to perform autopsies in secret. Foucault and the new historians reject this explanation. In general, the Church did not prohibit autopsies. Morgagni in the mid 18th century, and after him John Hunter, could have performed autopsies without a fear, and the professors at the hospitals used corpses in the study of anatomy and in teaching the art of surgery. Throughout the history of medicine, until the second half of the 18th century, locating the cause of an illness in the specific lesions of corpses was not an obvious and accepted idea. The localization of diseases did not require only the making of simple, empirical and objective acts of observation. On the contrary, this way of thinking required the formation of a new episteme, i.e. a dramatic shift in culture and society that created a new structure of knowledge, new rules, a new discourse, a new practice of medicine and in short a new way of perceiving and defining diseases and their causes (Foucault 1973: 124 – 148). Foucault agrees that the new program of Bichat and his colleagues was an integral part of the development of the industrial society:

If, on the contrary, you tried to establish the place of disease and of death in society at the end of the eighteenth century, and what interest industrial society effectively had in quadrupling the entire population in order to expand and develop itself, as a result of which medical surveys were made, big hospitals were opened, etc.; if you tried to find out how medical knowledge became institutionalized in that period, how its relations with other kinds of knowledge were ordered, well, then you could see how the relationship between disease, the hospitalized, ill person, the corpse, and pathological anatomy were made possible.[67]

The infrastructure of the modern state and the trends of industrial society were the background on which the new medicine appeared. Fragmentation, centralization, standardization, the bureaucratic surveillance on populations, systemic surveys, and new systems of analyses and classification - play a major role in all aspects of modern life. The bureaucratic-medical surveillance on the body and the education of the public by doctors are an integral part of these developments. As the French physician L. Le Brun described it in 1776, the medical supervision and control "relate as much to the police as to the field of medicine proper" (cited in Foucault 1973: 26). The state enforced standards and regulations in order to supervise the new practice of medicine and at the same time it gave medicine and doctors legal status, protection and power over the citizens' bodies. The origin of the Royal Society of Medicine was a council which in 1776 the French government nominated in order to supervise and control epidemics and epizootics. The state supported and funded the Royal Society of Medicine which was officially founded in 1778. Despite its resistance, the old academic establishment could not stand against the rising power of the Royal Society. From a council which supervised epidemics, the Royal Society became an institution in charge on the centralization of all medical activity and knowledge. New hospitals were opened by the state, specialized departments and institutions were founded, medical information about the public was gathered systematically, and medical surveys were conducted for enabling a thorough analysis of diseases and epidemics. The body was decomposed and rebuilt from the fragments (Foucault 1973: especially pp. 19 – 36).

- Modern medicine transformed the body into a machine and adopted the social organization of the industrial world. The hospitals of industrial medicine resembled the factories described by Adam Smith (1981 [1776], volume 1: 14 – 15) in the 18th century: the new form of organization was based on fragmentation, specialization and standardization, as I explained in chapter 2. Of course, instead of producing pins, the hospitals focused on fixing broken *body↔machines*.

As an integral part of the industrial society and the modern state, the new medical establishment was characterized by centralization, standardization and specialism. These developments are described through the eyes of English colleagues in the preface to the translation of the book of Rene Laennec, the prominent disciple of Bichat and his colleague Jean Corvisart. It is interesting to note that Dr. John Forbes, the English translator of the book, dedicates the translation to Matthew Baillie, who, as we have seen before, promoted the fragmentation trend in English pathology. Forbes praises the progress, advantages and superiority of the medical practice that developed in the hospitals of Paris during the early years of the 19th century. The description of Dr. Forbes and his friend Dr. James Clark (on which Forbes relied) reminds the admiration of Adam Smith in relation to the division of labor and its advantages in the industrial factories. One could say that they describe a *factory* for fixing broken *body↔machines*. According to this description, a general administration supervised all the hospitals of Paris and patients were examined in the offices of the administration. From there the patients were sent to the hospitals, according to the specialties of each hospital and its physicians: the general office had received applications from physicians who specialized in certain diseases or classes of diseases and the relevant patients were sent to the hospital in which they worked. The new system encouraged specialization of doctors and regular performance of autopsies. Clark specifically acknowledged the contribution of Jean Corvisart, Gaspard Bayle (a distinguished student of Corvisart) and Laennec to this process (Forbes in Laennec 1979 [1821]: vii – ix).

Historically, a clear trend of specialization, standardization and centralization appeared in medicine of the industrial age. During the first half of the 19th century the large majority of physicians were generalists. Many of them were unwilling to accept the idea that their colleagues specialized only in one part or aspect of the body. By the 1880's the growth rate of medical publications tended toward the specialists. In the International Medical Congress, the number of sections increased from eight specialties in 1875 to seventeen in 1900, and according to one estimate in 1915 the number of medical specialties was about 34. The proportion of full-time private specialists in the US increased from one out of four physicians in 1929 to more than three out of four in 1969. Specifically, the trend of medical specialization was based (a) on the idea that diseases are lesions which can be located in specific parts of the body, (b) on the increase in the number of medical and scientific instruments which required longer training time and (c) on the increase in medical knowledge. Medical specialism was also accelerated due to the appearance of large urban centers which could support medical specialists and due to the employment terms of generalists which had a bad reputation. Generalists lost their medical and scientific authority to experts who developed different practices, unique instruments and techniques. The rapid growth of knowledge dictated a division of labor (Reiser 1978: 144 – 157).

Pinel, Bichat and Corvisart, their colleagues and their disciples were leading the new trend. In 1792 Pinel was appointed by the Royal Society of Medicine to be the first trained physician in charge of a special hospital for mental patients. Pinel promoted the institutionalization of hospitals for mental patients and the formation of a new medical profession, psychiatry. Additionally, he promoted the idea that following the natural sciences medicine should adopt the principle of fragmentation: general or complex phenomena could be comprehended and controlled through sifting analysis and decomposition, and by using distinct categories and well-ordered limits in organizing the phenomena. Bichat and the new pathologists adopted this view. In fact, Bichat compared his approach to that of Lavoisier: just as in chemistry there are simple building blocks which create composite bodies by different combinations, in anatomy there are "simple tissues" which create the organs of the body by different combinations. The arrangement of tissues in different organs, their location in the body and their organic context, were pushed aside. When two tissues reacted in the same way to different chemical and physical agents – e.g. air, water, acids, alkalis, neutral salts, desiccation, putrefaction and maceration - Bichat defined them as tissues of the same kind. Indeed, the principle of fragmentation, or the analysis of complex bodies to their atomic components, united chemistry and the new anatomy. The focus of the new medicine had shifted: the old medicine was based on taxonomic classification of diseases and their shared characteristics, while the new medicine was based on an analysis in the purpose of locating the cause of the disease. Under the new perception, the *seat* of the disease had become an axiom. Medical observation, claimed Bichat, essentially means finding the seat of the disease. Later the French physician Jean-Baptiste Bouillaud confirmed this conviction: according to the axiom of modern medicine there is no disease without a seat; otherwise we also have to accept the absurd idea of a function without an organ (Foucault 1973; Cartron 2007: 158 – 163; Coleman 1979: 20; Haigh 1984: 120).

Standardization had become not just an important principle in medical bureaucracy, medical treatment and classification of diseases, but also in relation to the physiology of diseases. According to Foucault (1973: 34 – 36), until the end of the 18th century medicine related more to “health” than to “normality”, while 19th century medicine related more to “normality” than to “health”. 18th century medicine was still based on notions like vigor, suppleness and fluidity. Illness involved the loss of these qualities and medicine had to restore them. The healing process included considerations of diet and the person’s whole way of life. Thus one could even be his own physician. The trend had changed, and in the 19th century the first step in medical research was primarily based on analyzing the *standard* functioning of the body and on searching for the physiological *standards* that characterize the body. A system of physiological data, which was previously theoretical and marginal, became a key element in the medical practice. I think that a good example of this is the empirical observations and measurements which Beaumont performed on the conditions and functioning of St. Martin’s stomach (Beaumont 1838). Consequently, one could analyze the deviations from the standards, the appearance of pathological phenomena, and the causes of disturbance. Finally, one could determine how to fix the machine and bring it back into normal functioning.

Industrial standardization had gradually become dominant in medicine and physiology. In the more radical approaches the body had become a complete deterministic automaton which is conditioned by physiological and hereditary laws. Obviously the normal operation of the *body↔machine* was disturbed by malfunctions, but it was also disturbed by other deviations from standard action which were more difficult to explain. Otniel E. Dror argues that the expectations of physiologists and physicians who studied the *body↔machine* in the laboratory and the clinic were interrupted by *emotions*, as they defined it. For example, as I pointed out in the previous chapter, Beaumont recognized that the appearance of emotions can distort the standard action of the "human machine". When he found yellow bile in St. Martin's stomach several times, he suspected that the cause for this is "violent anger". Nonetheless Beaumont rejected vitalistic explanations and considered seriously only mechanistic explanations. In principle, the mechanist can explain the influence of violent anger on the action of the gastric system through a casual chain that connects different parts of the *body↔machine*. In order to obtain standard/normal/uniform results in curves and tables of body temperature, blood pressure, blood sugar levels etc., physiologists tried to neutralize the subjective encounter between the observer and the observed and to make sure that the laboratory animals will not be in a state of excitement (Dror 2008; Dror 1999; Beaumont 1838: 2, 47 – 48; 148 – 149). Finally, I would like to emphasize again that the appearance of anomalies within the mechanistic framework should not surprise us. Quite the contrary: our theories are based on grand and small metaphors, and all metaphors suffer from anomalies. As much as the industrial metaphors were powerful, dominant and successful, they were far from perfect. Anomalies concerning fragmentation, efficient causes and standardization appeared in different contexts and scientists tried to overcome them. This process is an open, ongoing struggle in which the transformation of techno-cultural environments, and the accumulation of anomalies and new discoveries, contribute to the replacement of old metaphors with new ones.

Let us go back to the pathology of early 19th century. The metaphoric framework of pathology defined diseases as *organic lesions* and specific malfunctions in the *body↔machine*. Through the pathological research of eminent physicians like Jean Corvisart (1755-1821), the mechanistic approach in medicine prevailed. Corvisart was a member of the school of Paris, a friend of Bichat and the physician of Napoleon. Rene Laennec and Georges Cuvier were among his students. In his book, *An Essay on the Organic Diseases and Lesions of the Heart and Great Vessels* (1962 [1806]), Corvisart demonstrated the advantages of fragmentation in the study of heart diseases. The tissue doctrine asserted that the organs consist of several different tissues and that one can distinguish between specific lesions which characterize different tissues. What had delayed the development of the new approach of pathological anatomy? Well, according to Corvisart, the ancients were ignorant of anatomy: their respect for the dead prevented them from discovering the truths of the science of pathology. Galen had to travel to Egypt in order to see a human skeleton. As an alternative to the dissections of human corpses the ancients dissected apes. They were "restricted by civil, political, and religious institutions" and did not pay attention to organic lesions. During the middle ages the center of scientific activity was in the Arabic world, but according to Corvisart Arabic medicine did not contribute to pathology. With the revival of science in Europe a great progress had been made in anatomy, but even the work of Morgagni was insufficient: according to Corvisart, the studies of Morgagni did not provide an efficient way to distinguish between diseases, and in themselves the unique characteristics which Morgagni found in the corpses did not provide a deep understanding of diseases, their mechanisms and physiology. Corvisart emphasized the role of physiology in the diagnosis of diseases. He witnessed many physicians who were well educated in anatomy, but still made false diagnosis, e.g. physicians who located a certain disease in the liver instead of the thorax and vice versa. Physicians may be familiar with the "various springs of the human machine", with their forms, place, relative position, etc. Still, if they are not educated in physiology, and if they cannot "animate by thought, all the wheels of this astonishing machine", then they could never fully understand organic diseases (Corvisart 1962 [1806]: 15 – 18).

- Although he rejected superficial and abstract attempts to use the mechanical metaphor in the study of life, Corvisart adopted the mechanical metaphor and explored the profound implications of the mechanistic order with regards to the medical research. According to his own testimony, he could not have avoided the mechanical metaphor:

Shall I be indulged with a comparison whose disparity, if not inconvenience, I probably feel as much as any one? Then I will compare the human body to a machine (Corvisart 1962 [1806]: 23).

Corvisart did not think that the body can be simply reduced to the mechanical laws of physics, but his approach was mechanistic and he perceived the body as a complicated machine. He warned the readers not to take the comparison of the human body and the machine too literally: if the comparison is taken literally, it becomes ridiculous and it may divert physicians from *correct* observations. Similar to Bichat, he emphasized that the *body↔machine* is much more complicated than any other automaton. Experiential anomalies appeared in the mechanical metaphor with respect to standardization and determinism. In mechanical systems, claimed Corvisart, the forces and causes are known and they can be rigorously calculated. Unfortunately "Nothing can be so well known, or calculated mathematically in the human machine". Now, the *body↔machine* is not perfect. It is obvious that the power of life, or the energy of the vital principle, cannot assure the normal functioning of the springs of the *body↔machine*: lesions may appear in the "springs of the machine" due to internal failures in the function of the springs or due to external causes. Corvisart claimed that the lesions of the heart appear due to numerous causes, but mainly due to the action of the organ and due to human passions. No other organ functions constantly as the heart. From the moment of birth to the age ninety the heart will beat 2,838,240,000 times. During life the hard work of the heart is needed in every action of the body, from crying and laughing to wrestling and dancing. Inevitably these efforts influence the functioning of the heart. Additionally, food, drinks, poisons, and passions like anger and fear, also damage the heart. Finally, the offspring inherits his characters from the parents, and therefore hereditary causes play a major role in the development of diseases (Corvisart 1962 [1806]: 22 – 30, 267 – 276).

According to Corvisart, autopsies are the most reliable way for learning on the "true seat of the disease". Under the new approach the goal was to achieve an optimal fragmentation of diseases. He divided heart diseases into five main classes: (1) the affections of the membranous envelopes of the heart (2) affections of the muscular substance of the heart (3) affections of tendinous or fibrous parts of the heart (4) affections concerning the different tissues of the heart (5) aneurisms of the aorta. For instance, Corvisart's review of the first class begins with pericarditis, the inflammation of the pericardium (the membrane that surrounds the heart). Acute pericarditis is characterized by sudden appearance, rapid progress and quick termination. The disease may be followed by similar symptoms in the lungs, thorax, diaphragm and even the stomach. Pneumonia, the inflammation of the lungs, appears with acute pericarditis more frequently than other complications. Since Corvisart's starting point was the mechanistic perception, he complained that the relative complexity of symptoms in acute pericarditis makes it difficult to diagnose the "principal disease" or the "true seat of the disease". Nevertheless the relative complexity of symptoms was an obstacle that had to be overcome through a rigorous analysis. The mechanistic perception had led Corvisart and his colleagues to assume that when they study a disease they have to discover "which is the real tissue affected". Corvisart claimed that carditis may affect the three types of tissues which compose the texture of the heart: the muscular, the serous and the cellular. He emphasized that one should distinguish between the manifestations of carditis in different tissues. In this respect the cellular tissue is more sensitive and vulnerable to the disease. The cellular tissue functions as a connective tissue and when it is harmed by carditis it becomes loose. The inflammation of the serous tissue in cases of carditis is similar to the inflammation of the pericardium in cases of pericarditis. When the muscular tissue is harmed by carditis it turns into a soft pale substance (Corvisart 1962 [1806]: 37 – 41, 50, 190 – 196, 315).

Rene Laennec (1781-1826) was the most distinguished student of Corvisart and Bichat. He did not define himself as a vitalist, but he is identified as a distinguished representative of vitalism. Through the work of Laennec, I will demonstrate again that vitalism articulated the increase in the power of the mechanistic perception. We will see below that even his references to the vital principle were mechanistic. Laennec's description of diseases in his book, *A Treatise on the Diseases of the Chest*, did not include a reference to holistic forces or even to vital forces: in this work one can only find detailed analytic descriptions of the development of organic lesions, local changes and malfunctions. Like his teachers, Laennec promoted the mechanistic and reductionist approach to diseases (Laennec 1979 [1821])

- In 1816 Laennec invented a mechanical device that became an indispensable tool in the practice of medicine – the stethoscope. As a mechanical extension of the ear the stethoscope enables the mechanistic analysis of the living body, just as autopsies enable the mechanistic analysis of the dead body. The mechanistic approach in medicine, and the idea that diseases are specific malfunctions in the *body↔machine*, had led Laennec to develop the stethoscope, and the stethoscope reinforced the impact of mechanical technology on medicine.

In his book Laennec briefly described the shortcomings of the diagnostic techniques that had led him to develop the stethoscope. Auenbrugger's technique of percussion was especially important to Laennec. The Austrian physician Josef Leopold Auenbrugger published his findings in 1761, but the technique became part of the medical practice only at the beginning of the 19th century with the aid of Corvisart. Already as a child Auenbrugger used a tapping technique to find out if the wine barrels in his father's cellar were empty or full. As a physician he discovered that by tapping on the thorax or the abdomen he can find changes of texture which indicate the presence of diseases. For example, a healthy chest will produce a hollow sound like an empty barrel, while the presence of a solid mass in the chest which indicates a disease will produce a dull sound like a full barrel. The mechanistic mind was fixed on specific lesions and malfunctions and the aim of the percussion technique was to enable the physician to locate them. General symptoms, wrote Laennec, may deceive the physician. Moreover, he claimed, before the discovery of Auenbrugger physicians were frequently mistaken in their diagnoses. Practically autopsies demonstrated that they were mistaken in one half of the acute cases of peripneumony (pneumonia) and pleurisy and almost in all the chronic cases of pleurisy. The percussion technique goes beyond general and equivocal signs and it provides a more accurate diagnosis. Therefore Laennec defined this technique as one of the most valuable developments in medicine. Yet the percussion technique has many disadvantages. For example, in many cases it gives no indication to the appearance of phthisis. Moreover, using this technique phthisis cannot be distinguished from chronic peripneumony. Peripneumony can hardly be detected through percussion when the inflammation is confined to the center of the lung or when both lungs are slightly affected. Additionally, peripneumony cannot be distinguished from pleurisy, hydrothorax (the accumulation of fluids in the pleural cavity) and other diseases of the chest, through percussion. In cases of pneumothorax (the accumulation of air in the pleural cavity) the technique is misleading. In cases of heart diseases percussion becomes efficient only when the heart is greatly enlarged and the disease is in advanced stage. The technique is inapplicable in the area of the liver. It is inefficient in many cases of obesity etc (Laennec 1979 [1821]: 281 – 283, 315).

Laennec explained that due to the disadvantages of the percussion technique with regards to heart diseases, some physicians including Laennec himself used to put their ears near the precordial area in order to improve the accuracy of the diagnosis. Yet, according to Laennec, this improvement was "very insufficient". Since Laennec had adopted the mechanistic approach to diseases, he tried to find an efficient method which will enable him to locate diseases in specific tissues. A specific case led him to develop the stethoscope. In 1816 Laennec examined a young woman who suffered from symptoms related to heart diseases. Due to overweight, percussion and palpation were ineffective in this case. Additionally, Laennec felt uncomfortable to put his ears directly on the heart due to the age and gender of the patient. He recalled that solid bodies can amplify sounds which are passing through them from one side to another. For example, the sound of a pin scratching one side of a piece of wood will be clearly and loudly heard on the other side. Laennec rolled papers into a cylinder shape, attached one side of the cylinder to the patient's heart and the other side to his ear. The new technique enabled him to hear sounds from the heart and the chest more clearly and to discover a set of new signs of chest diseases. Laennec made experiments with different materials and found that materials with moderate density, such as wood, papers and canes, efficiently transmit sounds. Eventually he designed the stethoscope using a cylinder of wood (Laennec 1979 [1821]: 284 – 286).

Relying on the approach of the Toronto School, Stanley Reiser explains that the stethoscope had transformed the relations of the *subjective* and the *objective* in medicine (Reiser specifically refers to an article of David Riesman in Carpenter and McLuhan 1960). The stethoscope promoted *objective* examination and pushed aside the subjective report of the patient:

The effects of the stethoscope on physicians were analogous to the effects of printing on Western culture. Print and reproducible book had created a new private world for man. He could isolate himself with the book and ponder its messages. As the sociologist David Riesman comments: "As long as the spoken or sung word monopolizes the symbolic environment, it is particularly impressive; but once books enter that environment it can never be quite the same again – books are, so to speak, the gunpowder of the mind. Books bring with them a detachment and a critical attitude that is not possible in an oral tradition.” Similarly, auscultation helped to create the objective physician, who could move away from involvement with the patient’s experiences and sensations, to a more detached relation, less with the patient but more with the sounds from within the body. Undistracted by the motive and beliefs of the patient, the auscultator could make a diagnosis from sounds that he alone heard emanating from body organs, sounds that he believed to be objective, bias-free representations of the disease process (Reiser 1978: 38).

As a disciple of Corvisart and Bichat, Laennec adopted the mechanistic approach of modern pathology. He analyzed diseases and broken them into pieces. In one case, for example, the autopsy of an insane man revealed that the “sufficient cause of death was detected in the brain”. Laennec also found in the corpse signs of consumption (tuberculosis) in the lungs: the left lung contained a few tubercles in an early stage of development and the right lung contained tubercles in different stages of development and an egg sized cavity filled with a clotted blood. The autopsy had enabled the physician to detect the location of diseases in corpses, but now the stethoscope helped him to detect the location of diseases in the living body. For instance, through auscultation distinct sounds may be detected in different parts of the lungs in cases of phthisis (the consumption of the lungs). One patient of Laennec and Bayle experienced the symptoms of consumption. The patient recovered, but since the doctors believed that phthisis is incurable they determined that he suffered from chronic catarrh (inflammation of the mucous membrane). Laennec suspected that the patient suffered from a disease which was more than a mere catarrh. Using the stethoscope he found that the respiration of the patient was good throughout the entire chest, except at top of the right lung. Now Laennec was “certain that this portion of lung had been the seat of an ulcerous excavation” that healed through a solid cicatrice (Laennec 1979 [1821]: 20, 33 – 36)

The general aspects of diseases were concealed by the mechanistic metaphor. Under the rule of fragmentation even the general reaction of the body to diseases had become a subsidiary subject. For example, Laennec notes that according to the physicians the general symptoms of peripneumony are difficulty in breathing, deep pain in the affected side, difficulty in lying on the other side, fever, cough and viscid sputa which is sometimes mixed with blood. Nevertheless, in some cases of peripneumony many of these symptoms do not appear and furthermore most of them are common to many other diseases. Relying on general symptoms, claimed Laennec, is good only for a preliminary diagnosis. It is insufficient and may be frequently misleading. The percussion technique provides a much more reliable diagnosis, but as we have seen before the percussion technique has its own disadvantages. The most reliable method is based on the use of the stethoscope: every case of pulmonary inflammation, and even the degree of the disease, can be discovered by the stethoscope. In other words, the stethoscope is much more accurate and efficient than the percussion technique in finding the seat of the disease. For instance, the stethoscope can detect a distinguished sound, *crepitous rattle*, which strongly indicates the appearance of peripneumony from the first degree. This sound, which resembles a cracking sound of solid salts in a heated vessel, appears only in two other diseases of the lungs except peripneumony. The second and third degrees of peripneumony are characterized by the disappearance of the respiratory murmur from the affected part. Finally, Laennec found an additional disadvantage of diagnosis according to general symptoms. In some cases of peripneumony the use of anti-inflammatory drugs can temporarily reduce the manifestation of general symptoms (e.g. fever and pain) and improve the health and strength of the patient. Still, the stethoscope and the percussion technique may reveal that the lesion did not disappear, and indeed in such cases after few days, or even weeks, the patient's health declines again. In this context it is important to note that Laennec's technique of sounds was far from perfect: though he wrote down the melodies that he heard in musical notes, the technique was hard to standardize and many did not hear what Laennec heard (Laennec 1979 [1821]: 311 – 314).[68]

Laennec was harshly criticized by the medical community and he suffered from hostility and mockery even after his colleagues recognized the importance of his invention. In the past it was claimed that the negative opinions and unpopularity of Laennec were due to his conservative views on social and political issues. He was a royalist and a member of the Congregation, an "ultra"-right Catholic society. Many colleagues of Laennec believed that he was appointed as a medical professor at the College of France, instead of the liberal Francois Magendie, thanks to his royalist loyalty. The hostility to Laennec also stemmed from the personal rivalry between him and the popular physician Francois Broussais. Politically, Laennec was in minority among his colleagues. Nonetheless, Jacalyn Duffin notes that other conservative Catholic physicians, like Gabriel Andral and Antoine Bayle, were treated better than Laennec although they admired Laennec and shared his political and religious beliefs. Duffin suggests that the hostility to Laennec mainly stemmed from his scientific approach, which was probably related to his social and religious beliefs. The supporters of organicism were the rising power in medicine. They promoted reductionism and rejected vitalism. Andral and Bayle were closer to organicism than Laennec. Laennec did not define himself as a vitalist, but he was ambivalent towards organicism. I would like to stress that the organicist view manifested the beginning of the second mechanistic phase in medicine. Formally the French physician Léon Rostan coined the term *organicism* in 1831, but the roots of this approach appeared in the previous decades. The physicians who promoted the organicist view, like Rostan and Bouillaud, thought that the body is a combination of physical and chemical laws. Rostan denied the existence of a vital principle. He argued that all diseases are actually physico-chemical changes which seem as organic lesions in the solid or liquid parts of the body. According to the organicist view, all disease must be characterized by organic lesions. For the organicists local changes were all that could be observed during a state of disease. Cases in which the organic lesions were not found created an anomaly in the organicist paradigm. Yet the organicists surmounted the obstacle by claiming that the absence of organic lesions in some diseases is a result of the inattention of the observer or due to technological limitations. They believed that future technological developments will enable them to locate the lesions of the entire diseases (Duffin 1988).

Practically Laennec was one of the main promoters of organicism, though he did not fully accept the implications of this approach. Due to his vitalistic reservations Laennec was in conflict with the organicists: the organicists were convinced that the essence and cause of diseases must be reduced to organic lesions, while Laennec had reservations about this radical view. Yet he avoided dealing with questions on the causes of diseases and dedicated his work to the pathological study of lesions. Unlike the organicists he recognized that in some cases, such as asthma and diabetes, the disease cannot be identified with a specific lesion which appears in a solid organ of the body. Laennec explained his position in lectures that he gave during the early 1820's. Eventually these lectures were not printed, although Laennec wanted to publish an edited version of them as a book. He divided all diseases into three classes of lesions: lesions of the solid organs, of the liquid parts and of the vital principle. Note that even the vitalistic aspects in the theory of Laennec manifested the principle of fragmentation: Laennec assigned an independent life to each of the three components of the body and claimed that each of them can be altered with or without affecting the other components. According to his view, solid lesions can be identified by physical examination and pathological anatomy, liquid lesions by chemical analysis and vital lesions by *physiology*, i.e. by an analysis of bodily functions. For example, Laennec relied on the work of the French chemist Antoine Fourcroy (an associate of Lavoisier and an advocate of the new mechanistic chemistry), and the French physiologist Francois Magendie who was a mechanist. Fourcroy and Magendie demonstrated that in rabies there are chemical changes in the saliva, and thus Laennec defined rabies as a liquid lesion. Syphilis and gout were defined by him in a similar way. Asthma and epilepsy were defined by Laennec as lesions which appear in the vital principle. He claimed that vital alterations in the functions of the body could be clinically measured. Using the stethoscope he tried to detect functional, non-anatomical changes, i.e. the vital lesions. For instance, a loud breath sound served Laennec as an indication for the existence of chemical or vital lesions and as a diagnostic sign of asthma. He defined these lesions as alterations in the metabolic need of the body for oxygen. Similarly he interpreted the work of Magendie on emetics and poisons as evidence that support the idea of vital lesions: clear organic lesions were not detected in the corpses, and therefore Laennec thought that the lesions in these cases were non-anatomical (Duffin 1988).

Generally, Laennec tended not to accept explanations that put the emphasis on vital or mechanical forces. He did not accept the definition of Bichat to the vital principle, but he recognized the existence of the force of life: According to this view, the physical and chemical phenomena of the body are under the influence of the vital principle. Like Barthez he compared the vital principle to Newton’s law of gravity and separated this principle from the soul: gravity or the vital principle cannot be directly observed, but their effects can be observed and measured. In other words, the vital principle is in line with the values of modern science. Laennec thought that lesions may be the observable effects of unknown causes and therefore they should not be automatically confused with the unobservable primary causes. This issue underlined the controversy between Laennec and the organicists. According to Laennec, an organic lesion may be defined as the cause of a disease if it meets the following conditions: the organic lesion is constant, it is proportional to the symptoms and serves as a sufficient cause for the symptoms, it precedes the symptoms or appears with them, it produces the same symptoms in every case, and finally a more serious lesion or a more probable cause cannot be identified. Duffin comes to a conclusion that perhaps Laennec can be defined as an "unwilling organicist" (Duffin 1988).

The analytic approach of the Paris school continued to develop in France and in other places. Among the distinguished representatives of this trend in France were Gaspard Bayle, Gabriel Andral, Antoine Bayle, Pierre Louis, Pierre Bretonneau and Jean Bouillaud. Young physicians from around the world came to Paris to learn the art of auscultation and anatomical diagnosis. One of these students, for example, was the American physician William Gerhard who described tubercular meningitis in children and helped to define the differences between typhus and typhoid fevers. New centers adopted the practice of diagnosis and principles of research of the Paris school. Around 1820 a new clinical school was formed in Dublin under the leadership of Robert Graves and William Stokes. This group discovered and defined new diseases, such as the Grave's disease and Cheyne-Stokes' respiration. Similar clinical schools appeared in London. Among the leading figures in London one can count Thomas Addison, Richard Bright and Thomas Hodgkin who discovered and defined the Hodgkin's disease. Under the leadership of Josef Skoda and Carl von Rokitansky the "new school of Vienna" introduced the research program of the Paris school to the German world (Faber 1923: 39 – 58). Rokitansky had become the leading anatomical pathologist in Europe and in the following section I will briefly describe his encounter with Rudolf Virchow and cellular pathology.

❖ *Cell Theory and the Second Mechanistic Phase*

One of the most important developments in 19th century biology was the appearance of cell theory. As a fundamental paradigm of the second mechanistic phase, cell theory played a major role in overthrowing the teleo-mechanical tradition. Via the new mechanistic paradigm the body was fragmented into a set of *independent* units, the cells, which work through specific physical and chemical processes. By the late 1830s, the German biologists Matthias Schleiden and Theodor Schwann developed the early version of cell theory. Like Helmholtz, Virchow and Reymond, they were students of Johannes Müller. Schleiden published his work in 1837 and Schwann in 1838. In the early 1840s cell theory became one of the most important paradigms in biology. At mid 19th century, Virchow and other biologists elaborated and updated the new theory. They demonstrated, for example, that cells do not reproduce by crystallization of matter, as Schleiden and Schwann suggested, but by a division of a pre-existing cell into two daughter cells.

Cell theory was one of the main paradigms that manifested the triumph of the second mechanistic phase. First, in the most basic sense, the development of cell theory was dependent on the presence and availability of microscopes. A *medium*, as McLuhan defined it, is a new ground of *services* and *disservices*, a process which creates new types of situations and possibilities. The microscope is a mechanical extension of the eye that enables the users to detect microscopic particles and microstructures and to decompose the body into small units and *separate* functions. On the perceptual and conceptual levels, cell theory applied and advanced the principles of the industrial-chemical program. Through an analysis based on fragmentation and efficient causes cells had become the atomic organizational units of the body and the center of physico-chemical activity.

Observations on cells were already made in the 17th century. The English natural philosopher Robert Hooke, one of the founding fathers of the mechanical sciences, coined the term *cell* following his observations using the microscope. In *Micrographia*, which was published by the Royal Society of London in 1665, Hooke described the microscopic structure of the cork as consisting of numerous cells. He estimated that a cubic inch of a cork's pores contains more than twelve hundred millions cells (Hooke 1961 [1665]: 112 – 116). The Dutch scientist Antonie van Leeuwenhoek, one of the fathers of microscopy, contributed to the microscopic analysis of the body and to the development of bacteriology. He constructed improved microscopes that enabled him to made systematic observations on minute structures, such as red blood cells and animalcules (singled cell creatures). Leeuwenhoek is considered to be the first researcher who detected protozoa and bacteria. In a famous letter to the Royal Society of London, sent in 1676, Leeuwenhoek described his findings in samples of rain-water, river-water and sea-water and also in infusions (Leeuwenhoek 1937 [1676]). Yet, botanists and zoologists of the 17th and 18th centuries did not define the cell as the basic structural and functional unit of life which is common to all living creatures. In his famous book *Zoological Philosophy*, which was published in 1809, Jean Baptiste Lamarck wrote that the cellular structure of living creatures is not a new discovery. Yet, Lamarck knew no one but himself who thought that the cellular tissue is "the universal matrix of all organization, and that without this tissue no living body could continue to exist". Correspondingly, his second condition for the definition of life was the existence of containing organs which are formed out of cellular tissue (Lamarck 1963 [1809]: 205, 230).

The rise of the new paradigm of the cell was made possible on the new ground of microscopy. Microscopes were already available since the 17th century, but the simple microscope had some disadvantages. The improvements in microscopy during the 19th century, explains Coleman, helped to the development and the acceptance of cell theory. The simple microscope had only a single, roughly spherical lens. On the other hand, the compound microscope of the 1830s had a line of several lenses of different shapes, it captured the reflected light more efficiently than a simple microscope and it provided images in higher resolution. Although the early stages of cell theory were developed with the aid of simple microscopes, by the early 1840s the compound microscope became common research equipment and it served to establish the theory of the cell (Coleman 1979: 22 – 23). In *Principles of Scientific Botany*, Schleiden claimed that if we take into consideration the developments which occurred since the beginning of the 19th century, only a "great fool" would not recognize the indispensability of the microscope to the study of life: no one can imagine botany and zoology without the microscope, as no one can imagine the study of the heavens without the telescope. Schleiden preferred the compound over the simple microscope. Technically, he claimed, the compound microscope was much better, and the proof is that main discoveries and observations of the previous two decades were made via the compound microscope. Schleiden was also convinced that all the objections against the compound microscope were removed (Schleiden 1849: 575 – 578).

In Schleiden's view, the life of the plant, and of its elementary parts, was no more than a complex of physico-chemical processes. The plant, he declared, should be studied in relation to the well known physical and chemical forces. Fragmentation reached a new level - the level of the cell. A fundamental metaphor that shaped Schleiden's thought was the metaphor of the "individual cell". Schleiden pointed out that the definition of the term *individual* is relative. For example, if we think in terms of *solar systems* then our solar system is seen as an individual, but if we think in terms of *planets* then the solar system is seen as an "aggregate of many individuals". Under the new perception, the plant, or the body, had become an aggregate of many individual cells. Therefore, the vegetative cell had become a "simple plant of the first order". Instead of a vital principle, the new analytic approach demonstrated that life is a combination of chemical reactions which can be isolated. In the plant we see a transition of from sugar into dextrin, from dextrin into starch, amyloid, cellulose, and vegetable jelly, from wax into sugar, from sugar and starch into wax, from starch into fixed oils, and from the fixed oils into sugar and dextrin. Hence, through chemical analysis the activity of the plant and its organs can be reduced. The reductionist program of Schleiden asserted that only unexplained phenomena "are comprehended as a whole, because we are too ignorant to separate the individual powers from their combinations, or again to reconstruct them". Science cannot accept concepts like the *vital power* or the *vital principle*, since they explain nothing. These concepts designate our ignorance of the real biological causes (Schleiden 1849: 24 – 25, 127 – 128, 456 – 459, 539).

My aim, proclaimed Schleiden, is to establish a program that assigns life to each separate cell. According to this program, the analysis of the body should begin with the operations of the individual cells and with the operations of small structures composed of few cells. Eventually, through microscopic analysis, one would be able to explain the structure of the entire body. Schleiden's conclusion was clear:

fragmentation or reductionism is at the heart of the mechanistic program. For him this was the only way to make progress in the study of life:

> The life of the entire plant is the result of life in its individual cells; we shall therefore gain no insight into our subject, and no possibility of explaining it, so long as we are unable to trace back the general results of vitality to their origin in the individual cells (Schleiden 1849: 456).

In his paradigmatic work from 1839, *Microscopical Researches* (Schwann 1847), Schwann promoted the new mechanistic biology. Schwann believed that the *individual cells* are the new allies of the principle of fragmentation. I will later elaborate on the impact which the values of industrial society and the modern state had on the perception and thought of the students of Johannes Müller, but already here we can identify the new pattern of thought: similar to Schleiden, Schwann defined the “separate cell” as an “individual” (Schwann 1847: 258). Through this metaphoric view, he located the operations of the *body↔machine* in the individual cells:

> The cause of nutrition and growth resides not in the organism as a whole, but in the separate elementary parts - the cells (Schwann 1847: 192).

I would like to stress that mechanists like Schwann did not deny the existence of systemic relations within the *body↔machine*. Quite the contrary, the body as a machine must be organized, well ordered and its parts must be connected through action and effects. Yet the whole is constructed from distinct parts and functions. As a result, the whole is reducible to the sum of its parts and functions, or to a series of efficient causes. In the metaphor of “cells as individuals” the body is perceived as an aggregate of individuals who cooperate and work together. If so, the body in Schwann’s thought was an industrial society or a modern state. The cell, he asserted, grows by its own individual powers, but at the same time it is under the influence of the whole body. The evidence shows that some cells which are separated from the organism can grow alone, for example cells of primitive plants. Schwann further claimed that all cells grow according to the same laws, and therefore the cause of growth cannot be in one case the cell itself and in another the whole organism. His conclusion was clear: independent vitality should be ascribed to all cells. But what about cases in which separated cells cannot grow alone? Well, according to Schwann, this fact should not trouble us. A bee that was separated from the swarm may not live long, but nobody can seriously deny the independent vitality of the bee. In order to function properly, the cell needs to be part of an organized body, but the organized body is reducible to the "fundamental powers of the individual cells" (Schwann 1847: 39, 186 – 193).

Schwann rejected the holistic approach to the body and the use of vital forces. The teleo-mechanists who preceded him (e.g., Blumenbach, Reil, Kielmeyer and von Baer) already excluded the use of non-material forces, but Schwann went much further. When Schwann spoke about the forces of the cell, e.g. the "metabolic force", he did not assign them any characteristic which is beyond the mechanistic framework. If all vital forces have to be strictly mechanistic, then the teleo-mechanical forces of the first phase are no longer legitimate. In *Microscopical Researches* Schwann identified the view of the teleo-mechanists as naively vitalistic. As an alternative he suggested a more mechanistic and reductionistic approach. The elementary forces of the body, he claimed, resemble the blind forces of physics that work out of necessity and have no purpose. On the other hand, the combination of molecules in the organic realm is different from the combination of molecules in the inorganic realm. Therefore the forces that work in the body are not identical to the forces of physics and chemistry, but they are not essentially different. Nevertheless, Schwann immediately added that no one can deny the purposive organization of the body. Within the body there is no operation of teleological forces, but there is a purposive organization of matter and parts. In this sense Schwann held a traditional Catholic view: he presupposed that a "rational Being" created the matter in the universe in a way which can be organized. Lenoir claims that to some degree Schwann still remained close to the teleo-mechanical tradition. He describes Schwann's belief as follows: "…a rational being created matter with such forces that by following the laws of mere mechanism a purposive organization, in this case the solar system, would result" (Schwann 1847: 186 – 193; Lenoir 1989: 127).

- I agree with the description of Leonir, but I do not agree with his interpretation. Indeed, to a certain extent the teleo-mechanists who preceded

Schwann still used the notion of teleology in the organic sense, while promoting a synthesis of the teleological and the mechanical. Schwann, on the other hand, did not accept the organic perception. Notice that according to the description of Lenoir himself the final cause, as defined by Schwann, does not coincide with teleology in the organic sense.

As I have pointed out before, under the mechanistic perception the final cause became an end state of a series of efficient causes and this is exactly the view that Schwann adopted. We will later see similar mechanistic versions of the final cause in the works of Erasmus and Charles Darwin, though the Darwinian mechanism of natural selection also provided an alternative to the traditional account of creation, i.e. to the creation of living beings through the action of the Supreme Being. Now, according to Schwann, there are two essentially different frameworks into which all the various opinions on the forces of the organized body may be reduced. First the teleological view asserts that the body contains a purposive force which is essentially different from inorganic forces. Schwann points out that this was the view of Stahl. Secondly, the physical view asserts that the body does not contain any force which is essentially different from the inorganic forces (physical and chemical forces). Hence all forces of the body work through the blind laws of necessity. Furthermore, the forces of the body do not appear in the inorganic nature probably because the combination of molecules in the body is different from the combination of molecules in inorganic nature. As a mechanist who represented the second phase, Schwann chose the physical alternative. He proclaimed that “there is no such necessity for admitting the teleological view in the case of organized bodies”. On the other hand, he added, the existence of adaptation to purpose in the body cannot be denied. For this reason Schwann mentioned the “rational Being”, who created the body in the same way that He created the well ordered and balanced planetary system. The universe functions through the blind laws of necessity and yet it does not collapse. The adaptation to purpose in the body differs from the adaptation to purpose in the planetary system only in a degree. Schwann emphasized that organic phenomena must be reduced by a physical explanation, but it does not mean that the known laws of physics and chemistry are sufficient for constructing this explanation. The science of biology

> is autonomous. As a physical science it has to discover forces which resemble the forces of inorganic nature, but they do not have to be exactly the same (Schwann 1847: 186 – 193)

As a biologist of the second mechanistic phase, Schwann promoted the fragmentation of the body. Against the holistic perception he assigned "an independent life" to the cells. According to this view, the combination of individual molecules in each cell generates a force which can attract new molecules. This is the basis of metabolism and growth that enables to reduce the body to the operations of its components. Before Virchow confirmed the hypothesis that cells are generated through the division of existing cells, Schleiden, Schwann and other researchers had tried to confirm the hypothesis that cells are generated from the substances of the cytoblastema (the organic fluid surrounding the cells). Their account of cell formation was, of course, anti-vitalistic. They contended that substances from the cytoblastema are used in the formation of structures of cells through a process similar to inorganic crystallization. Additionally, since cells attract substances from the cytoblastema, new cells can also be generated from granules in the cytoplasm of existing cells. The analogy to crystallization helped Schwann to put forward a mechanistic account of cell formation, but he recognized that the two processes are not identical: crystallization is based on apposition, a process in which new elements are placed on the surface of the growing crystal, while cell formation also depends on intussusception, a process in which new elements are placed among the old. Hence, the chemical affinities of organic matter differ from the affinities of inorganic matter. The attractive force of the cell draws substances from the surrounding cytoblastema in a selective manner. Cells also have the ability to modify the chemical composition of cytoblastemic substances. For instance, in an experiment conducted by Schwann yeast cells produced alcohol from organic solution through fermentation (Lenoir 1989: 124 – 134; Schwann 1847: 39, 186 – 215).

Already in its early days cell theory became an accepted paradigm by a young generation of scientists that contributed to its development. Carl Vogt, the noted student of Liebig and a leading member of the materialistic movement, was one of them. Unlike Schleiden and Schwann, Vogt claimed that new cells develop only in the nuclei of existing cells and not in the cytoblastema. However the exact details of cell theory are less relevant to this particular discussion than the general characteristics of the new paradigm. In his work from 1838-1842, Vogt rejected the view of the teleo-mechanists and strictly applied the reductionist approach. For instance, he decomposed the process of embryogenesis (the development of the embryo). According to the theory of Vogt, the organized body is generated via the combination of basic components. The structure of the embryo is contained in the egg as small granular objects or primitive embryonic cells. These rudiments of the embryo differ in their structural and functional characteristics. Fertilization of the egg by the sperm stimulates the development of the primitive cells which take their place in the embryonic structure. The mature body emerges from the specialized rudiments at the end of the developmental process (Lenoir 1989: 134 – 140). Notice that specialization is not only the result of embryogenesis, but also the starting point. Otherwise, it would be difficult to account for embryogenesis in mechanistic terms.

- Cell theory was not created as a pure paradigm of the second mechanistic phase. Thus, cell theory and the views of the first phase were not incommensurable. The ideas of Müller, who represented the beginning of the second mechanistic phase, were still rooted in the perception of the first phase.

Vital forces were rejected by the new paradigm of the cell that reinforced the mechanistic interpretation of life. Yet, during the formulation of the theory in the 1840s and 1850s elements of teleological thought remained in the work of the older generation which accepted the new paradigm. Since the early decades of the 19th century Ignaz Döllinger, Ernst von Baer, Rudolph Wagner and Johannes Müller (the teacher of Schleiden and Schwann and the teacher of many mechanists of the second phase) represented the teleo-mechanical approach. When cell theory appeared they accepted and contributed to the development of the new mechanistic paradigm. Teleological elements were combined in their interpretation of the new framework. Already in 1838, the same year that Schwann published his theory, Müller confirmed the theory of the cell. He reported that at high magnifications the cellular structure can be detected in numerous cancerous growths. The new framework enabled Müller to classify pathological specimen according to cell-type and cellular development. In order to explain cancerous growths, he combined cellular and chemical analysis. Yet, unlike his students, Müller did not see the cells as atomic units which enable the reduction of body. He contended that the normal function of the body depends on a holistic direction to which the cells must conform. On the other hand, cancer, for example, is a breakdown of the whole: the cells develop as independent units and they do not conform to the purposiveness of the body as a whole. In a similar context, Müller cited the argument of Kant: in inert matter each part contains its own cause, but in the living body the manner of existence of each part is derived from the purposive organization of the whole, and therefore isolated parts cannot survive outside the body (Lenoir 1989: 65 – 115, 140 – 155).

Nevertheless, the new generation had the upper hand, and the teleo-mechanical approach became irrelevant. The triumph of the second mechanistic phase in the second half of the 19th century is clearly manifested in the mechanistic view of the eminent German pathologist and physiologist Rudolf Virchow, who developed the field of cellular pathology and contributed to the development of cell theory in general. Cells, according to Virchow, are the locus of the action of "mechanical matter", an action that takes place according to physical and chemical laws. In a famous lecture Virchow gave in 1858, *On the Mechanistic Interpretation of Life*, he discussed the mechanistic doctrine. For him cells were the effective elements of life and the atomic units that build up the organism. Thus he equated life with "cell activity". As the organism is more complicated its cells become more differentiated and they form specialized tissues and organs. The cell units produce a variety of materials, structures and functions which comprises the organism, from the green color of the leaves, feathers, hair, eyes and blood (the coloring of leaves and blood is essential to respiration), through the rigid wood trees and to the freely movable muscle mass. The cell itself is made up of chemical substances which are arranged differently from inorganic matter, but these chemical substances are composed of and decompose into non living matter (Virchow 1958 [1855, 1858]: 84, 104 – 106). Despite the differences between the organic and the inorganic:

…the same kind of electrical process takes place in the nerve as in the telegraph line or the storm cloud; the living body generates its warmth through combustion just as warmth is generated in the oven, starch is transformed into sugar in the plant and animal just as it is in a factory… This activity cannot be other than mechanical. In vain has man attempted to find an opposition between life and mechanics (Virchow 1958 [1858]: 107).

The organic matter and the *body↔machine* work according to efficient causality. For instance, according to the explanation of Virchow, muscles do not contract of their own accord, but they must contract when the external stimulus on their interior parts is large enough. As a result, a linear chain of causes and effects arises: "The cause has the necessary effect in its train, and this effect in turn becomes the cause of a new effect". In Virchow's view, explaining the body and the world in mechanical-scientific terms is not to deny the beauty of nature and the human impression of the sublime. Quite the contrary: the natural-mechanistic law is the "miracle" itself minus the "aspect of illusion" and the myth of the "supernatural". The job of the scientist is to reveal the concealed mechanistic laws of nature which can be understood "only in a mechanistic sequence of cause and effect". No other form of knowledge can account for experience. Virchow argued that efficient causality can explain all aspects of the *body↔machine*, including the problem of freedom and mental activity and the nature of the body-plan. He asserted that freedom cannot be based on an arbitrary action: the free man acts according to a lawful necessity, i.e. through reasoned thought which is "always under the necessity of progression from cause to effect". Also, the free man can resist affects and passions. As for the nature of the body-plan, Virchow accused "one of the greatest chemists of our time" (who is not mentioned by name) in mixing spiritualism and science, because the chemist used the argument from design and compared God to an architect who designed the organism as a building which is constructed according to a determined plan. This issue, claimed Virchow, is beyond the bounds of experience and the phenomenal world of science: just as the chemist thinks that there is no room for the concept of Creator in chemistry, the concept has no room in biology either. The biologist has to search for the laws or the plan of the organism and reveal its mechanism. He cannot search for something which is beyond substances and mechanistic laws (Virchow 1958 [1858]: 107 – 115). Thus the actions of chemical substances in the living body do not require an involvement of an "architect" or a "foreign hand":

Everywhere there is mechanistic process only, with the unbreakable necessity of cause and effect. The plan is in the body, the ideal in the real, the power in the material (Virchow 1958 [1858]: 115).

The following passage from the speech *Atoms and Individuals*, given by Virchow in 1859, summarizes many aspects which we have discussed so far:

What is an organism? A society of living cells, a tiny well ordered state, with all the accessories - high officials and underlings, servants and masters, the great and the small. In medieval times it was customary to say that an organism was a microcosm, a little world. Nothing of the sort! The cosmos is no replica of the human being, nor is the human being a replica of the world! Nothing resembles life except life itself. The state can be termed an organism, since it consists of living citizens; conversely the organism can be termed a state, or a family, since it consists of living members of like origin. But here the comparison is at an end. Nature is bifurcate; the organic is something quite special, something entirely different from the inorganic. Although build up from the same materials, from atoms of the same character, the organic world consists of an interconnected array of phenomena essentially split off from the inorganic world (Virchow 1958 [1859]: 130).

The *body* in Virchow's thought had become a *state* composed of citizens and the state had become an organism composed of cells. Notice that the metaphoric argumentation of Virchow, who was a member of the Prussian parliament, pretends to be an innocent comparison. Apparently, Virchow only stated the plain truth about the connection between the body and the industrial society or the modern state. However, we have to be aware that techno-cultural environments have been shaping the *body* throughout the entire history. Thus in each era scientists declare that their metaphoric perception is no more than the plain truth. As Virchow himself notes, in medieval culture the body was a microcosm in an animistic universe. The body in Virchow's view reflected the industrial society, but in the 20th century scientists already began to redesign the body according to characteristics of the electro-cybernetic environment. Virchow's metaphor was based on fragmentation (cells as individuals and atoms), a republican view which was not radically liberal ("high officials and underlings"), and on the rule of efficient causes, as we have seen before. According to this mechanistic view, there are only material bodies and properties of those bodies, and therefore the "life force" is no more than "the resultant of that low of motion which presents itself to our senses as the formation of cells" (Virchow 1958 [1849]: 45).

The *cell↔state* metaphor had become prevalent in German biology: in the eyes of the German biologists the body was an ideal state. Each one of them interpreted this idea differently, according to his social views. For instance, the cell-state theory of Virchow was more egalitarian and liberal in comparison with the theory of Ernst Haeckel (a distinguished student of Virchow) which was more hierarchical and conservative (Weindling 1981). Virchow’s biological view conformed to his sociopolitical view and in fact they reinforced one another. It was important to Virchow to show that the natural, objective order of the body is also the natural, right order for society. He was a liberal and a rival of Bismarck, but he was not a radical. The *cell↔state* metaphor of Virchow was based on the idea of the republic. He did not advocate the more radical version of a liberal bourgeois society, in which the atomic individuals are less constrained and obligated to one another. Thus, the individual cells in the metaphor of Virchow are united in a conservative fashion. Although the body is “a free state of individuals with equal rights”, the unity of the organism is not in danger, because the cells are connected through “centers of organization” and they depend on one another in order to exist. Virchow explicitly made a connection between the “reform of science and society”. For him the 1848 revolutions manifested a critical struggle against the tyranny of the old regimes, just as science manifested a critical struggle against the old dogmas (Mendelsohn 1974: 407, 412 – 417; Temkin 1977: 272 – 274; Lenoir 1989: 224; Ackerknecht 1953: 45). During the revolutionary era of 1848, The Spring of Nations, Virchow wrote to his father that he can now be a man -

> …whose medical beliefs fuse with his political and social ones. As a natural scientist I can be but a republican. The republic is the only form in which the claims, derived from the laws of nature and the nature of man can be realized (Virchow cited in Mendelsohn 1974: 407).

Although Virchow was a proclaimed mechanist, we can see at the end of the citation on the *cell↔state* metaphor that he emphasized the autonomy of biology within the field of mechanical sciences. He made a clear distinction between the organic and the inorganic. Was Virchow, then, under the influence of so called vitalism? My answer is no, but in a narrow sense, Virchow's view was not in accordance with the radical version of reductionism, as the citation above demonstrates. For this reason some mechanists and materialists accused Virchow of indorsing “vitalism”. In response to the pathologist Gustav Spiess, who had accused Virchow of using the expression “life-force”, Virchow clarified that he never intended to use this expression as implying “special vital forces”. Virchow did not doubt the “mechanical origin” of life, but he refused to give a full explanation of life only on the basis of simple properties. He suggested a mechanical analogy to explain the issue. A celestial body does not move of its own accord, i.e. the power of movement cannot be derived simply from the form and composition of the object itself. Similarly, claimed Virchow, analyzing the micro-properties and the substances that make up the individual parts is not sufficient to account for the *body↔machine*. To do this one has to analyze the mechanical relations and the organization of the parts that constitute the *body↔machine*. Yet, in light of the radicalization that occurred in the mechanistic atmosphere, even a devoted mechanist like Virchow could have been condemned as a “vitalist”, if he was not careful enough (Virchow 1958 [1855]: 86 – 89).

Virchow observed that during the first decades of the 19th century the German scientific medicine was still “lay under the spell of Vitalism, whose unfruitfulness became more and more obvious in the later days of its domination”. He criticized the negative impact of vitalism on the development of biological sciences and celebrated the decline of the teleo-mechanical views which characterized the life sciences in Germany during the first mechanistic phase. To clarify his position, Virchow proclaimed that he can admit “Vitalism” only in a very strict sense: the biological sciences are autonomous and they cannot be simplistically reduced to the laws of physics and chemistry, even though (a) life is characterized by physical and chemical laws (b) the body is a mechanism that works through efficient causes. If someone wants to call this approach “Vitalism”, noted Virchow, nothing prevents him from doing so. However a special “life-force” does not exist and therefore it cannot be discovered. The conclusion of Virchow was clear: biologists have to put their trust in the principle of the *causa efficiens* (Virchow 1958 [1895, 1898]: 188, 193, 206 – 207, 232).

The rule of efficient causes was part of a larger mechanistic framework, in which fragmentation and atomization dictated the basic approach to the biological phenomena. Virchow continued the work of Morgagni and the Paris school, while creating a new dimension of reduction through the basic elements and functions of the body. For Virchow, the job of cellular pathology was to locate the cellular lesions associated with the diseases. According to this program, the researcher has to locate diseases in the cells or in “the site or sites of disturbance, i.e. of the 'where' of the disease, of the involved anatomical parts.” Fibrinous pneumonia, he noted, is a good example of local affection that should be studied via the reductionist approach. Virchow warned his audience not to ignore the general affection associated with this disease, i.e. fever: the local affection should be studied by means of pathology and the fever by means of clinical observation or experiment. But then he immediately added that fever itself may be located in certain sites of the nervous system (Virchow 1958 [1895]: 207 – 208).

According to Coleman, the idea that diseases are located in cells was already raised in the 1840s (Coleman 1979: 32). As the main advocate of this view in the second half of the 19th century, Virchow rejected of course the old idea of “general disease”, i.e. the idea that a disease is a manifestation of a general imbalance of the body fluids. His view had become the dominant paradigm in pathology. In 1858 he published the book *Cellular Pathology* (Virchow 1971 [1858]), which became a canonical text in modern medicine. The iatro-mechanical approach of the 17th century severely wounded the organic, holistic approach of ancient medicine. In the 18th century Morgagni and his colleagues focused their attention on malfunctions that occur in specific organs and parts of the *body↔machine*. Then Bichat his colleagues located the diseases in specific tissues. Virchow further advanced the reductionist-analytic approach of his predecessors: he reduced the body to the function of cells, located the diseases of the body in the cells and identified them as disturbances to the cellular functions. For instance, Virchow, who coined the term *leukemia*, set to find the place in which the problem of blood cancer arises. To do this he used morphological and cellular changes as markers, e.g. morphological changes of organs, the size of blood cells and nuclei and the number of nuclei in cells. The markers enabled him to locate the source of the problem mainly in the spleen and additionally in a number of lymphatic glands. He noted that the *ordinary splenic form* and the *lymphatic form* are frequently combined (Virchow 1971 [1858]: 203 – 204).

According to Virchow, then, diseases are reduced to disturbances of cells. His theory, as he defined it, was “a mechanistic hypothesis, in terms of fine-molecular changes”. Virchow's new approach had replaced the pathological anatomy. He demonstrated that anatomical or histological changes might not necessarily be found in pathological examinations. In 1846 the leading anatomical pathologist in Europe Carl von Rokitansky (1804-1878) presented a new theory of humoral pathology, which was based on the cell theory and on the idea that cells are generated from the cytoblastema (the organic fluid surrounding the cells). Rokitansky was a follower of Laennec and other pathologists who represented the Paris school. According to the theory of Rokitansky, the basic pathological changes are formed in the blood and the pathological cells are generated through the exudates (fluids which are secreted from the blood into lesions or areas of inflammation). Rokitansky tried to identify pathology as a series of "blood diseases", i.e. as chemical-humoral pathologies*/dyscrasias*/*crases*. Virchow, who became the greatest opponent of Rokitansky, pointed out that a material change in the body does not have to be anatomical, but rather molecular and physiological. He felt that "It was necessary to protect science from this false pathology of the humors". Already in 1846 Virchow published a critical review on Rokitanskyk's theory and received the support of Müller. He continued to attack Rokitansky in 1847 and 1854. Virchow demonstrated that cells are generated through the process of cell division, in which a cell is divided into two daughter cells and so forth. Finally Rokitanskyk accepted Virchow's critique and modified the following editions of his handbook. In 1895 Virchow wrote on the dispute retrospectively: "The 'crases' have not since appeared in the scientific marketplace. The last 'system' of general pathology was buried with them" (Virchow 1958 [1847, 1895]: 35 – 36, 195 – 196, 205 – 206; Lelland Rather in Virchow 1958: 16 – 17; Ackerknecht 1953: 11, 53 – 55, 60 – 63).

The students of Johannes Müller (especially Helmholtz, Schleiden, Schwann, Virchow, Emil Dubois Reymond and Ernst Brücke) paved the way to the predominance of the second mechanistic phase. Along with the German physiologist Carl Ludwig and others, they promoted the reductionist view and fought against the residues of the teleo-mechanical approach and against religious and conservative values. In 1848, Reymond defined the new program as reducing physiology to analytical mechanics. Physiology, wrote Ludwig at the same year, should be based on the chemistry and physics of the organism. The mechanistic program in the physiology of mid 19th century was also supported by the ultra-materialistic approach of Jacob Moleschott, Ludwig Buchner and Carl Vogt who believed that "man is what he eats", "genius is a question of phosphorus" "the brain secretes thought as the kidney secretes urine" and that "Mechanics and logic are identical". Like Virchow, the radical materialists associated their materialistic view in science with their social view that stood against the values of the Prussian state. Note, however, that the manifestations of the mechanistic order were wide and thus the second mechanistic phase cannot be identified with specific ideologies. Schwann, for instance, held a Cartesian position and yet he was also one of the most distinguished advocates of the second mechanistic phase. Unlike the atheists and the materialists he was a devout Catholic. A different manifestation of the second mechanistic phase can be found in the work of Ernst Haeckel who studied under Virchow and Müller. Haeckel was one of the main advocates of the recapitulation theory in embryology and the theory of evolution. He developed a mechanical-pantheistic view which he called "monistic religion". Biologically speaking, this view was ultra-mechanistic. As Haeckel wrote, for example, in *Monism as Connecting Religion and Science*: "Consciousness, like feeling and willing, among the higher animals is a mechanical work of the ganglion-cells, and as such must be carried back to chemical and physical events in the plasma of these" (Rabinbach 1990: 64 – 66; Gregory 1977: especially 64, 92 ,156 – 159; Haraway 1976: 20 – 21; Temkin 1968: 324 –325; Vogt 1864; Schwann 1847: 186 – 193; Haeckel 2004 [1892]: 3 – 4, 15).

- If so, it is important to emphasize again that the deep impact of technological environments is trans-paradigmatic and trans-ideological. The mechanistic order was much more than a paradigm.

Practically, argues Lenoir, by 1842 the German biologists accepted the new mechanistic framework of physiology, although a split among the students of Müller appeared in 1848. Helmholtz, Reymond, Brücke and Schleiden were more radical than Schwann and Virchow who remained more faithful to Müller. Eventually the more radical approach won (Lenoir 1989: 195 – 245). However, I do not agree with Lenoir that a radical mechanist like Virchow only wanted to reform the approach of Müller. Virchow fully accepted the principles of the mechanistic order, he was determined to promote a mechanistic and anti-vitalistic biology and he explicitly rejected the teleo-mechanical thinking. The only *crime* of Virchow was the emphasis he put on the autonomy of biological research and his claim that one cannot simplistically reduce the mechanistic laws of biology to the mechanistic laws which govern inorganic matter. The case of Virchow only demonstrates the radicalization of the mechanistic trend. Similarly, as I argued before, Schwann did not accept the traditional organic notion of teleology but the mechanical version that reduced the final cause via efficient causes. In any case, it is clear that Helmholtz, for example, was more radical than Schwann in some respects. Schwann showed that the chemical process of fermentation depends on the presence of a living body like a yeast cell. Helmholtz, on the other hand, wanted to implement the principle of fragmentation as far as possible. He was not satisfied that Schwann and other scientists attributed the process to the organized living body. If the body is a chemical factory, then the chemical processes that take place within the body obey the same laws of physics and chemistry. In fact each of these processes is a fragment which can be replicated outside the body. From 1843 on Helmholtz tried to confirm his ideas in a set of experiments. He was specifically influenced by the success of Liebig in analyzing vital phenomena using known chemical and physical forces. For example, he tried to demonstrate that through measurable chemical reactions muscle tissues can produce heat and force by themselves. Eventually Helmholtz redesigned the body as an engine that works through mechanical forces, heat and energy.

- The industrial world had generated increasingly higher levels of specialization in society, especially with regards to patterns of work. Science was an integral part of the process of industrialization and technological development. Specialization was a key factor in the rise of modern science, both mentally and socially. Thus the fragmentation/specialization trend in science was manifested in two related aspects: biological research was divided into many sub-fields and specialties and the body was redesigned as a set of specialized cells with specific functions. The field of biology, as well as the entire fields of science, went through an extensive process of specialization, due to the new mechanistic mentality, to the appearance of new forms of social organization, to the development of new technologies and experimental techniques and the expansion of knowledge.

We have seen that the practice of industrial medicine promoted specialization, but the process was much wider. From about 1670 the study of the body developed as an independent research field that was not necessarily confined to the faculties of medicine. Many MDs in France, England and Italy had begun to devote their time entirely to research. Some of them were members of official learned societies and some became professors in the faculties of medicine. The establishment of scientific communities and scientific research was officially supported by the modern state and it was promoted by the printing press that enabled the publication of scientific journals. From 1665 issues of the *Philosophical Transactions of the Royal Society* in England and other journals appeared. Centralization and standardization had become apparent. Under the control of the French Academy of Sciences, or the Royal Society in England, the journals had taken care of the rapid diffusion of knowledge to the distant provinces and to the regional academies which multiplied in France at the beginning of the 18th century (Roger 1997: 137 – 150; see also Eisenstein 1979).

Between 1825 and 1900 the entire scientific activity in Germany was institutionalized and began to be managed by bureaucratic systems. The growing dominance of analytic methods was involved with the division of research and education into many specialties and subfields. Scientific research based on systemic training and division of labor had become an integral part of professional academic careers. In 1850 the German intellectual August Boeckh acknowledged the power of the fragmentation trend, although he was not satisfied with it: “This division and splintering has incontestably taken a decisive upperhand in our age, in which the celebrated principle of the division of labor has come into widespread currency in science. This has given rise to a mass, indeed we could say a flood, of monographic treatises, to be acquainted with all of which is difficult, but which certainly has contributed very much to the broadening of our knowledge.” Liebig and Müller were forerunners of the new trend and they defined the new practice of professional research. Their professional careers combined long-term researches in certain specialties with teaching and training new generations of research students who gathered around them in the laboratories. Actually Müller’s appointment to the Berlin medical faculty in 1833 was part of a reform initiated by the State. Before the transition of Müller from Bonn to Berlin, the medical faculty was dominated by clinicians and practitioners. The aim of Müller’s appointment was to modify the activity of the faculty so that it will be more oriented toward scientific research and theory. By 1839 Müller and the reform party in the faculty won, and by 1840 all Prussian universities began to acknowledge the importance of specialized research as the main activity that should define the role of professors. Specialized scientific societies were founded in each discipline. The scientific societies promoted the development of pure science, but many of their members were also involved in projects of applied science. Physiology departed from anatomy and medicine. The new discipline was established by practitioners like Müller and his students along with the French physiologist Francois Magendie and his student Claude Bernard. Research institutes, characterized by bureaucratic organization, were established next to the universities during the last decades of the 19th century. Industries and technological institutes became important consumers of scientific research and then the producers of research (Ben-David 1971: 108 – 127; Turner 1971: especially 155 – 156, 174 – 176, 181; Mendelsohn 1974: 408 – 412).

The strong trend of specialization in the 19th century accelerated the decline of traditional outlooks. Students were encouraged to develop specialized techniques in order to generate, expand and master new fields of knowledge. Since they acquired special techniques and proficiencies, their teachers could not have competed with them. New positions were created for the most promising young researchers in the sub-disciplines that they developed. The young instructors had to compete intensively against each other for promotion and against the full professors for students. Many students detached from their teachers and their research tradition, and sometimes got into conflict with them. As a junior lecturer Reymond consulted Carl Ludwig on how to compete against Müller. Ludwig advised him to perform vivisectional demonstrations during his lectures in order to reveal the crassness of Müller's lectures. Reymond, Ludwig and the young generation were oriented towards specialized research and publication of results. They decried the writing of textbooks and the teaching of basic, general courses. In 1849 Reymond wrote to Ludwig: "I would unconditionally prefer as a teacher the one-sided scholar who is nevertheless outstanding in his subject to the roundly educated man who has never really achieved anything." The division of labor inside Müller's lab enabled Helmholtz and Reymond to develop and master new techniques and expertise. Their unique proficiencies accelerated their detachment from Müller. Specialization had given them advantages over Müller and it eventually enabled them to combat successfully the residues of the teleo-mechanical approach (Lenoir 1989: 276 – 280; McClelland 1980: 151 – 189; Turner 1971: 143 – 144, 180).

During the 1870s and 1880s the relationship between the life sciences and industry became more practical, thanks to the development of textile and dyestuffs industry which was based on organic chemistry. The German academy and the industry worked together and exchanged ideas and products. Combined with powerful new microscopes, the dyestuffs industry changed the biological research. Already during the 1870s the German physician and biologist Paul Ehrlich adopted the approach and techniques of textile dyeing and applied them to living tissues and cells. In his doctoral thesis, which was submitted in 1878, Ehrlich used the fixation of dyes to fibers and fabrics as a model for the fixation of dyes to animal tissues. Through the work of Ehrlich staining agents became tools in the study of the cell and its components and they helped to make in vivo biological measurements. The dyes were used, for example, in experiments on the activity of different cell membranes. Ehrlich discovered that one can compare the sizes of pores in membranes of different cells by the introduction of dye particles: if the molecular size of the dye particles is smaller than the size of the pores, the dye can be introduced into the cell. Ehrlich used the dyes in physiological and pathological studies. To detect physiological combustion, for instance, he used dyes that lose color as a result of reduction and gain color as a result of oxidation (Travis 1989; Ehrlich 1956-1960).

Ehrlich’s theory reduced the body to cells that work according to the principle of the *division of physiological labor*:

> It is undoubtedly a generally accepted and incontrovertible fact that everything which takes place in the body, whether assimilation or dissimilation, is to be attributed, ultimately, to the cell; and, furthermore, that the cells of different organs are differentiated from one another in a specific way, and perform their different functions only by means of this differentiation (Ehrlich 1956-1960 [1909], vol. III: 183).

Following the German physiologist Eduard Pflüger, Ehrlich perceived the protoplasm, or the content of the cell, as “a giant molecule” that consists of independent fragments: “the variously functioning cells have specific and individual internal structures”. The synthetic dyestuffs that the industry produced were more than analytical tools which enabled Ehrlich to study the protoplasm. He used them as models of the functions of the protoplasm. The model of molecules in organic chemistry was based on a molecular core attached to different substituents, “side chains”, or functional groups of atoms, each associated with a certain property, e.g., the derivatives produced by the combination of the central core of benzene rings with different functional groups. Ehrlich was influenced by the theory of the German chemist Otto Witt, who suggested that the dyestuffs contain substituents with separate functions: some substituents are responsible for color-rendering and others are responsible for dye-fixing or adhesion. Accordingly, Ehrlich suggested that physiological combustion in the protoplasm depends on two separate segments, the oxygen-adsorbing segment and the oxygen-consuming segment: first the oxygen combines with the protoplasm at a fixed site (“side chain”), and then the oxygen is released to another site in which a combustion process takes place. In 1909 Ehrlich came to a conclusion that in order to promote the reduction of the *unit* of the cell to the functions of its components, new methods that would overcome the limitations of the microscope must be invented: “Even now the time has come to find a way into the finest chemistry of cell life, and to dissect the inclusive concept of the cell into a large number of single and specific ‘partial functions’” (Travis 1989; Ehrlich 1956-1960 [1885 and 1909], vol. I: 436, vol. III: 183).

The strong trend of specialization appeared in other countries besides Germany. In England, for example, Thomas Huxley, a distinguished Darwinist and a biologist of the second mechanistic phase, greatly promoted professionalism in the new biology. Huxley emphasized that modern science is an integral part of the industrial world. On the one hand, he claimed, scientific discoveries enabled the development of modern industry. On the other hand, industry provides the conditions and infrastructure on which modern science develops. Mechanical skills, and materials such as glass, were developed for industrial ends and became indispensable in science. Research and measuring equipment, like microscopes and telescopes, were made available by industry. Moreover, claimed Huxley, industrial competition encourages scientific education (Huxley 1970 [1887], vol. 1: 54 – 56; Ruse 1996: 205 – 222). As Huxley explains:

> It has become obvious that the interests of science and of industry are identical; that science cannot make a step forward without, sooner or later, opening up new channels for industry, and, on the other hand, that every advance of industry facilitates those experimental investigations, upon which the growth of science depends (Huxley 1970 [1887], vol. 1: 55).

In the American academy structural changes, which took place since the 1860s, enabled the increase in specialization. These developments were based on the model of German Academies, but they were adapted to the English-American tradition. Consequently, new specialties appeared within existing departments, until they could stand on their own legs. For example, in the new academic structure the interests and popularity of subjects and domains among undergraduate students led to a demand for professional teachers and in some cases even to the development of Ph.D. programs in these domains (Ben-David 1971: 139 – 153). At the end of 1880s, the influential director of the Marine Biological Laboratory in Massachusetts, Charles Whitman, stressed that specialization and organization are "companion principles of all progress" and "the most important need of American biology." In fact, claimed Whitman, American biology was falling far behind German biology, largely because American biology was lacking on the subject of specialization and cooperation. He proclaimed that scientists have to adopt the division of labor that characterizes modern society as well as the mature biological body: at the beginning of the process the individuals in society and the individual cells in the body are independent units, but through a progressive development the individuals specialize and cooperate and the result is the formation of a complex social organization (Maienschein 1986: 17).

8

Transformism and the Design of the *Body↔Machines*

Design and *adaptation* are two of the main aspects which appear in the grand metaphoric framework of the *body↔machine*. The following assumptions were derived from this metaphoric framework: (a) the body was designed by an *artificer* (b) the body and its organs are adapted to certain purposes and conditions. I would like to emphasize that all the conflicting views which are described in this chapter - modern religious views and the argument from design, organo-mechanical and proto-mechanical theories of transformism and the ultra-mechanistic theories of transformism - were based on the metaphoric idea that the body is an artifact or a machine. Like all other metaphors and paradigms the mechanistic metaphor suffered from anomalies and limitations. Since the mechanistic metaphor was part of the grand-technological metaphor, it was based on the assumption that the *design* and *adaptation* of machines depend on the purposeful actions of intelligent artificers. In the mechanical religious universe, the mechanistic and teleological views were partially merged, although the conflict between these views was not resolved. Through a gradual and hybrid development from the first to the second mechanistic phase, the artificer himself was assimilated by the mechanistic metaphor, i.e. the Divine Artificer was replaced by an industrial mechanism. Charles Darwin’s theory of natural selection, which was based on the political economy of the industrial society, manifested the growing dominance of the second mechanistic phase. Different social views influenced the way the theory of natural selection was interpreted. Karl Marx and Peter Kropotkin, for example, rejected the capitalist interpretation of Darwin, while Asa Gray wanted to reconcile natural selection with the belief in the Divine Artificer or the Divine Industrialist.

In the organic framework the continuity of species was explained by essence and purpose, i.e. by formal and final causes. Two of the most important authorities on this subject were Aristotle and Galen. According to the Aristotelian view, the essence of the soul and its desires for eternity guarantee that offspring will have the same type of body as their parents and they will belong to the same species. In the Galenic version the continuity of species was guaranteed by the desires of nature for the eternity of her works. Thus living beings are subject to death, but the generation of offspring fulfills the *desires* of the soul/ the *desires* of purposeful nature/ the *will* of God. Moreover, the sterility of hybrids which are produced by the crossing of species was considered to be an expression of the wisdom that protects the continuity of the species. The Aristotelians had passed these dominant views to the early modern age. Although the Aristotelian outlook lost its power during the 17th century, the relative stability of species on the time axis remained the accepted view until the 18th century (Roger 1997: 62 – 73).

In chapter 4, I argued that the shift from the organic universe to the mechanical universe was gradual and it was characterized by hybrid phases. For instance, the hermetic tradition in the Renaissance combined mechanics and applied knowledge with animism, hermetic mysticism, magic and Kabbalah (Yates 1964; 1967). During the 16th and 17th centuries the animistic perception reflected in natural history through the *jokes of nature*. This metaphor attributed to nature artistic skills and creative powers. Nature was perceived as *playing* with its *works* or as *painting* them. Thus the works of nature were perceived as artifacts or as works of art. Unusual natural phenomena, e.g. unusual stones, monsters and even legendary creatures, were highlighted by this approach. Naturalists reported on the existence of "true" zoophytes, such as the Scythian lamb, which had the body of a lamb rooted to the ground by a stem. According to the reports, these lambs ate the grass around them. One of the naturalists who believed in the existence of Scythian lambs argued: "Indeed if Nature playfully brings forth the monk fish, affecting an imitation in the sea, why might she not give birth to a lamb in a row of plants?" Imitation and transformation were considered to be part of the powers of Nature. The German occult philosopher Heinrich Cornelius Agrippa, one of the most distinguished representatives of the hermetic movement, wrote in 1533: "The world is the image of

God, man the image of the world, animals that of man, plant life that of animals, metals that of plant life, and stones that of metals." A few decades later the French surgeon Ambroise Paré wrote in his book *On Monsters and Marvels*: "one sees in rocks and plants effigies of men and other animals, and there is no explanation for them, except to say that Nature is disporting herself (*se ioue*) in her creations." In the previous chapter we saw that Paré promoted the mechanistic approach in pathology, but in this book many types of monstrosities were explained by Paré as a product of theological causes, demons and sorcerers. In the 18th century the *jokes of nature* lost their power: under the influence of the mechanistic approaches, they disappeared from science (Findlen 1990; Paré 1982 [1573]).

According to the organic framework, the universe was created and designed by gods and by essential-teleological forces. In the monotheistic traditions the emergence of living beings on earth was explained as a product of special creations, i.e. as a product of the wisdom of the Divine Artificer who designed and adapted the species to certain purposes and conditions. This metaphorical outlook was also well established in the Greco-Roman philosophy, e.g. Plato's *Demiurge* and Aristotle's *Prime Mover*. In a similar way the argument from design, or the teleological argument, was based on the technological metaphor and on the view that the universe and the body are artifacts or machines. Long before Newton used the famous watchmaker analogy, the Roman philosopher Marcus Cicero (106-43 BC) described the Creator as a clockmaker. According to Cicero, we cannot claim that a clock, or of any other artifact, was designed by accident and not by an artificer, since we identify the complexity and the harmony of the clock's mechanism and its adaptation to a certain purpose (calculating time). In the same way, the harmonious order of the universe proves the existence of the Divine Artificer who designed it. A picture, a statue, a ship, a sundial and a water-clock are the artifacts which Cicero uses in the following passage as manifestations of the grand technological metaphor:

But if all the parts of the universe have been so appointed that they could neither be better adapted for use nor be made more beautiful in appearance, we must investigate whether this is accidental, or whether the condition of the world is such that it certainly could not cohere unless it were controlled by the intelligence of divine providence. If, then, nature's attainments transcend those achieved by human design, and if human skill achieves nothing without the application of reason, we must grant that nature too is not devoid of reason. It can surely not be right to acknowledge as a work of art a statue or a painted picture, or to be convinced from distant observation of a ship's course that its progress is controlled by reason and human skill, or upon examination of the design of a sundial or a water-clock to appreciate that calculation of the time of day is made by skill and not by chance, yet none the less to consider that the universe is devoid of purpose and reason, though it embraces those very skills, and the craftsmen who wield them, and all else beside (Cicero, *The Nature of the Gods*, 1998: 78).

The argument from design, then, was based on the *world↔machine* and the *body↔machine* metaphors. The English Christian apologist William Paley (1743-1805) was one of the most distinguished philosophers who defended this traditional approach between the end of the 18th century and the beginning of the 19th century. The young Charles Darwin was influenced by his writings. The watch allegory serves as the main example of the argument from design in Paley's *Natural Theology*. In the allegory Paley finds a watch on the ground. He asks himself how did the watch reach this place? When he inspects the mechanism of the watch, he identifies the adjustment and harmony between its parts and the purposes which they serve. Thus it "is inevitable; that the watch must have had a maker; that there must have existed, at some time and at some place or other, an artificer or artificers who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use." Paley and the traditional philosophers used the *world↔machine* metaphor to infer the existence of the Divine Artificer: "for every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of nature; with the difference, on the side of nature, of being greater and more, and that in a degree which exceeds all computation" (Paley 1802: especially pages 1 – 4, 14, 19). With regards the design and adaptation of the *body↔machine*, Paley proclaimed that nothing is more *artificial* than the body:

I challenge any man to produce, in the joints and pivots of the most complicated, or the most flexible, machine, that was ever contrived, a construction more artificial, or more evidently artificial than that which is seen in the vertebræ of the *human neck* (Paley 1802: 99).

Nonetheless, already during the second half of the 18th century the argument from design and the idea of special creations became insufficient in the eyes of many scientists and philosophers. For example, two of the most distinguished philosophers of the 18th century, Hume (2003 [1748]; 2007 [1779]) and Kant (2007 [1790]), raised doubts on the validity of the argument from design. Throughout *Dialogues Concerning Natural Religion* Hume undermined the conservative views. Cleanthes, one of the characters in the book who represented the modern theist view, defended the teleological argument in the following way:

> Look round the world: contemplate the whole and every part of it: You will find it to be nothing but one great-machine, subdivided into an infinite number of lesser machines, which again admit of subdivisions to a degree beyond what human senses and faculties can trace and explain. All these various machines, and even their most minute parts, are adjusted to each other with an accuracy, which ravishes into admiration all men, who have ever contemplated them. The curious adapting of means to ends, throughout all nature, resembles exactly, though it much exceeds, the productions of human contrivance; of human design, thought, wisdom, and intelligence (Hume 2007 [1779]: 19).

Hume summarized this position as follows: "The world, says *Cleanthes*, resembles a machine; therefore it is a machine, therefore it arose from design." Nevertheless, Hume tried to expose the weakness of the analogy. When we see a house, we conclude "with the greatest certainty" that an architect or a builder designed or built it, because as members of society we identify a pattern that we have already experienced many times before. Based on our experience, we attribute the same "species of cause" to the same "species of effect". On the other hand, we cannot identify the universe as a house because the house and the universe are dissimilar in many respects. Thus we cannot infer that the universe was created by a similar cause as the house. At best we can speculate that a similar cause created the universe, but this is only one of many possibilities. Hesiod and the ancient mythologists described the creation of the world as a birth of an animal. The Brahmins believe that the world was spun from the bowels of a giant spider. Hume noted that although the cosmology of the Brahmins seems to us ridiculous because spiders are considered to be insignificant, contemptible little animals, in a hypothetical planet which is wholly inhabited by spiders this explanation will be no less convincing than the explanation of Cleanthes which is based on design and intelligence: "Why an orderly system may not be spun from the belly as well as from the brain, it will be difficult for him to give a satisfactory reason." (Hume 2007 [1779]: 21, 56).

- *Progress*, an organizing principle that shaped the transformist and evolutionary views, was a product of industrial society. As we will see below, the idea that species develop, improve and transform from lower to higher forms was closely related to the idea of social progress. In general, the strongest supporters of the transformist idea also believed in social progress: their belief in organic progress and their belief in social progress reinforced one another and it was hard to tell them apart.

In the pre-modern world even the Greeks did not develop a general, metaphysical view of cultural progress, although they were convinced that they are better than the savages around them. The Greeks believed in a decline from a previous golden age or in the cycles of life. Similarly the notion of progress was also alien to Christianity and to the religious traditions in the middle ages. The "Great Chain of Being" was a dominant worldview that preceded and influenced the modern idea of progress although in itself it was not based on progressive movement. The idea of the chain was developed by the Greeks and survived until the modern age. According to this view, living creatures, as well as inanimate matter, were organized by the Creator from the lowest to the highest forms. The hierarchal, chain of living beings was dominant in medieval times. In the Christian tradition, the chain led from the physical to the spiritual. Angels and God above them were at the top of the chain. The world was organized perfectly so that there were no gaps between the species and there was no room for extinction of species. Any potential change was a threat to the order and unity of creation (Lovejoy 1950; Ruse 1996: 19 – 41; Bowler 2003: 62 –66).

The cultural roots of modern evolutionary view are found in the principles of the enlightenment. The idea of progress was an invention of the enlightenment which developed in the 18th century and replaced pre-modern views. Prominent French intellectuals of the enlightenment, such as Anne Turgot, Marquis de Condorcet, Voltaire, Bernard Fontenelle and Auguste Comte, promoted the progressionist view. The meaning of the idea of progress in the age of enlightenment was advancement which is manifested throughout history on the moral, psychic, social and cultural levels. Therefore one cannot reduce the meaning of the concept of *progress* in the enlightenment to a mere technological advancement (Postman 1999; Hopper 1991).

Nevertheless, it is important to emphasize that the progressionist view appeared on the new technological ground of the industrial age. The progressionist mentality broke away from the ancient traditions and it was based on the construction of linear history which is alien to oral cultures. For this reason Carpenter suggests that print culture served as the ground on which the new perception appeared:

…the book was ideally suited for discussing evolution and progress. Both belonged, almost exclusively, to book culture. Like a book, the idea of progress was an abstracting, organizing principle for the interpretation and comprehension of the incredibly complicated record of human experience. The sequence of events was believed to have a direction, to follow a given course along an axis of time; it was held that civilization, like the reader's eye (in J. B. Bury's words), "has moved, is moving, and will move in a desirable direction. Knowledge will advance, and with that advance, reason and decency must increasingly prevail among men." Here we see the three main elements of book lineality: the line, the point moving along that line, and its movement toward a desirable goal (Carpenter 1960: 167).

According to Carpenter, the concept of a definite moment, or a definite point in the present, is probably absent from oral cultures and it can only be found in book dominated cultures. He further notes that individualism and three-dimensional perspective, which are related to the concept of definite moment, were *nourished* and *bred* by print culture and they are absent from oral cultures. The argument of Carpenter relies on the theory he developed together with McLuhan, which defines the differences between the *acoustic space* of oral cultures and the *visual space* of literate cultures. I have reviewed some of the main themes of this theory in chapter 2, but a detailed account of Carpenter's argument is beyond the scope of this work. I'll try to briefly clarify Carpenter's argument on the connection between print culture and the construction of linear history. Preliterate societies "live" in the present. They experience the past in terms of the present. Since preliterate societies do not have records of the past other than memories preserved in an oral medium, they don't tend to recognize the contradictions between their present views and what has been said decades ago. Parts of their cultural heritage, myths and tales which become irrelevant are forgotten or tend to be modified according to the present situation and contemporary social relations. Therefore preliterate societies tend to be more *homeostatic* than literate societies in which a much stronger sense of the differences between the past and the present is enforced by writings, annals, dictionaries etc. (Goody and Watt 1968: 30 – 34; Ong 1982: 41 – 49, 96 – 101). Additionally, we should keep in mind that modern technological environment had contributed in other ways to formation of abstract, linear and continuous axis of time. The perception of time was modified by the clock and especially by the mechanical clock. As McLuhan explains, the identification of time as duration "begins with the division of time, and especially with those subdivisions by which mechanical clocks impose uniform succession on the time sense. As a piece of technology, the clock is a machine that produces uniform seconds, minutes, and hours on an assembly-line pattern." The abstract, uniform units of the mechanical clock helped to create the mechanical universe, and in addition they helped to separate time from the rhythms of human experience and to separate life from seasonal rhythms and recurrence. This process already began in the medieval monasteries, where the abstract, uniform units of the clock rearranged the way of life, work, eating and sleeping (McLuhan 1964: 145 – 156)

There were clear connections between the mechanistic mentality, the industrial revolution and the progressionist view. We can see it, for example, in the approach of Turgot and Condorcet who were the pioneers of the progressionist view. Turgot argued that modern science and technology enable the triumph of good over evil and the improvement of humanity. Condorcet, who was influenced by the view of his friend Turgot, argued that future progress is guaranteed by modern technology and especially by the printing press: print insures the diffusion of knowledge and reason, thus creating social, moral and material improvement (Ruse 1996: 24; Bowler 2003: 5). Fontenelle was a Cartesian mechanist who thought that the universe is a giant watch in which everything "is conducted by regulated movements that depend on the arrangement of the parts". Similarly, Voltaire was committed to the Newtonian approach (Roger 1997: 167, 379, 515 – 529).

Another section of the enlightenment included Voltaire's friend, Diderot, and the entire movement of radical materialism that represented the strong mechanistic outlook. The connection of Diderot to the industrial world was clear: as I've noted before, Diderot's *Pictorial Encyclopedia of Trades and Industry* manifested the importance of mechanical fragmentation and the division of labor to the industrial development. Adam Smith, one of the earliest formulators of the industrial economy, was influenced by the *Encyclopedia* of Diderot and adopted the principle of fragmentation and the division of labor. The idea of progress was part of the ethos of the industrial revolution and Smith's work is a good example of that. Smith believed that progress is driven by the growth of freedom and by rational human agency. In this context he determined that society benefits from the existence of the free market. During the 1760s Smith defined four stages of social progress on the basis of technological development: (a) the age of hunting (b) the age of herding (c) the age of agriculture (d) the age of commerce. Following Smith, Dugald Stewart linked the idea of progress with the values of the free market. Led by Henri Milne-Edwards and afterwards by Charles Darwin, biologists developed the idea of biological progress. Their approach was based on one of the basic principles of the mechanistic order and industrial society, as described by Smith: the principle of the *division of labor* (Diderot 1959 [1763]; Smith 1981[1776]; Ruse 1996: 19 – 41, 158 – 161; Bowler 2003: 48 – 57; Milne-Edwards 1863: 189 – 191; Darwin 1872: 59, 74, 89, 97).

❖ ***Organo-Mechanical and Proto-Mechanical Theories of Adaptation and Transformism***

In the following pages I will try to explain how the science of transformism and adaptation developed in a hybrid and gradual manner, in light of the decline of the organic order and the rise of the mechanistic order. It is noticeable that during the 18th century many organo-mechanical theories and even materialistic theories tried to explain the origin of species and their adaptation to the conditions of the environment. Generally, these theories combined mechanical and organic elements along with religious values and beliefs. In most theories of the 18th century the idea of transformism appeared in a very limited sense, but it became more popular thanks to the principle of progress which characterized the enlightenment. Eventually the great chain of being collapsed and the power of the mechanistic approach increased.

The modern classification of species, which was invented by the eminent Swedish naturalist Carl Linnaeus (1707-1778), was partially based on a religious outlook:

species, according to this worldview, were created according to a divine plan and they continue to exist in the same form in which they were created, except for some recombinant species which might have appeared in the course of time. Linnaeus first published the principles of his method in 1735 and continued the work on the classification of species in the following decades (Linnaeus 1775; Bowler 2003: 48 – 95).

- According to Bowler, Linnaeus "ignored the debate over whether life could be explained in mechanical terms, and sought to revolutionize the life sciences by understanding the pattern of creation" (Bowler 2003: 67). Indeed, on the surface of things Linnaeus did not take a significant part in the debate on the mechanistic view. Nevertheless, I would like to claim that the *visual space* as defined by McLuhan, the mechanistic mentality and print culture had a deep impact on the Linnaean program. Beyond the explicit use of concepts and images, technology has a deep psychological and social impact: perception and mentality are modified, culture and social organization are modified as well, and a new set of hidden assumptions and expectations appear.

Besides the fact that Linnaeus was directly influenced by the science of his age (his work contained direct references to the works of distinguished mechanists, e.g. the works of his friends Boerhaave and Haller), I maintain that Linnaeus's methodology and taxonomy expressed the motivation and principles of the first mechanistic phase. Linnaeus developed a comparative analysis of species which was based on mechanical fragmentation. The aim of the empirical study in the Linnaean program was to (a) define and isolate some *important* characters from the inclusive pattern of the plant or the animal (b) make visual comparisons between the isolated characters of a plant or an animal and the corresponding characters of a plant or an animal from another species. The result was the grouping of species to higher forms of classification: genera, orders and classes (Linnaeus 1775; Foucault 1970: 132 – 145).

The field of events to which I'm referring is the rise of visual space and the dominance of the mechanistic order. I will try, again, to explain it briefly. Phonetic alphabet and the printing press were the ground on which visual space had become dominant: under the stress of the new media, a *split* of sight and sound had occurred and the balance of the senses had been modified. The mentality of industrial society, and its mode of observation, was based on the characteristics of the new media: fragmentation (reductionism and specialization), abstraction, detachment, objectivity and linear thinking. Furthermore, the phonetic alphabet (the starting point of visual space) and the printing press (the point from which visual space became dominant) served as early prototypes of the mechanical-industrial solution (McLuhan 1962; 1964; McLuhan and McLuhan 1988; see also Ong 1982; Ong 1958). In the mechanistic approach, which was represented by Galileo, Descartes and afterwards by John Locke, *primary* qualities were separated from *secondary* qualities. One can find a partial agreement between McLuhan and Foucault on the present subject. Foucault describes the new mode of *observation* that developed in modern science as follows: "Hearsay is excluded, that goes without saying; but so are taste and smell, because their lack of certainty and their variability render impossible any analysis into distinct elements that could be universally acceptable. The sense of touch is very narrowly limited to the designation of a few fairly evident distinctions (such as that between smooth and rough); which leaves sight with an almost exclusive privilege, being the sense by which we perceive extent and establish proof, and, in consequence, the means to an analysis partes extra partes acceptable to everyone". The microscope only reinforced the new trend. Foucault further notes that under the new mode of observation even colors "can scarcely serve as a foundation for useful comparisons" (Foucault 1970: 132 – 133; Galilei 1957 [1623]: 274 – 279; Locke 1849 [1690]: 76 – 82). Colors belong to the sphere of visual sense, but as McLuhan explained, they are associated with tactility and with the interplay between the senses. Thus I would like to note again that visual space is not something that developed from the visual sense per se, but from the modification of the visual sense and its interrelations with the other senses via the characteristics of the phonetic alphabet and print, i.e. via fragmentation, abstraction, linearity etc.[69]

Let us examine how all this is related to Linnaeus. The work of Linnaeus was part of a current that developed at the end of the 17^{th} century by the English naturalist John Ray and by other naturalists. In this context, Bowler himself admits that the mechanical philosophy influenced the development of the new approach of Ray and his colleagues, which was based on the assumption that the only legitimate qualities in the study of nature are the primary-objective qualities of matter (Bowler 2003: 43). Ray did not think that one can decide what the most important characters to the process of classification are. Thus he tried to take into account each visible character of each species, but dealing with infinite number of variables was impractical. The methodology of Linnaeus was much more mechanistic than the methodology of Ray and it was more practical and easy to apply. Through fragmentation and abstraction Linnaeus decided what the most important characters for classification are. The inclusive context had given way to abstract visual fragments. Linnaeus asserted, for instance, that in botany the most important characters for classifying the species are those of the reproductive organs (i.e. the flowering parts) which allow the continuity of the species. The primary-objective qualities, as they were defined in the mechanical philosophy, served Linnaeus and his colleagues in their reductionist program. The Linnaean paradigm was based on four variables: the quantity of the elements, their form, their position in space in relation to each other, and their relative size. As Linnaeus puts it, “All specific distinctions must necessarily be taken from the number, figure, proportion, situation, and connection, of the various parts of plants.” Using the four variables, the structure of each part of the plant can be analyzed: the roots, the stem, the leaves, the flowers and the fruits. In the reproductive organs of the plant, for example, one should examine the existence of pistils and stamens, their number, their form, the shape which determines their positions in the flower (circle, hexagon, triangle), and their size in relation to other organs. In order to assign a plant to class and order one should only count the number of stamens and pistils in the flower. The plant can be further classified into genus and species, according to the structure of these parts (Linnaeus 1775: 104, 112, 251 – 252, 313 – 314, 330 – 331, 364; Bowler 2003: 37 – 95; Foucault 1970: 132 – 145).

Linnaeus emphasized that the examination of other characters, such as size (unlike relative size/proportion), color, smell and taste, “are often fallacious, and not to be dependent upon”. Taste, for example, depends on the person who tastes, and during life the judgment of people regarding taste is modified. Furthermore taste depends on soil and climate. Hence taste cannot serve to distinguish one species from another. The smell of individuals varies even within the same species and is not reliable either. In fact it is the least reliable quality: “Smells admit of no determined limits, nor can they be defined”. Color is another quality which greatly varies within the same species. This phenomenon is clearly manifested in domesticated animals and cultivated plants. Flowers easily mutates in respect to their color. The color of many flowers frequently change from red and blue into white (Linnaeus 1775: 104, 311 – 314).

Let us examine the connection of Linnaeus to the techno-cultural environment of print. The characteristics of the new medium were the ground on which new mentalities and new social situations appeared and the Linnaean program was an integral part of this revolution. First, I think that Linnaeus’s system of analysis and classification owes a great debt to the new mentality which appeared with Peter Ramus and the textbooks of the 16th century. As Ong explains, the characteristics of the new medium created and promoted standardization, abstraction and dichotomy, and a new analytic mentality that leads to systematic classification. In addition, the printed page enabled and encouraged the formation of complex lists and charts (Ong 1982: 117 – 135; Ong 1958). Similar to the other sciences, modern botany took part in the printing revolution, as described by Eisenstein. Print was the ground on which modern scientific communities were established. These communities depended on the conditions which the new environment provided: systematic collection and classification of data, comparative analysis, efficient diffusion of new observations, standardization and the mass and uniform production of journals, textbooks, images, illustrations etc. By the mid 16th century, new schematic illustrations, which were based on technical advances in print, facilitated the efficient classification of the rapidly expanding data pool. Pocket editions of the new guides were prepared for field trips. Print shops in Europe were engaged in a large-scale program of botanical publications. Famous editors received new seeds, specimens, reports and drawings from distant regions (beyond the developments in communication, of course, the geographical range of botanical explorations increased as part of the developments of the Age of Discovery). Uniform texts and images had become available to many readers whose comments and observations helped to revise later editions. If the ancients had described about 600 plants, by 1623 the number grew to 6,000. Modern botanists challenged the authority of the ancients, but more gradually than their colleagues in the field of anatomy (e.g. Vesalius’s critique of Galen). Linnaeus was born in the 18th century deep into the printing revolution. In this respect his work was incorporated into a process which began in the mid 16th century. As part of the trend that began by 16th century book editors, Linnaeus received packages of seeds from members of the reading public who wished to be immortalized in the next volume of his work (Eisenstein 1979: vol.1, 265 – 267, 486 – 487).

So the characteristics of the new environment shaped Linnaeus's mentality and practice. Staffan Muller-Wille and Sara Scharf, demonstrate how Linnaeus gradually developed his technique while dealing with the overload of data. Practically Linnaeus wanted to find a system of organization which will enable him to efficiently retrieve data and incorporate new data into the existing patterns. The solution of Linnaeus was to keep information on particular subjects on separate sheets and as a result he was able to reshuffle the sheets and add new sheets when needed. After a long process of experimentation, the technique which Linnaeus developed resembled a system of index cards. According to Muller-Wille and Scharf, Linnaeus's technique successfully utilized "one of the main cognitive advantages commonly assigned to writing – the possibility to abstract words and statements from their context and rearrange them freely in lists, tables and filing systems". In addition, the rapid and efficient distribution of his printed works "organized and accelerated – just like pumps – the stream of facts constantly pouring from networks of correspondents dispersed all over the world onto an individual naturalist's desk, where it was re-arranged and collated to be released out into the learned world again as printed text" (Muller-Wille and Scharf 2009).

Under the strong influence of print Linnaeus tried to create a spatial-textual metaphor of plants. As part of his program he wished to develop botanical calligrams which would translate the structure of the plant into the printed text or vice versa: according to his view, the printed page in its form, arrangement and magnitudes should copy the structure of the plant. In the Linnaean vision the textual description of the plant on the printed page has to be divided into paragraphs and typographical modules. The number of paragraphs on the page has to correspond to the number of parts in the plant: "A description should delineate the distinct parts of plants in separate paragraphs; the parts of the plant should be printed in Roman characters, and the description in Italics". Additionally the main parts of the plant should be represented by large fonts and their components by small fonts. In this context it is important to emphasize that the concept of *structures* in the new paradigm was based on a certain mode of observation which enabled the naturalists to translate the plant into the printed text: the four variables of Linnaeus defined elements and quantities which can be arranged through a series of linear-textual descriptions. The French naturalist Michel Adanson had even hoped that botany will eventually become a mathematical science (Linnaeus 1775: 270, 340 – 341, 364 – 368; Foucault 1970: 135 – 136).

In conclusion natural history as constructed by Linnaeus and his colleagues was part of the first mechanistic phase and the classification of living beings became part of the mechanical universe which was designed as a clock by God. The mechanical methodology of Linnaeus and his colleagues prevailed and the great chain of being began to collapse or at least to take a mechanical form. Once again we encounter a scientist who apparently was not influenced by the mechanistic perception, and yet in practice implicitly adopted and promoted the mechanistic order. Linnaeus, then, is another great contributor to the mechanistic interpretation of life, although he is not officially labeled as a mechanist.

Most naturalists of the 18th century were willing to accept the idea of transformism only in a very limited sense. Ray and other naturalists asserted that local conditions produce local varieties from the original form of the species, but these were considered to be only minor and reversible modifications and not part of a mechanism which produces new species. Moreover, although Ray was familiar with the geological evidence he refused to believe that a caring God would let the species he had created to become extinct by catastrophes. At the last decade of the 17th century he suggested that the fossils of unknown living beings represent species which still live in unexplored regions of the globe. Later he accepted the idea of the Welsh naturalist Edward Lhwyd that fossils are only seeds which grew within rocks. Linnaeus, on the other hand, did not reject the possibility that local varieties may become a new species. Furthermore, Linnaeus thought of another mechanism which can generate new species: he suggested that the interbreeding of plants from different species may sometimes produce a new hybrid species which combines the characters of the parent species (an idea which is very well established in the science of evolution today). His ideas on transmutations and hybridizations did not receive much attention. In any case, Foucault emphasizes that the ideas of Linnaeus and his colleagues were far from the modern evolutionist idea. Their system allowed the appearance of small modifications in the nature of species, but these modifications did not deviate from the pre-existing patterns, as defined in the divine plan. New characters did not appear in the hybrid species, but only a recombination of pre-existing characters. In fact, the hybrid species in the Linnaean system were nothing more than intermediate stages of the parent species. For Linnaeus an open process of modifications and evolution was inconceivable. In other words, the pattern of relationships that united the species remained intact. Moreover, the approach of Linnaeus and his colleagues was part of 18th century enlightenment which was biased towards classification rather than explanation: instead of developing explanatory mechanisms, they wished to discover a classification system that corresponds to the real structure of the world. Foucault describes the existence of a sharp epistemic break between the 18th and the 19th centuries. In his opinion, the mentality and the socio-cultural values of the 18th century prevented the development of the evolutionist approach. Indeed, one can identify a huge shift between the 18th and the 19th centuries. Nevertheless, we will see that the development of the evolutionist approach was more gradual and hybrid. A clear progression towards an open process of transformism (which was not based on a divine plan or on a static view of nature) can be found in the work of 18th century radical materialists (Bowler 2003: 37 – 49, 69 – 70; Foucault 1970: 125 – 165).

With the rediscovery of Greek and Roman philosophy, and its revival via print culture, the Epicurean idea on the origin of life was retrieved. Modern mechanists were influenced by the ideas of the atomists and especially by the ideas of the Roman poet and philosopher Lucretius who coined the prevalent *world↔machine* metaphor. The Epicurean universe and the Epicurean idea on the origin of life were manifested in Lucretius' work. In his great poem, *De Rerum Natura* (Lucretius, *De Rerum Natura*, 2008: 189 – 250), which was written in the 1st century BC, Lucretius explained how random movement and chance combination of atoms created many worlds and how living creatures were generated from the earth under the influence of the sun and rain. Yet, according to Lucretius, every world and every object may eventually dissociate into the atoms which compose it. In the same way many types of animals became extinct because they were born without essential organs or because they were unsuccessful:

Time changes the world, and one state of things declines into another. Nothing remains as it was. Nature compels us all to adapt and adjust. One thing grows weak and something new appears, some upstart to take its place. This also describes what happened to the earth itself as it aged and could no longer bring forth new life as it use to do. Along the way there were many curious trials that did not quite work out, or were wonders, or some would call them portents: hermaphrodites, for example, that were equal part women and men; or some who were born without feet or without fingers and hands; some did not have mouths; and some were without any eyes. Some had all their limbs, but bound to their trunks and useless. None of these monsters, or call them rather false starts, could grow or feed themselves, or live to reproduce, all of which are required for a species to carry on and survive through the generations with seeds that renew their kind. Some of course could manage to grow and produce young, but nevertheless they perished, lacking either in courage or cunning or speed that would have protected them or helped them feed on the breath of life (Lucretius, *De Rerum Natura*, 2008: 222 – 223).

The manuscript of the poem was rediscovered in 1417 and it was distributed in many printed editions and translations since 1486. Some scholars Christianized the Epicurean account. Descartes, who rejected the atomistic view, was among those who retrieved the ancient idea of Lucretius, but he did not develop this “fable” much further (Wilson 2006: 377 – 378). The atomistic explanation echoed in the theories of 18th century intellectuals, and as we will see below, the Epicurean ideas, on the material origin of life and the disappearance of different types of animals as a result of monstrosities and other disadvantages, were retrieved on a new ground by the mechanistic and materialistic approaches.

Theories of organic transformism appeared around the mid 18th century. The spirit of the mechanical sciences undermined the miracle framework of creation and consequently alternative solutions were suggested. In 1748, the *Telliamed*, a famous work of the French intellectual Benoît de Maillet, was published posthumously and promoted the idea of transformism. His work was encouraged by Fontenelle (the Cartesian mechanist, who believed in the idea of progress and perceived the universe as a giant watch), but the publication of the work was delayed due to its blasphemous content. According to the theory of de Maillet, pre-existing seeds are scattered throughout the universe and on earth. De Maillet postulated that the matter in the universe, including the seeds of life, always existed, although at least formally he did not entirely reject the possibility that the seeds were formed by an act of creation.

With Regards to this issue, de Maillet, and La Mettrie after him, retrieved the old idea of Lucretius and Epicureanism. The theory of de Maillet also postulated that the seeds adapted to the conditions in their new habitats, but he had no mechanistic explanation for the formation and development of the seeds. The ancient ocean might have been a suitable place for the seeds to develop in the absence of parents and wombs. Earth was covered with water and thus the first living beings of each species were aquatic. How did terrestrial species appear? According to de Maillet, the composition of water and air is not so different. The air on the land is mixed with water particles, and water itself contains air. In certain climates and seasons the air above the sea and above the land is an equal mixture of air and water. Aquatic animals can be easily adapted to the very moist air. Consequently terrestrial species began to appear as modified forms of aquatic ancestors. Birds, for example, evolved from flying fish. In some cases animals living in a dry lake "have been forced to accustom themselves to live upon land". Relying on testimonies of sailors who saw mermaids, de Maillet thought that the sea-men, the aquatic ancestors of the human species, still exist and are still being transformed into humans. De Maillet accepted transformism in a very limited sense. He believed that terrestrial and aerial animals kept the basic form of their aquatic ancestors and the transmutation of each marine species was minimal. Thus changes of conditions in water, earth, air and climate serve as a trigger for the expression of pre-existing patterns within the living beings: the transformation of flying fish into birds resembles the transformation of a caterpillar into a fly or the appearance of wings on the body of ants. De Maillet believed the reports on the existence of different species of man, including men with tails, but he did not think that all the species of men were derived from the same origin, nor did he believe that the transformed species can further evolve. He also rejected the possibility that blacks and whites belong to the same species or derived from the same origin (Maillet 1750: 216 – 284; Bowler 2003: 72 – 73; Roger 1997: 420; Foucault 1970: 153).

The Swiss naturalist Charles Bonnet was a leading figure among 18th century naturalists. Influenced by Leibniz, he thought that the living body is a mechanical automaton which was pre-designed by the Divine Artificer. Leibniz, Bonnet and the majority of scientists and scholars of the first mechanistic phase did not believe that the mechanical laws of nature can account for the organization and generation of the *body↔machine*. Their solution was based on the organo-mechanical theory of pre-existence, which was the leading theory of generation until the late decades of the 18th century. Pre-existence theory determined that the universe and the body are machines which work according to mechanical laws. Although mechanical and chemical laws can explain how the *body↔machine* works, these laws alone cannot explain the purposeful design and the generation of the organized machine. Thus, according to pre-existence, all living beings were already created by God at the beginning of the universe as pre-existing germs which were planted in the first living beings from each species. Yet, pre-existence was also committed to the idea that nature works in a mechanical way. Therefore, according to this theory, the germs develop to an adult form through the mechanical laws of the universe, i.e. through a process of mechanical enlargement and unfolding of the organized rudiments of the *body↔machine* (Duchesneau 2006; Roger 1997).

The belief in the great chain of being was a consensus in the 18th century. In 1764 Bonnet proposed his own model of the chain. He emphasized that the species are perfectly preserved as they were created by God, although parental and environmental influences produce variations among individuals. Bonnet and many conservative Christian naturalists believed that in a single event God created and planted in living creatures the pre-existing germs. They saw the germs as miniature versions of adult creatures from the same species. According to this view, the continuation of the species is assured, since future generations come from pre-existing germs through the process of reproduction. Bonnet contributed to the confirmation of pre-existence. He found that aphid females can generate offspring during several generations without the donation of males (parthenogenesis). Towards the end of his career Bonnet adopted a modified view of the chain, according to which the germs of some species were created during the early history of earth, although they probably did not develop into mature bodies at this early stage. In other words, Bonnet advanced the temporalization of the chain by claiming that simpler species appeared before the higher forms in the chain. In doing so he responded to the geological evidence regarding the history of the earth and the appearance of species in different geological epochs. Moreover, Bonnet believed that the effects of the seminal fluid on the pre-existing germ, as well as the effects of climate and nourishment, contributed to the rise of new varieties and intermediary individuals. Nevertheless he was still under the influence of the mode of thinking which characterized the 18th century, and thus he did not adopt evolutionism in its modern sense, i.e. the belief in an open process of transformism in which different species evolve independently. According to Bonnet's theory, the entire chain of being advances towards perfection, i.e. towards God. Furthermore, all the species in the chain of hold their position in relation to each other. As Foucault describes it, transformism in the theory of Bonnet was "nothing more than the interdependent and general displacement of the whole scale from the first of its elements to the last" (Bowler 2003: 48 – 95; Roger 1997: 505; Foucault 1970: 150 – 152).

The work of the eminent French naturalist Georges Buffon (1707-1788) marked the way for the materialistic outlook in the study of transformism and adaptation of species. Buffon promoted the proto-mechanical theory of degeneration which became popular during the second half of the 18th century. The theory of degeneration only slightly broke away from the *static* view of species. Did the progress idea of the enlightenment have an impact on Buffon view? According to Ruse, Buffon was part of the old establishment and a rival to Condorcet, Turgot and the progressionists in general (Ruse 1996: 51 – 52). Yet, Buffon adopted the modern myth of the "state of nature" from which mankind developed. This view, which Hobbes and Locke promoted during the 17th century, influenced the development of the progress idea. According to the description of Buffon, which appeared in the supplementary volume (from 1778) of his *Natural History*, the earliest humans struggled to survive in the harsh conditions of nature: "Naked in mind as well as in body, exposed to the injuries of every element, victims of the rapacity of ferocious animals, which they were unable to combat, penetrated with the common sentiment of terror…" These conditions eventually forced them to socialize, in order to protect themselves by their large number and to enjoy the benefits of mutual aid which encouraged the building of shelters and the development of weapons and human art (Bowler 2003: 56 – 57).

The foundations of the new geological science in the late 18th century provided new empirical evidence regarding the history of the earth. Buffon, who associated with the radical materialists, had presented an alternative to the biblical story of creation and therefore the Church confronted him. The new timescale of earth history was dramatically expanded in comparison with the biblical timescale and Buffon and the radical thinkers were astounded by it. According to the first volume of Buffon's

Natural History (from 1749), the earth was cooling from its molten state for a period of seventy thousand years. Additionally, Buffon did not find evidence for the biblical flood. The Church censored Buffon's work and Buffon had to formally renounce his estimations. Thirty years later Buffon was able to publish again his theory. This time he divided the history of the earth into seven epochs as a reference to the seven days of creation. Yet Buffon rejected the attempt to give "a physical explanation" to "theological truths". He emphasized that natural history has to be separated from the sacred writings. For example, the English theologian and mathematician William Whiston tried to reconcile the history of earth with the deluge and the story of Noah's ark, as they appear in the sacred writings. In his critique of Whiston's theory Buffon claimed that such an attempt is always involved with obscurity and absurdities. Indeed, during the second half of the 18th century, the new timescales of geology pushed aside the biblical story and timescale. After a great controversy most naturalists accepted fossils as the remains of living creatures, and suggestions were already made that some fossils may represent extinct species. But the systemic use of the fossil record in the reconstruction of the history of life remained to 19th century paleontologists (Bowler 2003: 56 - 58; Buffon 1791: 97 – 132).

In the first volume of Natural *History*, Buffon rejected the system of Linnaeus and the grouping of species to higher forms of classification, which he thought to be abstract and not real categories. Alternatively, he thought that species are defined and maintained by reproduction. Buffon was motivated to account for life in material–Newtonian terms only. Therefore pre-existence was not considered by him as a legitimate explanation. He adopted the theory of epigenesis which during the second half of the 18th century became more accepted than the theory of pre-existence. But Buffon could not have explained how exactly the organic particles from the semen arrange themselves into the complex structure of the embryo. Buffon postulated that each species has an "internal mould" that directs the particles to their place in the body, but the inability to account for the internal mould in mechanical terms was a significant disadvantage for his materialistic program. In Buffon's metaphor, external matter filled the container of the internal mould, as bronze filled the smelter's mould through the action of weight. However, the exact mechanical forces that direct the organic matter remained unknown. In 1766 Buffon came to a conclusion that some of the related species in the classification system of Linnaeus have common ancestors:

the Linnaean genus, or family in modern terminology, contains species which were diverged from an original population. According to his proto-mechanical theory of degeneration, the original population of ancestral cats, for example, was divided into separate groups which migrated to different geographical areas. Under the influence of different climates, and especially through the qualities of organic particles taken up as food, each group was modified and deviated from the original form of the species. In addition, new species also appeared as a result of artificial selection and domestication. Dogs, for instance, belong to the same genus which includes foxes, wolves, jackals and coyotes: the ancestors of dogs degenerated under domestic conditions, and since dogs can unite with both wolves and foxes they are probably an intermediate species. Buffon now saw the genus as the true species with a unique internal mould. He claimed that the formation of hybrids between different species of the same genus confirms this assertion. In other words, he still believed in the idea of fixed species which can only slightly deviate from their internal mould. Buffon used the old idea of spontaneous generation in order to explain the appearance of the genus without a reference to a divine creation. He tried to confirm that simple life forms are spontaneously generated from organic particles. He then asserted that at earlier periods even higher forms of life were spontaneously generated. The first living creatures were formed in a hot environment and eventually they became extinct when the earth cooled. In a later period spontaneous generation produced the ancestors of the present species (Buffon 1792: 1 – 26; Buffon 1785: 16 – 54; Bowler 2003: 75 – 80; Roger 1997: 426 – 474).

Radical theories of transformism which, to some degree, anticipated some of the aspects of the mechanistic theory of evolution appeared already in the mid 18th century. In *The Earthly Venus* which was published in 1745 (Maupertuis 1966 [1745]), and in later writings, the French mathematician and intellectual Pierre Maupertuis developed one of the earlier theories of mechanical transformism. Maupertuis was a leading exponent of the Newtonian worldview who formulated the principle of least action (to a large extent, this principle was kind of an expression of mechanical teleology in physics). He associated with scholars like Buffon, La Mettrie, Diderot and Kant. Frederick the Great appointed him president of the Prussian Academy of Sciences. Similar to Buffon, his ideas were not based on pre-existence, but on the rival theory of epigenesis. I would like to emphasize that the gradual increase in the power of the mechanistic perception was evident in both paradigms, and yet pre-existence did not break away from the framework of miracle creations that accounted for the design and organization of the *body↔machine*, while Maupertuis had to assume that beyond the known forces of Newtonian mechanics matter has the ability to spontaneously organize itself into complex structures. According to Maupertuis, the idea that infinite generations of animals were formed at once within the body of the first member of the species did not solve the problem of generation, but only made it "more remote". In addition, pre-existence did not coincide with Harvey's observations of the formation of the embryo and it was not able to explain the contribution of both the male and the female to the characters of the offspring, as can be seen clearly, for example, in the mulatto person who is an offspring of a black parent and a white parent or in hybrid animals such as the mule. Alternatively, Maupertuis suggested studying how the embryo is generated from the mixture of male and female seminal fluids, in the spirit of Descartes who tried to solve this problem through the laws of motion and fermentation. Nonetheless, as most intellectuals from the first mechanistic phase, Maupertuis did not believe that the generation and organization of the *body↔machine* can be reduced to the same mechanical laws which govern the movement of atoms. He speculated that in each of the seminal seeds there are particles which are predetermined to form different body parts and each of them has a "special attraction" to the particles "which are to be their immediate neighbors in the animal body." In *System de la Nature* he admitted that he can explain this subject "only by analogy" to notions like *intelligence*, *desire*, *aversion*, *memory* and *instinct*. According to this metaphor, each particle in the male and female's seminal fluid remembers its place in the arrangement of the adult body and it will try return to the same place in the fetus (Maupertuis 1966 [1745]: especially 40 – 44, 51 – 58; Bowler 2003: 73 - 75; Zammito 2006: 322 – 336).

I believe that the clear distinction between mechanism and vitalism is completely blurred when we examine a scientist like Maupertuis. Although the above mentioned forces may be defined as vital forces, Maupertuis was committed to the mechanistic program in the life sciences and he was one of the first intellectuals who developed the idea of mechanical transformism. Maupertuis argued that nature is characterized by degrees of self organization which are found even in inanimate matter and in the process of crystallization. He identified an increase in self organizing capabilities, which leads from crystals, through plants, to animals and humans. In addition, he postulated that modifications and malformations, such as the appearance of a sixth finger on the hand, might occur during the process of reproduction and be transmitted to future generations. The second part of *The Earthly Venus* begins with a discussion on the aesthetical differences between the races of man. Maupertuis points out that the large differences between the “regular” features of the white races, the “ugly features” of the black races, and the features of “extreme types of the human species” (e.g. the Lapps and the Patagonian giants), made people wonder whether or not they belong to the same species. According to the theory of Maupertuis, the human races evolved over generations by accidental modifications which were transmitted through the male and female seeds. The seminal fluid of each individual contains parts suitable for the formation of characters which resemble the characters of the individual. These parts have a strong affinity for one another and their number in the seminal fluid is greater than the number of dissimilar parts which can generate different characters than those of the individual. Chance combination may result in the unification of regular and dissimilar parts and thus the characters of the offspring will be different from the characters of the parents. Yet in most cases “the original species will regain its strength” in a few generations or even in the next generation. Maupertuis added that “In order to create species from races that become established, it is really necessary to have the same types unite for several generations.” He speculated that climate and external conditions can also produce changes in bodily characters which are transmitted to successive generations. Thus, the dark skin of some races can be either the result of accidental modifications in the process of reproduction or else the product of climate conditions. Geological catastrophes can especially produce new combination of elements and thus lead to the production of new animals and plants. The mechanism of chance combination was based on the Epicurean idea and in a narrow sense it anticipated the mechanism of natural selection. Actually the survival of new forms of life in the theory of Maupertuis depended on their “aptness”: the majority of individuals which were blindly produced by chance combination did not survive because they were not arranged properly and could not satisfy their needs (e.g. animals without mouths or reproductive organs), but the species which exist today survived because they are properly arranged. The characters of properly arranged bodies are preserved by memory, until the arrangement of particles is modified by chance and a new species is formed. In 1751 Maupertuis extended his theory to the early days of earth: he suggested that when earth was covered with water, active particles of matter organized and formed the first living bodies, which might be the common ancestors of species that exist at the present era (Maupertuis 1966 [1745]: 63 – 84; Bowler 2003: 73 – 75; Zammito 2006; Foucault 1970: 153 – 154).

The mechanistic motivation of the materialists in the age of enlightenment was evident and new alternatives to the argument from design were on the rise. In the mid 18th century, radical materialists, e.g. Diderot and La Mettrie, ridiculed the argument from design. In *Man a Machine*, La Mettrie presented the view of 18th century atheists and materialists. He explained that the alternative to the idea of Creator is not the creation of the universe and the living creatures by chance, but by the mechanical laws of nature (La Mettrie 1961 [1748]: 122 – 128, 145). La Mettrie put humans and animals on the same scale. In this view, both humans and animals are the result of the same natural law which is based on the principle of motion of organic matter. The transition from animal to man is not "violent": man is just the most perfect example of the natural law, and he only has a few more wheels and a few more springs in comparison with the most perfect animals. Similarly the flute player that Vaucanson designed is more complicated than the duck he designed. La Mettrie speculated that if we improve our mechanical skill even further, like Vaucanson did, we could probably make a talking, mechanical man. He thought that this is not an impossible task (La Mettrie 1961 [1748]: 100 – 104, 128, 135, 140 – 141, 146). The conclusion of La Mettrie was clear:

> [Man] is to the ape, and to the most intelligent animals, as the planetary pendulum of Huyghens is to a watch of Julien Leroy (La Mettrie 1961 [1748]: 140).

The radical materialists (La Mettrie, Diderot and d'Holbach etc.) were not expert naturalists, but at least philosophically and theoretically they were the avant-garde which marked the mechanistic way. In *Letter on the Blind*, which was published anonymously in 1749, Diderot attacked the argument from design through the character of a blind mathematician, Nicholas Saunderson. There is no need to invoke an intelligent creator, claimed Saunderson, in order to explain the perfect design of the *body↔machine*. In a similar way, people are unable to understand how a blind man like himself learned geometry. Due to the ignorance of people, they tend to refer to miracles and to "the work of God" when they don't understand how nature works. In the same year of the publication of the work the French Government was facing a crisis and used a heavy hand against subversive elements, including atheists like Diderot. Diderot was arrested and imprisoned for several months due to the publication of *Letter on the Blind* and some other works (Furbank 1992: 47 – 64). D'Holbach rejected the argument from design in the same way as Diderot and blamed human ignorance. First, he claimed, we judge nature or the machine of the universe anthropomorphically: since we produce complex artifacts by the use of our intelligence, we also incorrectly tend to assume that the things which impress us in nature are produced by an intelligent agency and not by nature itself. However this tendency results from our ignorance. We know as little about the production of Newton's head as we know about the production of a stone in nature. Secondly, if a savage who has no knowledge about human artifacts sees the moving mechanism of a watch, he may incorrectly conclude that it is an animal and not a human artifact. The Native Americans, for example, regarded the Spaniards as Gods because of their use of gunpowder, horseback riding, etc. When the inhabitants of the island Tenian saw fire for the first time, after the arrival of the Europeans, they thought it is an animal that devours wood (D'Holbach 1836 [1770]: 233 – 234).

The transformist view of the radical materialists is a clear example that deviates from the description of Foucault regarding the sharp epistemic break between the 18th and the 19th centuries. The materialists were indeed more radical than Buffon in their view of nature: they did not believe in the existence of preordained forms of life, an idea which was a residue of the traditional belief in teleological deign and divine creation. Yet we can easily trace traditional elements in their view. Like Buffon, the radical materialists believed in spontaneous generation of life from matter. La Mettrie, for example, was influenced by the discovery of the Swiss naturalist Abraham Trembley regarding the ability of freshwater hydras (polyps) to regenerate two bodies when one body is cut in half. In his writings from the mid 18th century La Mettrie suggested that the first germs of life, including the seeds of men, were formed in the air. Similar to the monstrosities which we see today, the first seeds of animals and men were imperfect, but after a long time, and an infinite number of combinations, animals were produced more perfectly. La Mettrie was also influenced by the ideas of de Maillet and Lucretius on the development of the first “human eggs”: according to this hypothesis, the first human eggs were nourished on plants or on the milk of animals which adopted them. The survival of only one human pair is all that was needed for the success of the species. Moreover, not a single element in the generation and development of life was considered by La Mettrie as teleological. All the occurrences were rather bound by the blindness and determinism of the laws of nature. In 1746 Diderot accepted the argument from design and the theory of germs, but later he adopted an extreme form of materialism. Under the influence of La Mettrie he claimed that the mind is a by-product of the body. He then rejected the argument from design and retrieved materialistic ideas from ancient Greece concerning the origin of species. Living creatures, according to this view, were spontaneously generated at the ancient history of earth, but not according to a divine plan, and thus most of them were deficient and eventually they died out. Occasionally some living creatures were generated by chance with all the essential organs and thus they were able to survive and reproduce. Diderot, then, adopted a proto-mechanistic idea which was based on a natural process of trial and error. In a very narrow sense, this idea anticipated the mechanism of natural selection. However, Diderot’s theory was not based on the transmutation of species, but on the traditional idea of spontaneous generation. Later, after reading Buffon, he came to think that if matter can be organized without a plan (not even Buffon’s internal mould), then the species are not necessarily fixed: under the conditions of need, animals may acquire new traits and new organs and the new characters may be inherited by their offspring. Diderot saw in the production of monstrosities an evidence for the production of new forms and a conformation to the idea that the universe is not constrained by preordained forms. The radical materialists overtly challenged the traditional worldview. From among them, Baron d’Holbach was the most radical and his book, *The System of Nature*, was the manifest of atheist philosophy. D’Holbach rejected the idea of divine creation and teleological design. He explained the spontaneous generation of life (the ancient idea which the radical materialists did accept) by postulating affinities that dictate the combinations of matter: in the active material universe new combinations may appear, according to the affinities of matter and under the right conditions (Bowler 2003: 81 – 84; Roger 1997: 397 – 399; D’Holbach 1836 [1770]; see also Crocker 1968).

- In conclusion, the radical materialists in mid 18th century France were among the most devoted mechanists of the first phase. They aspired to develop a complete mechanistic account of life. Yet, while they were trying to explain the formation of life, they encountered a perceptual and a conceptual block. Seemingly, the *body↔machine* metaphor implied that the body was designed in a purposeful manner by an artificer. The solution of the materialists was based on a rear view mirror: they sneaked animism through the back door, discussed it in mechanistic terms and developed a materialistic version of animism.

In this respect, the explanations of 18th century radical materialists for the formation of the *body↔machine* were often concluded with attributing the properties of life to matter itself: matter became alive and as a result of its activity spontaneous generations appeared. Maupertuis, La Mettrie and Diderot attributed a "dull" sensitivity to matter. As Maupertuis claimed, for example, the uniform, blind law of gravitation cannot explain the arrangement of parts in the living body. His solution to this problem was based on a principle of sensitivity which was ascribed to organic matter: the living elements comprising the embryo have similar properties to desire, aversion and memory which enable them to find their place in the developing body (Bowler 2003: 54, 81 – 84; Roger 1997: 390 – 392; Foucault 1970: 153 – 154).

The theory of transformism was in the air in 18th century Germany, although the idea that life originated strictly by mechanical laws was generally rejected. For instance, Kant suspected that due to the homology between living beings there is a common origin or even a common ancestor to all living beings, from polyp to man. Yet, he rejected the idea that life appeared and evolved by means of mechanical transmutation:

> For to suppose that crude matter, obeying mechanical laws, was originally its own architect, that life could have sprung up from the nature of what is void of life, and matter have spontaneously adopted the form of a self-maintaining purposiveness, he [Blumenbach] justly declares to be contrary to reason (Kant 2007 [1790]: 253).

The teleological integrity of the body prevented one species from transforming to another species. Kant's rejection of the radical mechanistic approaches to the question of the origin of life was motivated by traditional values: the belief in divine origin of the universal order, as well as the belief in the nature of the self which is directed by free will, protected morality, religion and the foundations of society from civil disorder and personal libertinage. On the other hand, Kant had to deal with the scientific developments in the fields of geology, natural history and comparative anatomy and he was influenced of course by the intellectuals who promoted the idea of transformism and/or the mechanistic mentality, e.g. Descartes, Newton, Maupertuis, de Maillet, Buffon and Erasmus Darwin. Kant adopted the mechanistic explanation for the formation of the universe. According to Kant, the Newtonian forces of attraction and repulsion produced the orderly physical universe from a state of chaos. In the dynamics of the universe, suns explode and planets eventually crush into their suns. Similarly, plants and animals die out and reproduce every day, they become extinct by catastrophes and thrive again in other regions which previously were covered by water. Already in 1735 humans and apes were placed in the same genus by Linnaeus. In 1771 Kant reviewed a book by Peter Moscati on the upright posture. He tended to agree with the author that humans developed from the quadruped, i.e. from an animal state, to the bipedal state. This transformation occurred within the species and it was followed by the development of reason and culture. Influenced by the theory of Buffon, Kant thought that the black, brown and yellow races may have developed from the white race, but he revolted against the idea of transmutation from one species to another, especially if it implied a common descent of humans and animals. Nevertheless, over time he had adopted a more moderate view. Probably following Bonnet, Kant even suggested that in a future revolution of nature chimpanzees or orangutans may be perfected in their organs and thus become closer to humans and develop a social culture. In his later writings Kant considered the possibility that many species diverged from basic common schemas. His ideas resembled those of de Maillet, although they were probably nothing more than a hypothetical suggestion. In practice Kant was not one of the main supporters of the transformist theory (Wilson 2006; Lovejoy 1968).[70]

When his student, the philosopher Johann Herder, developed a transformist theory during the last decades of the 18th century, Kant rejected the theory for being a product of creative imagination and for being too vitalistic. Herder hypothesized that the earth and the planets developed out of nebular chaos and according to universal laws. Afterwards, plants and animals were created in suitable habitats: according to the hypothesis, vital powers, or "the fingers of God", had created the basic forms of the species and drove them to evolve in a progressive manner and to become more complex, although many species did not survive the harsh conditions of the early days which included numerous active volcanoes. Finally, the age of creation had passed, and since then improvements can be made by the vital powers only within the limits of species. Herder believed in a religious cosmology in which all was intended to serve and to lead to the creation of mankind (Richards 2000: 21 – 23).

Towards the end of the 18th century the interest in transformism increased. From Blumenbach on transformism became part of the teleo-mechanical framework. As the father of teleo-mechanism and one of the founders of the racial science, Blumenbach was one of the most influential scientists of his time. The issue of race played an important role in the life sciences of the colonial age, especially in relation to the transformist theory. Let us then examine the techno-cultural aspects of Blumenbach's transformist theory in relation to the teleo-mechanical approach and the racial science. Blumenbach published the first edition of his well known treatise *On the Natural Variety [Varieties] of Mankind* in 1775. His theory was based on the idea that the body is a unique machine which is organized and regulated by the *formative force*, i.e. by the unification of the mechanical and the teleological. Blumenbach argued that on certain conditions the formative force may deviate "from its determined direction and plan" in three ways: (a) by the production of monsters / abnormal characters due to malfunctions of the force or due to external disturbances such as pressure, (b) by hybrid generation, i.e. by the mixture of genital liquids from different species and (c) by degeneration of the species into varieties due to the conditions of life (Blumenbach 1865 [1795]: 193 – 195, 208).

Blumenbach was one of the many supporters of the proto-mechanical theory of degeneration. He claimed that races appear as deviations from the original form of the species due to migration and changes in the conditions of life. Climate, nutrition and the mode of life (e.g., cultivation and habits in domesticated animals), produce bodily changes. When the cause is continuous the impact is stronger and its effects may last for many generations. Climate is the main factor which can cause the appearance of degeneration, especially with regards to warm-blooded animals. The air itself, noted Blumenbach, is not a simple element as was once thought, but a mixture of elements and qualities like gasiform constituents, light, heat and electricity. Climate and air are varied and they produce different effects on the body. Blumenbach perceived the lungs as a "living laboratory" in which air is decomposed into elements. These elements which circulate throughout the body may modify different parts of the body, as demonstrated and confirmed by the advances in chemistry and physiology. According to Blumenbach, the effects of climate are clearly evident in the color of many species: animals from the same species have a white color in the northern regions, while in the temperate zone they have other colors, e.g., wolves, hares and falcons. The white color is an effect of cold and the best evidence for this are animals that during winter change their summer color into white or grey, e.g. weasels, hares, squirrels and reindeer. Similarly, diet may produce variations in species. The quality of food, for instance, affects the color of animals: when larks and finches are only fed with hemp seeds, they grow black; when African sheep are transported to England, their diet changes and as a result the texture of their hair also changes. The third cause is the mode of life which includes factors beyond climate and diet. Blumenbach mainly referred to cultivation and custom: according to his analysis, their impact is clearly evident in domestic animals which degenerated from wild animals (Blumenbach 1865 [1795]: 196 – 200).

Blumenbach declared that in dividing mankind into varieties or species we should follow the Newtonian rules of reasoning in philosophy - the vera causa principle and the principle of assigning the same causes to the same effects. Using comparisons of the structure of the skull and face, and other bodily characters such as skin and hair color, Blumenbach divided the human species into five principal races: the Caucasian ("the most handsome" race), the Mongolian, the Ethiopian, the American and the Malay. Each race can be further divided into sub races. Although many Europeans, like Voltaire, refused to see themselves and the Africans as members of the same species, Blumenbach clarified that scientifically and physiologically all races belong to the same species. Blumenbach had reservations concerning radical racism and unlike many other scientists and scholars in the modern age he was careful not to ascribe intellectual supremacy to the Caucasian race. Still, he regarded the Caucasian race as the primeval race from which all other races were originated. On one direction the Caucasian race degenerated into the Ethiopian race and on the other direction into the Mongolian race. The Malay race stands between the Caucasian race and the Ethiopian race, and the American race stands between the Caucasian race and the Mongolian race. Blumenbach consciously relied on Western standards of aesthetics and beauty ("our opinion of symmetry") and concluded that the Caucasian race is the "most handsome and becoming" of all races. The other races seemed to him as aesthetically deformed varieties of the original stock. He hypothesized that the Caucasus was probably the birthplace of mankind. The conditions of this region produced "the most beautiful race of men" and the "most beautiful form of the skull, from which, as from a mean and primeval type, the other diverge by most easy gradations on both sides to the two ultimate extremes". Moreover, according to Blumenbach, white skin color has to be the original color of mankind because white can be easily degenerated into brown, but dark skin cannot be easily degenerated into white after the secretion and precipitation of the dark pigments have "deeply struck root" (Blumenbach 1865 [1795 and 1806]: 190 – 191; 264 – 276; 293 – 312).

In the *Contributions to Natural History* (the first edition was published in 1790 and the second edition in 1806) Blumenbach developed transformist ideas. First he declared that the extinction of old species and the creation of new species do not threaten the physical, moral and religious order of the world. Despite the instability of nature, Blumenbach identified the guidance of the Creator. According to the fossil evidence, species and entire genera disappeared due to catastrophes. Probably, claimed Blumenbach, an "old pre-Adamite creation" was completely destroyed. A new creation replaced the ruins of the old world. The Creator designed the forces of nature in a way which allowed the repopulation of earth with new species. The mechanism behind this occurrences depended on the formative, teleo-mechanical force that controls the *animal machine*. Since the material circumstances had changed after the great catastrophe, the formative force was modified (Blumenbach cited Lucretius on this issue). The result was the formation of new species which to a certain extent are similar to the creatures of the old world, although only few of the creatures in the present creation are exactly like the creatures of the old world, e.g. the shellfish of the Atlantic. Moreover, the evidence shows that the appearance of new species continues. For example, the pimple-worms are not found in wild pigs, but only in domestic pigs which descended from them (Blumenbach 1865 [1806]: 281 – 290).

A great step in the gradual development of the theory of evolution was based on shifting the emphasis from spontaneous generation to the transmutation of existing species. This shift was manifested in the theory of Erasmus Darwin (1731-1802) and then in the theory of Jean Baptiste Lamarck (1744-1829). The proto-evolutionary theories of Erasmus Darwin and Lamarck were based on the idea that spontaneous generation produces only the simpler forms of life, while the mechanism of "the inheritance of acquired characters" produces the more complicated species from the simpler forms. The inheritance of acquired characters was an ancient idea, attributed to Aristotle and Hippocrates among others, and Erasmus and Lamarck used it to construct their theories of transformism. Even Charles Darwin, who was influenced by Erasmus and Lamarck, adopted the idea of inheritance of acquired character. Nonetheless, I will later briefly explain that Charles Darwin reinterpreted this idea via an ultra-mechanistic framework. Erasmus Darwin was a vitalist who rejected the ultra-mechanistic approach. His approach fused together organic and mechanistic elements and it was actually a soft mechanistic approach. Moreover, I will argue that like other prominent vitalists Erasmus significantly contributed to the mechanistic interpretation of life.

Erasmus Darwin was a famous English physician, a natural philosopher, a mechanical inventor and in general he was a man of the industrial age. Dozens of inventions were sketched by Erasmus, but most of them were not developed to the stage of a full product by Erasmus himself. Many of his inventions were later developed or reinvented by others. Among his mechanical inventions were a new method for steering carriages which was later adopted in early modern cars, a mechanical copying machine and an oil lamp. One interesting design of Erasmus was a detailed sketch of an artificial bird with a power supply to support a short flight. Erasmus also contributed to physics, chemistry, meteorology, and astronomy (Smith and Arnott 2005). What was Erasmus's view on progress? Like the Greeks, his cosmic view was based on cycles (developments and collapses). On the other hand, he adopted a progressionist view concerning the earth and its history and especially concerning life on earth. According to his view, nature is improving and progressing, from the simple forms of organic life, through the whale, the lion and the eagle, and to man who in the image of his god "rules the bestial crowd" by language and reason. This progress will continue "for ever and ever". Erasmus's belief in progress corresponded to his religious beliefs as a deist, but mostly to his social beliefs as a radical of the enlightenment, who supported the American Revolution and also the French Revolution and its hope for freedom (at least before the Terror). In addition, Erasmus was a founding member of the Lunar Society - a group of industrialists, intellectuals and scientists that included noted figures such as Joseph Priestly and James Watt. According to Ruse, the members of the club were committed to the ideas of the enlightenment, to social progress, science, technology and to free enterprise in the spirit of Adam Smith (Ruse 1996: 59 – 64).

In *Zoonomia; or the Laws of Organic Life*, which was published in 1794-1796, Erasmus Darwin presented a vitalistic approach. He wrote in the preface to the book that those who study the body "busied themselves in attempting to explain the laws of life by those of mechanism and chemistry; they considered the body as an hydraulic machine, and the fluids as passing through a series of chemical changes, forgetting that animation was its essential characteristic". He further claimed, for example, that animal contraction is not governed by the laws of mechanics, chemistry, magnetism and electricity, but "by laws of its own" (E. Darwin 2007 [1796], vol. I: 19, 74). On the other hand, as I've already explained, we have to distinguish between the organic elements of vitalism and the belief in the autonomy of life sciences. The mechanistic perception of Erasmus is evident even in relation to the life sciences. As Philip Wilson (2005) points out, through his education in Edinburgh Erasmus was under the influence of the Boerhaavian medicine and the mechanistic view of the body. In *Zoonomia*, for example, he described the body as a combination of inanimate atoms which unite by the powers of attraction. Erasmus shared with his Edinburgh professors the mechanistic view of diseases. Diseases were perceived by Erasmus as mechanical defects and especially as disturbances in "one or more of the classes of fibrous activity". Some of Erasmus's contemporaries even criticized him as a materialist. In *Zoonomia* he declared "I beg to be understood" that the "spirit of animation" may consist of matter of a finer kind, just as the powers of gravity, specific attraction, electricity and magnetism, but "the ultimate cause only of all motion is immaterial, that is God". He immediately clarified that the phrase "spirit of animation" relates only to the organic parts of the living body, and not to the spiritual soul which can be discussed only in religious terms (E. Darwin 2007 [1796], vol. I: 111).

Erasmus, then, did not accept the complete reduction of the body to a mere mechanical automaton. As a vitalist he postulated that the spirit of animation, i.e. the living force, enables the animal and the plant to adapt to the conditions of the environment. His theory of transformism was based on teleology, but the more interesting part of this theory was an automated-mechanistic process which anticipated Charles Darwin's mechanism of natural selection.

Erasmus Darwin began to work on his proto-evolutionary theory around 1770, after he had been exposed to the fossil evidence. He developed his ideas on natural history under the influence of the writings of Linnaeus and Buffon. His ideas on the transmutation of species are discussed in *Zoonomia* and they also appear in his popular books which were written as poems: *The Botanic Garden* (1825a [1791]) and *The Temple of Nature* (1825b [1803]) which was published after his death. It should be noted that Erasmus's theory of transformism was appealing to the general public, but his ideas did not initiate a paradigmatic research program. Additionally, conservative scholars, who felt threatened by the French Revolution and the idea of progress, effectively ridiculed his theory. Erasmus listed in *Zoonomia* six sources of evidence that confirm the transmutation of specie. First, one can see drastic changes and development in the ontogeny of the individual, from a crawling caterpillar to a butterfly and from a young boy to a man. Secondly, one can see changes in animals (e.g., horses, dogs and cattle) as a result of artificial or accidental cultivation. The bull-dog, for example, had been cultivated for strength and courage, but the lap-dog had been cultivated as a play-dog for children. The reliance on artificial selection, which was greatly advanced during the industrial revolution, would reappear in the theories of Lamarck and Charles Darwin. Thirdly, Erasmus counted different phenomena which alter the generation of animals. For example, hybrids like the mule are produced by the mixture of species; in Italy there is a breed of dogs without tails, and according to the conjecture of Buffon, this breed was created as a result of the costume of cutting tails; there are monstrous births which are probably the result of the nourishment supplied to the fetus, e.g. in the cases of animals that are born with additional limbs. Some of the abnormalities are inherited and can lead to the creation of new species. Fourthly, from the evidence of comparative analogy and isomorphism, and following Linnaeus who had made similar claims in respect to the world of vegetation, Erasmus claimed that the origin of the great variety of animal species may have been the mixture of few natural orders. Ultimately it is possible that they all came from “a single living filament”. Erasmus concluded that “when we revolve in our minds the great similarity of structure, which obtains in all the warm-blooded animals, as well quadrupeds, birds, and amphibious animals, as in mankind; from the mouse and bat to the elephant and whale; one is led to conclude, that they have alike been produced from a similar living filament”. Fifthly, from its first rudiment to its death the animal undergo perpetual transformations which are partly the result of desires and aversions, pleasures and pains, irritations of external bodies and associations of fibrous motions by habit (the idea of associations was taken from the psychology of the English philosopher David Hartley who was a materialist). For example, desires, particularly lust, hunger and security, direct the behavior of animals and consequently they give rise to the transformation of their body. Many of the acquired forms are transmitted to the offspring. The fifth point is very much relevant to our discussion, and I will immediately show how Erasmus uses it to explain in mechanical terms the transmutation and improvement of animals. Sixthly, the cold-blooded fish are so radically different from warm-blooded land animals that it may seem improbable that they were all produced from the same living filament. Nevertheless, there are intermediate forms that unite the animal kingdom: whales, seals and frogs (E. Darwin 2007 [1796], vol. I: 448 – 454; Ruse 1996: 55 – 59, 77 – 83).

Teleological elements were predominant in Erasmus’s theory of transformism. Basically, he thought that God, “the great first cause”, designed the first living filaments (or he tended to believe, as a deist, that the non interventionist God designed the laws which govern the world and the laws of generation which produced the living filaments). With the creation of the filaments in the early history of earth God also created “animality” that enables the filaments to “improve” themselves in varying conditions by acquiring new organs and traits. The mechanism of animality works through irritations, sensations (pleasures and pain), volitions (desires and aversions) and associations. According to the theory of Erasmus, the new organs and traits gradually develop over the generations and they are inherited by the offspring. Consequently over the generations new species are created. In Erasmus's view, this power was progressively working towards perfection "without end". Teleology provided the framework for this progression: new organs are developed "for the purpose of" something which is derived from the needs and wants of the animal (E. Darwin, 2007 [1796], vol. I: 452 – 453; 456 – 457). In addition, Erasmus accepted the traditional beliefs about the power of mind and imagination in inheritance. He described, for example, a man who during the conception of one of his children was obsessed with a darkly colored young woman, and whose wife gave birth to an exceptional child with dark hair and eyes (Ruse 1996: 57 – 58).[71] These were the elements of traditional and teleological thought in Erasmus's theory of transmutation. Yet, this theory also comprised the elements of an automated-mechanistic process.

The proto-evolutionary theory of Erasmus Darwin was an organo-mechanical hybrid that pertained to the first mechanistic phase. Erasmus introduced a new mechanistic dimension that anticipated and directly influenced the highly mechanistic theory of his grandson Charles Darwin: as the citation below demonstrates, Erasmus's model of transmutation already contained elements of the industrial-capitalist phase, which echoed in Charles Darwin's idea of sexual selection. The hypothesis of Erasmus was based on two observations (a) there is a desire of males to possess female in an exclusive manner (b) male organs are used as weapons and they are mostly effective against other members of the same species. Erasmus compared the fight of armored males over females to the fight over the ladies in the times of chivalry. Under the mechanistic order the efficient cause became dominant and the final cause became an end state of a series of efficient causes. The following mechanism suggested by Erasmus Darwin in *Zoonomia* represented the mechanistic version of the final cause:

> The birds, which do not carry food to their young, and do not therefore marry, are armed with spurs for the purpose of fighting for the exclusive possession of the females, as cocks and quails. It is certain that these weapons are not provided for their defence against other adversaries, because the females of these species are without this armour. The final cause of this contest amongst the males seems to be, that the strongest and most active animal should propagate the species, which should thence become improved (E. Darwin 2007 [1796], vol. I: 452).

I'm not arguing that Erasmus presented a coherent theory that belonged to the second mechanistic phase. Yet, the above mentioned mechanism anticipated the Darwinian explanation and in principle it provided a mechanistic alternative to teleological design: the mechanism is based on a series of efficient causes and on a capitalist-industrial model of competition between individuals. Eventually the mechanism leads to the final cause, i.e. to the improvement of the species. It should be emphasized that Erasmus remained faithful to the organo-mechanical framework and he did not intend to suggest an ultra-mechanistic solution to the problems of adaptation and transformism. In the following pages of the book Erasmus explains how the need and want for food transform the animal via the development of organs. The discussion proceeds in teleological terms: through its desire for food the nose of the swine became hard "for the purpose of turning up the soil in search of insects and of roots"; the elephant's trunk was a nose that became longer for the purpose of pulling down branches of trees; for similar purposes beasts of prey acquired jaws or talons, while cattle acquired rough tongue and a rough palate which allow them to feed on thorny grass (E. Darwin 2007 [1796], vol. I: 505).

- In conclusion, Erasmus Darwin can be counted as another vitalist who was not only a mechanical inventor and a man of the industrial revolution, but a distinguished member in the movement that advanced the mechanistic perception in the life sciences.

❖ *Transformism in the Early Decades of the 19th Century*

Let us review the developments of transformism at the beginning of the 19th century. Until the last decade of the 18th century Jean Baptiste Lamarck, one of the prominent naturalists of the modern age and one of the scholars who influenced Darwin, believed in the fixity of species, but his view was radically changed. In his book, *Zoological Philosophy*, which was published in 1809, he explained and defended his theory on the mutability of species. The theory was based on the increase in the complexity of organization and on gradual transformism (Lamarck 1963 [1809]). Lamarck was a mechanist and his outlook pertained to the first phase. He rejected vitalism and developed a materialistic mechanism to explain the adaptivity of living beings to their environment. Still, Lamarck's theory of adaptation contained organic and teleological elements. This was the reason for which Lamarck was later criticized and ridiculed by the neo-Darwinians.

Before we examine the issue of adaptation and transformism in Lamarck's *Zoological Philosophy*, I want to review his ideas in physiology. Lamarck explicitly rejected the vitalist outlook. Physiologically speaking, Lamarck defined life, or the organic body, as a "machinery of movement", composed of (a) solid parts (b) visible liquid parts and (c) the exciting cause which is the motive power of the machine. The liquid parts of the body, e.g. the blood, are contained inside the solid tissues and they move between them under the control of the exciting cause. Without the exciting cause the organic movements would stop, fermentation would cease and the organic body would decompose. Lamarck had a reservation regarding the famous clock analogy. The organic body consists of three types of components. On the other hand, the clock consists of only two types of components: (a) wheels or moving parts, and (b) the spring or the part that keeps the movement of the machine by tension. Lamarck's reservation is directly related to the controversy over the self motive power of the body (a subject which we have already discussed). He claimed that the comparison between the watch and the living body can be improved: we have to see the exciting cause as analogous to the spring of the watch and the supple containing parts, together with the contained fluids, as the machinery of movements. If so, life can be defined by a reference to the basic aspects of the watch: (a) without the exciting cause the organic watch would not produce any movements (b) when the moving parts are not arranged properly (as I've noted before, for example, Lamarck emphasized the importance of cellular organization), the effective power of the organic *spring* is lost. At this point Lamarck was completely satisfied with the comparison between the living body and the mechanical automaton (Lamarck 1963 [1809]: 201 – 229). In a following chapter, Lamarck disputed the vitalistic outlook of the French surgeon and physiologist Anthelm Richerand, who was a disciple of the French physiologist Pierre Cabanis. He summarized the position of Richerand in this fashion:

> M. Richerand himself agrees that there occur, in the living machinery, effects that are quite obviously chemical, physical and mechanical; but these effects are always influenced, modified, and weakened by the forces of life (Lamarck 1963 [1809]: 251).

Earlier I have summarized the vitalistic position in a similar way: in general, the vitalists did not deny the relevance of the mechanistic order to the body, but they developed an organo-mechanical view, according to which the mechanical construct of the body is under teleological forces, i.e. vital organizing powers. Instead, Lamarck suggested the *exciting cause*. He denied that the exciting cause is a spiritual force or a vital force which does not belong to the material nature. As a modern scientist, Lamarck declared that the only legitimate source of evidence are the observable effects of empirical phenomena and nothing beyond the natural laws is needed in order to explain these effects. He stressed that his explanatory framework is exclusively physical and chemical, and the only quality which makes the living different from the non-living is the special arrangement of the organic machine: the exciting cause requires the special organic arrangement, just as the effective power of the clock requires the special arrangement of the clock. In the presence of inorganic substances the exciting cause leads to their decomposition. But Lamarck had difficulties in finding an empirical basis for this mechanistic force. The exciting causes, he claimed, are actually subtle, invisible fluids (as opposed to the large and visible fluids). They run throughout the body and can be found in the environment of living bodies. Lamarck speculated that there are specialized exciting fluids working within the body, but the most essential fluids are the caloric and the electric. Caloric fluids are responsible to the liveliness of the body, to the basic conditions of life, to the *orgasm* (a kind of erethism or tension of the organic parts) and to the *irritability* of the body and to the process of fermentation. Complex living beings can produce caloric fluids by themselves, but even they become torpid and die in the conditions of very low temperatures. Electric fluids, on the other hand, are responsible for the active movements of the body. The nervous impulse, for instance, is transmitted by electric fluids that move much faster than the large, visible fluids (Lamarck 1963 [1809]: 201 – 229, 250 – 251).

In his introduction to Lamarck's book from 1914, Hugh Elliot noted that the exciting causes of Lamarck are obviously analogous to the ancient idea of "animal spirits". Lamarck even referred to the caloric fluid as the "material soul of living bodies". Subtle, invisible fluids were accepted theoretical entities in the physics of Lamarck's age, and thus Lamarck saw no tension between the exciting cause and his materialistic view (Lamarck 1963 [1809]: lxviii). The notion of animal spirits was predominant even in the 18th century, and as we saw earlier Descartes and La Mettrie, also adopted, modified and adapted the old idea of animal spirits into the mechanistic paradigms of the body. Finally, Lamarck's view on human and animal psychology was also in accordance with his materialistic physiology, and he rejected the spiritual concept of the mind. Human and animal psychology is equated by Lamarck with organic activity, i.e. an activity of nerves, the brain, and the subtle fluids which can be studied by their effects, but not directly measured (Lamarck 1963 [1809]: 285 – 289; part III).

Materialism was not the only element in Lamarck's outlook that conformed to transformism. Lamarck believed in moderate political reform and supported social and political progress. He was identified with the progressionist view of the French intellectuals Étienne de Condillac, Claude Helvétius, Pierre Cabanis and Condorcet. Furthermore, Lamarck rejected the traditional Christian beliefs and adopted a deist view of a non interventionist God (like Erasmus Darwin). His social and biological views were interwoven with each other. Improvements, he suggested, occur through the mechanism of the inheritance of acquired characters, and since the Europeans belong to the oldest race of humans they climbed higher up the scale of perfection and achieved their natural superiority. Although Buffon saw the non-European races as a product of degeneration caused by alien climates, Lamarck put them along the progressive line (Ruse 1996: 50 – 55).

In *Zoological Philosophy* Lamarck rejected the traditional, religious view on the subject of adaptation and the origin of species. The traditional belief that God was involved in special creations and put the species in suitable environmental conditions became irrelevant in the Lamarckian paradigm. In this respect, and similar to his approach in physiology, Lamarck adopted the values of the mechanical sciences. According to Lamarck's view, the simplest species are continuously generated in favorable physical conditions. As to the question how all other species are generated, the answer lies in the mechanism of inheritance of enquired characters and in the tendency of living beings towards an increase in their complexity. The transmutation of species, according to Lamarck, is gradual and it depends on the permanency and change of environmental conditions (Lamarck 1963 [1809]).

According to Lamarck, the simplest forms of life, i.e. infusorians, polyps, radiarians and worms are generated directly by nature, under the conditions of heat, light, electricity and moisture, and not through reproduction. Like other materialists before him, Lamarck used an ancient idea on a new ground: he developed a materialistic version for the ancient belief in *spontaneous generation*, although he also had reservations about naming the process *spontaneous* and attributing it to all species with simple organization (e.g. insects). On the other hand, Lamarck also rejected the new assertion that all living beings are generated by reproduction. He contended that only species which are at the beginning of the animal and vegetable scales, and maybe some of their branches, are generated directly by nature. A subtle fluid, which is analogous to the fertilizing fluid, is spread all over the world and gives rise to direct generation of the simplest living beings. Unlike the fertilizing fluid, the exciting fluid which is responsible for direct generation operates on small gelatinous or mucilaginous bodies. Theses bodies are not shaped according to pre-existing organization, but they are soft enough to become organized. Lamarck's theory goes further than the traditional view of direct generation. For Lamarck, direct generation is only the first step in an evolutionary process: organic bodies, he claimed, tend to evolve, to produce higher forms of organization in favorable conditions. Reproduction preserves the acquired organization. The more complex species evolve from simple species. Simple living beings which are directly generated, e.g. infusorians, polyps and radiarians, live exclusively in water. Worms are also directly generated and they live in very moist places or in water. Since moister is essential for the development of life, and since all simplest animals (which are also the most numerous) live in water, the origin of the entire animal kingdom is in water. One initial branch of the animal scale is formed by worms and the other by infusorians. For instance, Lamarck estimated that amphibian insects, such as gnats, evolved from aquatic worms that had adapted to air. All other insects evolved from the amphibian insects (Lamarck 1963 [1809]: 175 – 180, 236 – 248).

Lamarck, then, criticized the conservative naturalists who were not aware of the dynamics and transmutation of species. Instead, they continued to believe in special creation of species by the Supreme Author. The fixity of species, determined Lamarck, depends on the stability or the variability of environmental conditions surrounding the living being. Therefore a variability of environmental conditions can give rise to heritable bodily changes through the inheritance of acquired characters. On the one hand, Lamarck identified a tendency of increasing the complexity in animal organization. On the other hand, he identified the existence of another force comprising various environmental conditions that distort the increasing complexity of organization. The modifications of the body are accompanied by the active resistance of the body to alterations which may destruct its organizational complexity. Lamarck clarified that the conditions of the environment do not produce structural and organizational modifications in a direct manner. They do so indirectly. Great and permanent alterations in the environment produce great alterations in the needs and behavior of animals. As a result, over a few generations animals in the altered environment will gradually enhance the use of some organs on the expense of parts which are no longer necessary. Useless parts gradually shrink, degenerate and disappear. The “efforts” of the animal, in light of his needs, induce the formation of the needed part or enhance an already existing part. The acquired character will be inherited if the modification is common to both parents or at least if the female parent who produces the offspring acquired the modification. Lamarck’s famous example deals with the shape and size of the giraffe. Because giraffes live on arid and barren soil, he claimed, they adopted the habit of stretching their limbs and necks in order to reach high branches of trees. Thus the efforts of giraffes resulted in stretching and enlargement of their legs and necks. The “willing” issue in Lamarck’s theory is perhaps more clarified in another essay of Lamarck, where he explains that the inner consciousness of higher animals controls their bodily actions and is therefore a key factor in their development. Plants have no habits nor do they have activities, admitted Lamarck. Yet, in plants modifications may appear due to significant changes in the environmental conditions. More specifically, changes in nutrition, in absorption and transpiration of nutrition, in the quantity of calories, in light, in air and moisture received by the plant, and in the movements of the plant itself - produce heritable modifications in the development of parts (Lamarck 1963 [1809]: 36, 106 – 127, 122 – 123; Ruse 1996: 48).

The industrial revolution made a deep impression on Lamarck and on the appearance of the transformist view during the 18th century. The best example of transmutation due to environmental changes was directly taken from the development of agriculture, breeding and artificial selection. Afterwards, during the 19th century, artificial selection helped to establish the second mechanistic phase through the metaphor of *natural selection* on which the Darwinian argumentation was based. According to Lamarck, when humans take animals and plants out of their natural habitat and put them in different environmental conditions, they acquire new characters. In the same way, if individuals or populations of the same species live in different environments they could eventually become different races. Domesticated animals and cultivated plants clearly demonstrated that environmental changes induce alteration of species. Cultivated wheat, for example, does not grow in nature, but only under special, artificial conditions. Races of dogs too are the result of domesticating an original race from nature which is closely related to the wolf or perhaps the wolf itself. Lamarck claimed that the process of variation is gradual and affected by interbreeding (Lamarck 1963 [1809]: 108 – 111).

At first glance, we can define Lamarck's theory of transmutation not only as a materialistic theory, but also as a mechanistic theory. Lamarck suggested a materialistic process of transmutation, as an alternative to the teleological account which was based on special creations. Moreover, it seems as if the inheritance of acquired characters is based on a simple mechanical model: the expansion, strengthening and enhancement of organs which the animal uses, and the degeneration and disappearance of organs which the animal no longer uses. Additionally, on the physiological level Lamarck endorsed a mechanical and an anti-vitalistic outlook.

Yet most theories of transformism and adaptation which were developed during the first mechanistic phase were organo-mechanical hybrids, and in this respect Lamarck's theory was not an exceptional. In general, the science of physiology became more and more mechanistic before the science of transformism and adaptation. Lamarck's ideas on transformism and adaptation were not based on cosmic-religious teleology, but they were still based on materialistic teleology. First, as we have already seen, Lamarck's theory of transformism postulated that living beings have an innate tendency to increase in their complexity and also that the conscious "willing" and intentional "efforts" of the animal direct its adaptation. Lamarck's view on the extinction of species demonstrates that he was not completely free from the teleological perception. Although the evidence of fossils indicated that many species and races which had existed in the past finally became extinct, Lamarck refused to believe that "the means adopted by nature to ensure the preservation of species or races have been so inadequate that entire races are now extinct or lost". Lamarck accepted that some large terrestrial animals may have become extinct by men, but he gave a different interpretation for the majority of cases. First, many parts of the earth were poorly investigated by mankind and many other parts were not reached and observed at all, especially parts of the sea-bottom. Hence many species and races may still exist on the unexplored parts of earth. Moreover, old species may have evolved to the species which are found today (Lamarck 1963 [1809]: 44 – 46).

The overtly teleological residues in Lamarck's theory were rejected by Darwin, as we will see below, although Darwin himself also accepted a more mechanistic version of the inheritance of acquired characters. Charles Darwin's (1872 [1859]) natural selection, Gregor Mendel's (1866) units of heredity and August Weismann's (1893) germ cells reinforced the mechanistic order through the second phase and in the beginning of the 20th century. The principle of fragmentation had triumphed. When the perception became more mechanistic and less organic, there was little or no place for a complex interplay of *figure* and *ground*. In the case we are discussing, there was little or no place for a complex interplay between the body and the environment: the effects of hereditary factors were separated from the effects of environmental factors. The mechanistic order did not promote a complex interplay which is based on flexible, circular reactions and holism, but it rather promoted fragmentation, abstractions, sequential operation, efficient causality and standardization. The Lamarckian living being was still able to adapt its body to changes in the environment teleologically and even consciously. In this respect, Darwin's theory of natural selection was much more mechanistic. According to the theory of natural selection, the body, as a collection of heritable variations, can only be positively or negatively selected by an efficient cause. But according to Lamarck's theory, for example, some herbivorous animals, like antelopes and gazelles, were forced to adopt the habit of flight from carnivores by swift running, and thus their bodies became more slender and their legs much finer (Lamarck 1963 [1809]: 122). The Lamarckian theory was not purely mechanistic, because instead of fragmentation it still enabled a complex interplay between the body and the environment: the body, according to Lamarck's theory, has a kind of a teleological tendency to increase its complexity, to actively and flexibly adapt itself to the conditions of the environment and to resist alterations which may destruct its organizational complexity. On the other hand, according to Darwin's theory, animals and all other organisms, survive and reproduce under the conditions of intra-specific and inter-specific struggle over resources. In other words, heritable traits of animals are selected mechanically as a result of competition and the conditions of the environment. For example, characters which are related to the speed of antelopes, gazelles and carnivores, are heritable. They already exist in the body or else they appear due to random variations. The body and its characters are passively selected under the conditions of competition: the fastest herbivores and carnivores will survive, reproduce and their characters will become more common in the population. Even when Darwin referred in the *Origin* to the concept of the inheritance of acquired characters, he meant nothing more than the mechanical influences of environmental conditions on the body.

Lamarck was close to the modern scientific establishment that was formed during the French revolution. Buffon was involved in the publication of Lamarck's earlier work, and in 1779 Lamarck was elected to the academy of sciences. Together with Jean-Jacques Rousseau, one of the eminent philosophers of the enlightenment, Lamarck made botanical trips (H. Elliot's introduction in Lamarck 1963 [1809]). Although Lamarck was a distinguished scientist who influenced many of his contemporaries, his transformist theory was not accepted by the establishment, especially by the French naturalist Georges Cuvier who was a conservative Christian. Cuvier led the conservative reaction against the idea of transmutation. In Napoleonic France, the establishment identified radical materialism as a threat. In Britain, as well, the establishment associated radical materialism with the dangers of the French Revolution. In addition, the scientific establishment rejected Lamarck's theory because it was too speculative and also because the belief in spontaneous generation did not coincide with the conventional views in the new biology and chemistry. In this respect, Lamarck was an old fashioned scientist who still held the theory of four elements. Nevertheless the more radical forces in Britain and France continued to promote the materialistic theory of transformism and the ideas of Lamarck (Coleman 1964; Cuvier 1801; 1817; Bowler 2003: 94; Ruse 1996: 79 – 80).

- Lamarck was trying to build a materialistic theory of transformism, but he did so through the rear view mirror: he was not able to free himself from the great chain of being.

Traditional views surely had an impact on the thought of Lamarck. Unlike the branching path in modern evolutionary theory, Lamarck's classification system still contained elements from the simple hierarchic order of the chain of being. According to his theory, all of the evolving creatures are climbing up a main path, either of animals or plants. In other words, Lamarck's model of transformism still depended on the unfolding of pre-existing pattern. This piece of data demonstrates again how human knowledge gradually develops by hybrids and rear view mirrors: Lamarck was not a conservative naturalist, and yet in constructing his innovative theory he could not entirely free himself from the traditional perception. Cuvier, on the other hand, totally rejected the approach that underlies the chain of being. As described below, Cuvier suggested a new system of analysis and classification which was based on comparative anatomy and was free from the chain of being (unlike earlier works in comparative anatomy, e.g. the work of the English physician Edward Tyson). Similarities and differences between species were defined in the new system of Cuvier through structural and functional analysis of internal tissues and organs. This new system was in contrast to the Linnaean system, in which species were classified according to external characters of organs and visible patters of surfaces and lines.

Cuvier divided the animal kingdom into four different groups, according to the unique body type of each group: vertebrates, mollusks, articulates and radiates. Although Cuvier was not a materialist and did not believe in transformism, Foucault emphasizes that his new approach manifested the epistemic break between the 18th and the 19th centuries. Eventually comparative anatomy had led to the Darwinian model of evolution: an open-ended process of adaptations in different directions (Lamarck 1963 [1809]: 175 – 180, 236 – 248; Bowler 2003: 50, 93 – 94, 108 – 109; Ruse 1996: 46 – 47; Cuvier 1801; 1817; Foucault 1970: 137, 263 – 279; Coleman 1964).

At the end of the 19th century, and during the 20th century, Lamarck was ridiculed by the neo-Darwinians (from August Weismann to the modern synthesis), who developed theories of evolution and adaptation which were much more mechanistic than the theory of Lamarck. In fact Lamarck was criticized by all scientists and scholars who wanted to get rid of any residue of teleological thinking in science. Even Darwin himself, who was greatly influenced by Lamarck, called Lamarck's "willing doctrine": "absurd" (Darwin 1987 [1837]: 224 – 225; see more on the impact of Lamarckism in Gissis and Jablonka 2011). For many people of his generation Lamarck's theory of transformism was overly materialistic, but for later generations this was not enough. He developed an unusual and sophisticated version of the organo-mechanical hybrid. Eventually, it was another intermediate stage in the gradual process of replacing the organic perception with the mechanistic perception. Darwin's mind was more mechanistic than Lamarck's and he replaced the theories of the first mechanistic phase with the theory of evolution which was much more mechanistic.

Carl Kielmeyer was a student of Blumenbach. He adopted the progressionist worldview of the Romantic Movement and the idealist philosophy. According to this outlook, the world is ordered in a progressive manner leading to mankind. Kielmeyer's contribution to the field of comparative zoology included a systematic, comparative study of the organizing principles and laws of the *body↔machine*. He introduced a new dimension to comparative anatomy: a comparative method based on embryology. Following the ideas of Lamarck and Blumenbach, Kielmeyer concluded at the beginning of the 19th century that many species had probably developed from other species "as the butterfly emerges from the caterpillar". Changes of conditions on earth produce changes in the formative force, i.e. in the teleo-mechanical force that organizes and maintains the body. Kielmeyer claimed that in each epoch in the history of earth there was a unique system of interrelated species which was modified due to the change in circumstances. Principal plans continue to exist, but the species of the new epoch are very different from the species of the previous age. In 1793 Kielmeyer gave a famous lecture in which he explained at length the romantic view of nature. Nature, according to his view, should be perceived as if working in a purposeful manner although it has no intentions. The living body is organized teleologically, that is, body parts serve as cause and effect for each other. Apparently influenced by Newton's principle of inertia, Kielmeyer defined a vital force as a force that produces permanent effects under the same conditions. He identified five vital forces: sensibility, irritability, reproductive power, power of secretion, and power of propulsion. The early formulation of the recapitulation theory and the law of parallelism was given by Kielmeyer who argued that the developmental stages of the embryo follow the developmental stages of the species. In the early stage of development the reproductive force is the primary force at work. Strong reproductive and regenerative power characterizes the lower forms of life, and indeed in the early stage of development birds as well as men are plant-like. In the following developmental stages irritability and other forces become significant (Lenoir 1989: 37 – 53; Bowler 2003: 121 – 122).

Eventually Kielmeyer adopted the Lamarckian view, but only in part: for him, transformism was a limited phenomenon that takes place only within certain classes. Other scientists like Lorenz Oken advanced a pre-evolutionary view in Germany. Oken was a romanticist, a distinguished representative of the Naturphilosophie and an embryologist. According to the theory he proposed in 1809, all living forms came from different kinds of organic "mucus". Each form of life was originated in certain material conditions and especially under the effects of light on seawater. Oken postulated, for example, that man was originated in the warm and shallow parts of the sea near the land, maybe in one spot only (in India) and at a certain time in which a certain mixture of water, heat and light was available. Oken's theory was interwoven with a German progressenist worldview which was based on spiritual advancement of man, the self conscious and the free individual. This worldview suggested an upward, teleological climb that leads from the less complicated infusorians, through the most complicated mammalians, to the spiritual peak of the universe, i.e. man. Nevertheless Oken's theory was not based on transmutation of species which evolve and produce new species through a branching path, but rather on the idea that each species developed separately from the starting point or the mucus (Ruse 1996: 64 – 72).

The hybrid development of knowledge is clearly manifested in the work of the French scientist Georges Cuvier (1769-1832), who was the leading zoologist in early 19th century. Cuvier was influenced by Kielmeyer. Afterwards many German students of Blumenbach, Reil and their associates became followers of Cuvier (Lenoir 1989: 54 – 65, 71). Let us put side by side Cuvier's view of the body on the physiological level and his view on adaptation, transformism and the origin of life. The industrial-chemical phase had an enormous impact on Cuvier's view. Cuvier's universe was a machine governed by the laws of the Creator. For him mechanics was as an ideal science based on mathematics, while chemistry was "still" at the experimental level and natural history was in many respects only at the level of observation. Cuvier was not convinced that the undiscovered laws of natural history would necessarily take a mathematical form in the future. From a physiological perspective, Cuvier's outlook was under the influence of the new chemical approach that had begun to replace earlier mechanical models. He adopted the engine metaphor of Lavoisier and in general he was sympathetic towards mechanical models. He also rejected vitalism and "special forces". The ideal model for physiology, according to his view, was the Newtonian paradigm. He expressed his perception through the following image: "Every animal may be considered as a particular machine, having certain fixed relations to all the other machines, that together form the Universe". The moving organs are passive instruments, e.g. *pullyes*, and *levers*, while the sensitive principle is the *spring* of the *animal↔machine*. Cuvier claimed on behalf of Buffon that without the sensitive principle plants are like sleeping animals. In addition, animated machines differ from man-made machines due to their ability to maintain and to repair themselves (Coleman 1964: 26 – 43; Cuvier 1801: especially 19 – 20).

Cuvier was a conservative and revolutionary scientist at the same time. On the one hand, he was a conservative Christian who rejected transformism and adopted a strict teleological approach concerning the design of the *body↔machine*. On the other hand, his approach to the arrangement of species was unmistakably detached from the chain of being. As the founder of modern comparative anatomy, Cuvier was among those who developed a new mode of perception that redefined living beings through functional analysis. The new approach was also very different from the 18th century methodology. The visual comparisons of Linnaeus were based on form, magnitude, quantity and arrangement of organs and structures. Cuvier, on the other hand, searched for a more abstract resemblance, a resemblance which was based only on the functions of internal tissues and organs. Gills and lungs may differ in form, magnitude and quantity, but they both function as organs of respiration. Cuvier established the order of things according to function. The grouping of species via the new method did not coincide with the chain of being. In this respect, as Foucault argues, Cuvier's approach was far more revolutionary than Lamarck's (Foucault 1970: 263 – 279). Nonetheless, I would like to stress that Cuvier was far from being a radical mechanist. First, as a Conservative Christian, an advocate of the teleological view and a representative of the French establishment, he rejected radical materialism. Secondly, he did not accept even the teleo-mechanical approach to transformism. Concerning this issue he still held a traditional, non-mechanical outlook. Indeed, Cuvier was the founder of modern comparative anatomy which was later used in order to find the common ancestors of groups, but Cuvier himself interpreted the adaptations of the body in a teleological framework. In Cuvier's view, organisms were created so as to fit the "conditions necessary for existence". Thus the body and its parts are instruments designed with a purpose. The body in its wholeness, as a functional unit, has to be coordinated with the surrounding conditions:

> In fact, there is not a single function, which does not require the assistance and co-operation of all the other functions, and which is not affected by the degree of energy with which the other functions are exercised (Cuvier 1801: 51).

Thus, for example, the process of respiration cannot be carried out without the proper operation of the circulation of the blood, and the circulation of the blood itself depends on the muscular action of the heart and arteries. Yet, muscular irritation depends on the nervous system, "which brings us back to the circulation of the blood, the source of every secretion, and consequently of the matter composing the nerves." Cuvier used this insight in practice. For instance, if the anatomist finds teeth and other parts which are adapted for meat eating, he can infer the type of organs from which the animal was made as well as the type of organs which are incompatible with the parts that were already found. Once all the parts are found, one can confirm the predictions. Cuvier asserted that all body parts are perfectly correlated with each other and that the living being is perfectly correlated with its environment. His conclusion was that any change from the norms of the species would bring a disaster to the integrated whole of the living being. Thus he rejected the idea of species transmutation even in a teleological framework. He interpreted the fossil evidence only as an indication of extinction, but not as an indication of transformism. Although Cuvier usually did not rely explicitly on the Christian interpretation of the bible in scientific matters, he was committed to show that no contradiction can be found between science and religion. He tried, for example, to link the latest era of catastrophes with the Noachian Deluge and to find further evidence for these occurrences in the ancient writings of other cultures. Cuvier did not use the argument from design, and he tried not to use any other religious argument in scientific matters, but his religious motives were obvious: he was a faithful Protestant who thought that the design of the *body↔machine* is purposeful and this purposeful design can only be explained as an act of the Divine Artificer. His work in comparative anatomy and paleontology later contributed to the development of the theory of evolution (Cuvier 1801: 50 – 79; Cuvier 1817: 148 – 163; Coleman 1964: 26 – 43, 170 – 186; Bowler 2003: 108 – 115; Ruse 2006: 410 – 414).

The fossil evidence was interpreted by Cuvier under the assumptions of the conservative view. Against the transformist view he claimed: “If the species have changed by degrees, as they assume, we ought to find traces of this gradual modification… we should be able to discover some intermediate forms; and yet no such discovery has ever been made”. Also, we see no difference between the Egyptian mummies and humans and animals in our time. Even the presence of successive forms in the fossil evidence from the less to the more complex, and the absence of humans from this record, was not interpreted by Cuvier as supporting the theory of transformism or as an indication to the late appearance of humans on earth. According to Cuvier, the layers of fossil are mostly the remains of species that became extinct due to the catastrophic floods which occurred throughout the history of earth. Present life forms which appear to be created more recently are not the product of transformism or of a new act of creation: their supposedly later appearance is the product of migration from one place they occupied in ancient times to another. Progressionism did not coincide with Cuvier's social values. Cuvier was taught in Germany by Kielmeyer and he was familiar with the Naturphilosophie, but he identified the Germanic spiritual progressionism with pantheism (the belief that God and the universe are one and the same) which stood against his religious beliefs. Finally, there is another aspect which can shed light on the rejection of the progressionist view by Cuvier. According to Ruse, Cuvier was not just an arch-conservative, but a politician and a bureaucrat who knew how to stay in power in an age of revolutions: at the beginning he lived under the dictatorship of Napoleon, and after the restoration he lived under a conservative monarchy. He was therefore an opponent of the progressive movement that greatly inspired the revolutionary ideas (Cuvier 1817: 114 – 127; Ruse 1996: 84 – 91).

The French Naturalist Etienne Geoffroy Saint-Hilaire was the greatest rival of Cuvier. In their earlier days Cuvier and Geoffroy collaborated and even lived together, but eventually their friendship was over and they became hostile towards each other. The hostility developed during the Cuvier–Geoffroy debate that took place in 1831 before the French Academy of Sciences. Geoffroy, who contributed to the research in comparative anatomy, was greatly influenced by the ideas of Buffon and he was a friend of Lamarck. His support in the transformist theory gradually developed. In 1818 Geoffroy denied the "progressive succession of beings", but a decade later he already accepted the idea of natural progression from the less to the more complex. Unlike Cuvier, Geoffrey was attracted to the progressionist worldview of society and nature. He was particularly influenced by the Naturphilosophie regarding the progressive nature of life, but he rejected the teleological aspects of German progressionism. By 1825 he endorsed Lamarck's *Zoological Philosophy*, but only in principle. In practice he did not accept the Lamarckian mechanism which was based on the increase in organic complexity as a function of the animal's "needs". Furthermore, Geoffroy thought that organic transmutations occur due to the effects of environmental conditions on the embryo and not on the adult animal. Instead of gradual changes, Geoffroy's model proposed that a decrease in atmospheric oxygen leads to the development of "monsters", and that some of these monsters are better fitted to the new conditions than their ancestors. Thus, Geoffroy's theory was much more mechanistic than Lamarck's (Ruse 1996: 91 – 97).

Geoffroy was a man of the enlightenment and a deist. Like Buffon and Lamarck, he believed in a non interventionist God who designed the laws of the universe. According to the deist view, the universe is running without the involvement of God. While Cuvier promoted a strict teleological outlook in which the organic structures derived from their purposes (according to "the conditions of existence" as designed by the Creator), Geoffroy put the emphasis on the study of homologies. Homology was defined by analysis and comparison of structural features that belong to different species. Geoffroy and his colleagues searched for variants of the same type: structures were defined as homologous (or analogues, in the terms of Geoffroy), when the parts that constitute them were organized in the same way, even if they served different purposes and had different shapes (Appel 1987). The new approach was highly mechanistic and it was based on the principle of fragmentation. Different body parts were abstracted from the inclusive pattern of the organism and were compared with the corresponding body parts of an organism from another species. Cuvier who believed in the adaptive wholeness of the living body could not have accepted such an approach: "…to use the language of Kant, it depends on the living body as a whole, what mode of existence shall belong to its different parts; whereas, among unorganized bodies, the mode of existence of every part depends solely upon itself" (Cuvier 1801: 6). Although he disagreed with his experimental approach, the physiologist Claude Bernard explained some decades later the position of Cuvier:

> It is doubtless because he felt this necessary interdependence among all parts of an organism, that Cuvier said that experimentation was not applicable to living beings, since it separated organized parts which should remain united (Bernard 1957 [1865]: 89).

Although it seemed that Cuvier, the voice of the conservative establishment, won the debate against Geoffroy, the long term effect of the debate was a compromise between the opposing views of Cuvier and Geoffroy. Toby Appel explains that the rivalry between the two schools was pushed aside while the majority of naturalists in the 1830s and 1840s adopted elements from both. They accepted Cuvier's distinction between four plans of organization in the animal kingdom (vertebrate, articulate, mollusk and radiate plans), which according to Cuvier's view should be clearly separated from one another on the ground of fundamental structural differences.

However, the position of Cuvier that God created each part in the body to fulfill a purpose was not considered to be a sufficient explanation for adaptation. French naturalists tried to find natural laws or regularities and looked for homologies between different elements of organization. They were not satisfied with Cuvier's conditions of existence. For them, the teleological explanation was insufficient. This trend characterized not just the 30s and 40s in France, but in Britain and Germany as well. For example, following the Cuvier–Geoffroy debate Richard Owen, one of the leading conservative naturalists in England who did not believe in transformism, promoted a synthesis between Cuvier and Geoffroy or between the teleological and morphological views (Appel 1987: 202 – 237).

- Prominent vitalists were actually soft mechanists who contributed to the trend of fragmentation. I will demonstrate it once again in relation to the French zoologist Henri Milne-Edwards.

Milne-Edwards was the leading zoologist in mid 19th century France. In his work he contributed to the synthesis between the approaches of Cuvier and Geoffroy. Generally speaking, Milne-Edwards accepted Cuvier's conviction that the interdependence of the parts of the *body↔machine* prevents "all idea of change in its construction". Yet he clarified that in addition to the law of *organic harmony*, there is another law dealing with the *subordination of characters*: despite the harmony between different parts of the body, the second law makes a distinction between the *dominating* organs which cannot be modified to a large extent without affecting the other parts and the less important organs which can be modified to a large extent without affecting the other parts. Milne-Edwards rejected the transformist idea and accepted Cuvier's distinction between the four plans of organization in the animal kingdom, but he was not satisfied with Cuvier's "conditions of existence" which implied not much more than a teleological design made by God. Consequently he tried to find the regularities or "tendencies" that characterize the nature of living beings and direct their proper development. He accepted the existence of a distinct vital force in organisms that did not contradict the forces of physics and chemistry. In addition, he did not deny Cuvier's conviction that the purpose of an organ precedes the structure of the serving organ. Yet in practice he was another vitalist who was doing the job of the radical mechanists. Often he gave primacy to structure: while paying lip service to the traditional teleological view (by declaring that in the "admirable machines" of the Creator the physiological properties are not derived from the structures but quite the opposite), he tended to explain organic diversity by morphological laws and not by a reference to the free choice of the Creator (Milne-Edwards 1863: 5, 31, 199 – 230; Appel 1987: 215 – 222).

In 1827 Milne-Edwards suggested his version to the idea of the *division of physiological labour*. The idea, which was directly taken from Adam Smith and the political economy of industrial capitalism, had become the main theme in the work of Milne-Edwards and his school. According to the analysis of Milne-Edwards, the simplest *animal machines* are barely differentiated in structure and they are not composed of different parts with special functions. He saw the simplest animals as a workshop in which every worker performs the same set of tasks. When polyps, for example, are cut into pieces each piece is able to regenerate the entire functions of the original body. The function of their body is *gross* and *imperfect*, since "an organ always performs its part better as it is more specialized". Higher animals, on the other hand, are highly differentiated in their structures and each part of their bodies performs a specialized task. Thus they are more *elevated* and *perfect* (see the similarities to Smith's analysis of the production of pins in factories, as described in the previous part). Following Smith, Milne-Edwards identified the division of labor as the driving force in the "progress of human industry and technology". Not surprisingly, the driving force of social progress also served as the criterion for defining the place of animals on the scale of being: "The principle which nature seems to have adopted in the perfecting of animals, is one which has been found to exercise the most beneficial influence over human progress; it is, *the division of labour*." In other words, organisms are perfected by the increase in the division of labor. The ideas of Milne-Edwards, as we will see, had a great impact on Charles Darwin's thought. As Thomas Huxley (Darwin's bulldog) claimed, Milne-Edwards had shown how "the principle of the division of labour is carried out in the living economy" (Milne-Edwards 1863: 189 – 193; Appel 1987: 215 – 222; Ruse 1996: 159 – 161; Ruse 2004: 13, 19; Huxley 1970 [1868], vol. 1: 137 – 138).

Dov Ospovat (supported by Appel) suggests that instead of seeing the developments in natural history during these decades as a struggle between creationists and transformists we should see them more as a struggle between traditional teleologists who followed Cuvier and their new rivals who in many respects were non-teleologists. Ospovat describes a gradual decline in the power of teleological explanation in Britain of the 30s and 40s. Traditional teleologists believed that there is a strict purposeful relation between the organic and inorganic. According to this view, living beings were specially and perfectly adapted to the conditions of their habitat by a Divine intervention. Successive appearances of new life forms on earth were explained by the conservative teleologists as a result of a Divine action. They claimed that God created the new life forms through a special adaptation to the altered conditions in the environment. The new trend threatened this traditional approach to the design and adaptation of the *body↔machine*. Generally the advocates of the new trend did not deny the ideas of creation and perfect adaptation, but they argued that living beings were adapted to the environment by general laws sanctioned by the Creator. They were not satisfied with the teleological argument and they rejected the idea that organs and living beings were specially adapted to a certain set of conditions. Instead, they argued that the same living being may be perfectly adapted to different conditions and different species may be adapted to the same conditions (Ospovat 1981: 6 – 38).

The *body↔machine* metaphor was always on the background of the debate. Teleologists, of course, used the argument from design which is based on the assumption that the body is an organized machine: the body is designed as a machine, and its organs are adapted for certain purposes like parts of a machine, and therefore the body demonstrates the existence of the Divine Artificer. In this framework the structure of organs was explained by the purposes that the creator gave to the organs. As a representative of the new trend, Richard Owen was not satisfied with the teleological argument. Indeed, he claimed, we create many devices for transportation on the earth, the sea and the sky, but they are not made according to a general pattern or plan and each of these devices is adapted to a specific function: the balloon scarcely resembles the boat, and the boat scarcely resembles the carriage etc. If we try to explain the organization of the body only in terms of adaptation to function, we will not expect to find general patterns of organization shared by organs that serve different purposes. Yet, we know, for example, that the forelimbs of man, horse, bat, mole and dugong share the same pattern although they do not serve the same functions. In conclusion, the non-teleologists argued that the teleological explanation is deficient because it does not help the naturalist to discover morphological laws. Charles Darwin developed his theory during these years and he was influenced by the new trend (Ospovat 1981).

In Britain of the early decades of the 19^{th} century the idea of transformism was part of the struggle between the establishment and the radical forces. Medical practitioners and social working-class agitators promoted the transformist view. The establishment was identified with the upper classes, while the supporters of the transformist theory were identified with middle class practitioners, with middle and working-class students who wanted a chance to study medicine, and in general with the demand of social change. Lamarckism was used in order to undermine the authority of the establishment. Much of the radical activity was taking place in Edinburgh, where the academy was not under the direct control of the churches and the political activity of the middle-class was extensive. From the mid 1820s, medical graduates, who came from Edinburgh and Paris to London, brought with them the ideas of Lamarck and Geoffroy and the practice of comparative anatomy (Desmond 1989; Bowler 2003: 127 – 129).

Around 1830 the British scientists who represented the establishment, e.g. the geologists Charles Lyell and Adam Sedgwick, still rejected transformism and supported the views of Cuvier. Since Geoffroy and his supporters denied the argument from design and the divine act of creation, they threatened an entire worldview including some of the most basic values of society. Moreover, transformism was often linked to the idea of social progress explicitly. As a follower of Cuvier, Sedgwick warned against the rise in popularity of Geoffroy and his "dark school" in England. On the other hand, the philosopher and political economist John Stuart Mill represented the radical intellectuals who criticized the anti-progressionist outlook of Sedgwick and his milieu. Out of the old establishment a new movement of scientists in London was born. This movement associated with the "Radical" group in the parliament, which stood up against the political power of the establishment and struggled to benefit more equally the social classes. Some major members in the new scientific movement were Scottish scientists who were influenced by French and continental thought. Among them was the noted comparative anatomist Robert Grant, who knew Cuvier and Geoffroy. Grant was a mechanist who believed in the autonomy of life sciences. He perceived the *body↔machine* as the most complicated and perfect mechanism in the universe (Ruse 1996: 97 – 104; Grant 1829). The analysis of the natural philosopher, claimed Grant, reveals that the body is an organized set of machines:

> Even in the most complicated animals he finds the solid frame-work, the skeleton and its joints, constructed according to the strictest laws of mechanics, and the muscles act in exact accordance with the principles of the lever; the functions of respiration, digestion, and nutrition, are simple chemical processes, and the various secretions of the living body are complicated products of chemical action; the nerves are a kind of galvanic wires, which establish an instantaneous communication between the most distant parts, and the whole circulating system, with its tubes, valves, fluids, and moving powers, is a complicated hydraulic machine; the larynx, the organ of voice, is an exquisite wind instrument, and the ear is admirably constructed according to the principles of acoustics; the eye is the most perfect of optical instruments, and indeed every part of the animal frame is constructed according to the strictest rules of proportion, fitness, and beauty (Grant 1829: 33).

Nevertheless, since the *body↔machine* is very complicated, it cannot be reduced by the general laws of chemistry and mechanical philosophy. Grant was a Lamarckian who believed that the adaptation of the *body↔machine* occurs through transformism. Already in 1814 he referred to *Zoonomia* in his medical dissertation and he later adopted the idea of transformism under the influence of Lamarck, Erasmus Darwin and Geoffroy. In general Grant believed that society, science and life are directed by the principle of progress. One cannot find in his work a clear distinction between the social and the biological aspects of *progress*. In his later days Grant adopted a more pessimistic cosmological view, according to which all life will eventually be frozen. Grant's ideas on transformism were mainly discussed in his lectures to lower-middle class medical students on the subject of comparative anatomy. One of the students who were influenced by him was Charles Darwin (Ruse 1996: 97 – 104; Grant 1829: 5, 18, 33).

The popularity of the progress idea in Britain was rising. In 1844 Robert Chambers anonymously published his best-seller book, *Vestiges of the Natural History of*

Creation (Chambers 1860), which appealed to the general public and popularized the idea of transformism. Chambers was a Scottish businessman and not a specialist in one of the scientific fields. Yet his theory was based on the ideas of leading figures from different scientific fields. Not many scientists supported his grand-theory and he was heavily criticized, but he spread the idea of transformism in Britain. The mechanistic approach of the 1830s and 1840s shaped his view. The vital principle had declined, he reported in his popular work. According to the noted scientists he quoted, the distinction between vital and chemical affinities was erased. Chambers based his conviction, for example, on a prize winning essay (awarded by the professors of Edinburgh University) of the English physiologist William Carpenter. From the work of the English-American physician and chemist John Draper he quoted that living structures are the product of combined natural forces: “Gravity, cohesion, elasticity, the agency of the imponderables, and all other powers which operate both on masses and atoms.” In his book from 1844 Draper ridiculed the residues of the “ancient system”, “a system which, at the outset, ought to have been broken down by the most common considerations, such as those connected with the mechanical principles involved in the bony skeleton, the optical principles in the construction of the eye, or the hydraulic action of the valves of the heart.” From here Chambers continues to the model of crystals in order to explain how the laws of nature can direct the organization of matter. In fact, he claimed, through crystallization one can organize matter into semi-vegetable forms. Crystals, then, stand between inorganic and organic matter. Finally Chambers presented the new theory of the cell that provided the mechanistic basis of life. These were the citations and views that Chambers introduced to the general public (Chambers 1860: 111 – 122; Draper 1845: 2; Ruse 1996: 104 – 111, 132; Bowler 2003: 134 – 140).

Yet the radical theories of transformism were softened for the Victorian public through the version of Chambers. He claimed that the progressive development in nature was taking place according to a divine plan and through the creative wisdom of the Divine Author. The transformist theory of Chambers was based on the *principle of progressive development*: a natural, universal law that dictates an upward development, from simpler to more complex forms. Two *impulses*, “under the providence of God”, control the transformation of species: (1) an impulse that modifies the organization of the body and advances the living being in definite times

(2) an impulse that modifies the organic structures of living beings in reaction to external circumstances, e.g. food and the conditions of the habitat. On Chambers' view, this principle rules the organic realm, as Newton's law of gravity rules the inorganic. Directly and indirectly Chambers was influenced by the German Romantic thought. He saw a progressive advancement in the fossil evidence and in embryology, "from the simplest and oldest to the highest and most recent." As the law of parallelism demonstrated, during its development the embryo goes through stages that characterize lower forms of life. In fact the developmental stages of the embryo are analogous to the developmental stages of the species. Thus, for example, in early stages of their development there is a great resemblance between human and fish embryos. With regards to this issue Chambers specifically referred to the works of Geoffroy, Von Baer and Tiedemann. Needless to say, Chambers held a progerssionist view. Actually, one cannot distinguish between the organic progression and the social progression which are found in his work. He explained, for example, that the human brain develops through animal stages (from the fish stage to the human stage) and then it continues in an upward progression from the Negro, Malay, American and Mongolian to the Caucasian brain type. Thus in the final stage the brain "assumes that perfect character which it bears in the superior nations comprehensively called Caucasian by Cuvier." For Chambers, natural development was the best evidence for social and political progress (Chambers 1860: 123 – 163, 232; Ruse 1996: 104 – 111, 132; Bowler 2003: 134 – 140).

Let us examine the status of transformism in Germany during the first half of the 19th century. Organo-mechanical theories of transformism were widespread at the early 19th century. Teleo-mechanists like Friedrich Tiedemann, Gottfried Treviranus and Johann Meckel adopted and promoted the recapitulation theory. Through this theory species were seen as *individuals* that develop progressively. As Tiedemann defined it: "Just as each individual begins with the simplest formation and during its metamorphosis becomes more evolved [*entwickelt*] and developed, so the entire animal organism [i.e., kingdom] seems to have begun its evolution [*Entwickelung*] with the simplest animal forms, that is with the animals of the lowest classes." On the other hand, the individual develops according to the evolutionary course of the species. As Tiedemann explained: "Every animal, until it reaches its own structure, passes through the organization of one or more of the animal classes standing under it…" Among the German scientists who represented the teleo-mechanical approach in the 19th century was the eminent embryologist Karl Ernst Von Baer, who was influenced by Cuvier and worked in the tradition of Blumenbach, Kielmeyer and his teacher Ignaz Döllinger. Von Baer criticized the recapitulation theory. He claimed that in many cases the theory is not in line with fetal development. Moreover, Von Baer accepted Cuvier's distinction between four plans of organization in the animal kingdom, and therefore he rejected the transition from lower to higher forms of life. The transformist view of Von Baer was based on the assumption that original types degenerated in different environments, even though the potential of transmutation is limited. For example, all species of apes probably have a common origin, but man could not have evolved from apes especially due to his intellectual abilities. In the teleological framework of von Baer a lower form organization cannot evolve to a higher form organization: species that descended from a common ancestor can only have the same degree of organization as the ancestor or a lower degree of organization, or in other words they have to be potentially contained in the ancestral type. Since Von Baer represented the teleo-mechanical tradition, his account of organization and transformism was materialistic and he did not invoke forces exterior to organized matter itself in order to explain the organization of matter (Richards 1992: 42 – 62; Lenoir 1989: 72 – 95).

From the end of the 18th century many romantic scholars argued that nature improved itself by creating higher forms of life. Generally they believed that each species was created anew, but some romantic scholars believed in the transmutation of lower into higher forms. According to Owsei Temkin, the idea of progress and the values of the mechanical sciences accelerated the acceptance of transformist ideas in Germany a decade before the publication of Darwin's work. For instance, the botanists Stephan Endlicher and Franz Unger suggested in 1843 a model of spontaneous generations. Vegetation, according to the model, appeared on earth by intervals "eternally progressing towards perfection". According to this view, the intervals of the spontaneous generations depend on violent changes that occur on the surface of earth. Many biologists relied on the idea of spontaneous generation in order to explain the appearance and evolution of specie. Even Virchow emphasized the importance of the idea in 1856. Yet, the idea that many occurrences of spontaneous generations can replace the concept of special creation was problematic: as von Baer argued in 1859, the concept of spontaneous generation did not explain much more than the concept of creation, but without the connotation of supernatural intervention. After the publication of Darwin's theory and the experiments of Pasteur, the idea of spontaneous generation became less central in the evolutionary process and it was confined to the beginning of evolution in distant history (Temkin 1968: 327 – 332, 339 – 340).[72]

The idea of transformism became more and more popular in Germany of mid 19th century and more materialistic. For instance, the geologist Bernhard Cotta, who like many other of his colleagues adopted the values of the mechanical sciences, was not satisfied with the idea that each species was formed by special act of creation. He thought that this approach substituted an explanation with an assumption based on ignorance. The transformist view had two other advantages: first it reduced the need to invoke many occurrences of spontaneous generations and secondly it coincided with the progressionist view of man and society. According to Cotta, the progress of mankind is evident in the abilities of humans, in their knowledge and morality. Further development in the next thousands of years may even produce more advanced beings. Correspondingly all existing species had gradually developed from other species through a law that determines the organization of matter and which was yet undiscovered. Simplest external conditions produce simplest organic forms from certain substances. When the conditions change and diversify, organic forms also change and diversify. Cotta observed that besides him many other scientists and intellectuals adopted the transformist view. He specifically mentioned the great impact of Chambers' *Vestiges* which was translated into German in 1851. The noted philosopher Arthur Schopenhauer was among the intellectuals who were influenced by the book. Karl Baumgartner, a professor of clinical medicine and one of the scientists who were influenced by the book, published his ideas between 1853 and 1859. His view combined a physiological theory of transmutation with the idea of progress and a belief in a Divine plan that governs the developmental and organizational changes of species. Baumgartner explicitly linked the "law of transformation of germs and of the progressive evolution of mental life [which] shows us that at any rate the movement marches on and that, therefore, our hopes for a higher destination are no empty illusion". According to Baumgartner's theory, the simplest cell was formed by spontaneous generation from nitrogen, carbon, hydrogen and oxygen. Similar to the process of differentiation in the development of the egg, the original cell differentiated and probably produced primitive plants and animals. A catastrophe, which included cosmic phenomena and forces of electrical polarization, destroyed earlier forms of life and at the same time modified the surviving seeds. As a result, higher species, including the human species, were formed by gradual transformations of simple embryonic forms. Spontaneous generations that occurred in each era also contributed to the generation of new forms of life (Temkin 1968: 332 – 341).

As we saw in the previous chapters, the approach of the second mechanistic phase became dominant in Germany of the mid 19th century. At the meeting of the society of German scientists and physicians in 1854, the participants debated the questions of creation and the human soul. The mechanists and materialists had the upper hand. Romanticism and Naturphilosophie declined at that age. Schleiden, who believed that the universe was created by God, supported the transformist view and interpreted it through the new theory of the cell. In 1848 Schleiden suggested that all plants descended from a single cell and that varieties and species gradually evolved under varying conditions. For instance, according to Schleiden's theory, in tropical conditions moisture and warmth are the main causes of the diversity of forms. When conditions produce a variation in the chemical processes of the plant its form changes. Permanent changes of conditions will transform the new variety into a sub-species and eventually into a new species. Johannes Müller, the teleo-mechanist who was the teacher of the leading figures of the second mechanistic phase, allegedly discovered in 1851 snails that develop within echinoderms. Since both of them belong to different phyla, Müller and many of his followers concluded that the process of transformism involves large mutations. Among the scientists who favored this view were Baumgartner, Ludwig Buchner and the botanist Carl Nageli. Buchner, who was one of the main figures among the medical materialists, described the idea of transformism in 1855 as a founded scientific theory. He accepted the discovery of Müller and asserted that the conditions in the past were suitable for a similar process, in which higher animals produced individuals of a new species through a great embryonic leap, e.g. a monkey which generated a human being. Also, Buchner did not dismiss the possibility that spontaneous generations take place among the lowest forms of life. Nageli was a mechanist and an idealist who believed in progress. In

1856 he linked the progress of mankind towards perfection, which is achieved through a change of individuals, with the progress of species. In Nageli's metaphor species became individuals who change, develop and produce new individuals/species. Gradual changes occur over time, but at a certain point a sudden change may produce a new species. In the short run, one can observe how the combination of heredity and external influences produce new races, as in the process of artificial selection. In the long run of history, the result is the appearance of new species (Temkin 1968: 323 – 352).

Carl Vogt was one of the scientific materialists whom I've mentioned earlier along with Buchner and Moleschott. Despite his contribution to the second mechanistic phase, the early Vogt of 1849 did not believe in transformism. Nevertheless, he was the German translator of Chambers' book. Following the publication of the Darwinian Theory, he became one of the promoters of Darwinism and was known as "monkey Vogt". The early Vogt was sympathetic towards transformism, but he thought that the theory was scientifically unsound. Unlike the author of *Vestiges*, Vogt postulated that a transmutation from one species to another did not occur, but rather a total extinction of species and generation of new species in every geological period. Moreover, as a materialist Vogt was unwilling to accept explanations that contain references to the Creator, whether these explanations referred to the God who created the world and its laws and then retired (the deist view of Chambers) or to the God who changed the world and his mind twenty five times. Vogt was willing to accept only explanations based on natural mechanistic laws. This position, as we have seen before, was based on an entire worldview. Vogt was a radical republican. The 1848 revolution failed and cost him his academic position. In the preface to Chamber's book he sarcastically claimed that the princes should take an example from the "constitutional God" that the author of *Vestiges* "constructed": this God had created the laws of nature, but he then gave up autocracy and allowed the laws to govern the universe instead of him. Scientists like Vogt and Virchow were sympathetic towards transformism because they thought that it would reinforce the mechanistic framework of life, but before the appearance of Darwin's book they were very skeptical about the empirical foundation of the transformist idea (Temkin 1968: 345 – 351; Vogt 1864: 443 – 469).

In his lecture *On the Mechanistic Interpretation of Life* Virchow made the point clear. The lecture was given in 1858 (a year before Darwin published the *Origin*), although Virchow published the written version only in 1862. According to the 1862 version, Virchow asserted that the mechanistic biology must account for origin of life (Virchow 1958 [1858]: 118). The basic facts, claimed Virchow, are that a certain plan is inherited from generation to generation and type does not deviate from type, but we also know that these types were not always present. Furthermore, since geological evidence demonstrates the appearance of lower species before the appearance of higher species, one can assume the transformation of one species to another. Therefore science has to explore the conditions on earth that enabled the appearance of life and the transmutation of species. Virchow believed that every natural phenomenon should be explained in mechanistic terms and the issue of the origin of life was not an exception:

> For geology teaches us to recognize a certain hierarchical order in which species follow each other one after the other, higher after the lower, and much as the experience of out time argues against it, I must still confess that it appears to me a scientific necessity to assume the possibility of a transition from species to species. Only then does the mechanistic theory of life achieve genuine security in this respect (Virchow 1958 [1858]: 118).

❖ *The Second Phase: the Darwinian Mechanism and the Industrial Revolution*

With the publication of Darwin's book, *On the Origin of Species* (1872 [1859])[73], the mechanistic interpretation of life achieved a "genuine security", as Virchow hoped. Darwin's work is the best known example of the connections between the life sciences and industrial society. Many books have been written on this subject. Based on the definitions I suggest in this work, I describe the Darwinian outlook as an integral part of the second mechanistic phase. The Darwinian Theory matured around 1838, i.e. about the same time in which cell theory was formulated. Yet Darwin's ideas were first published in 1858, after Darwin received an essay from the British naturalist Alfred Wallace who developed a similar theory during the second half of the 1850s. Darwin and Wallace decided to publish their work at the same time. Transformism, of course, was not a new idea, but non-transformist views were still accepted by conservative scientific circles and conservative thinkers still explained the adaptation of species using the idea of special creations or the wisdom of the Creator. Therefore Darwin had to confront natural theology, i.e. the religious outlook that relied on the argument from design.

The framework of the discussion was based on the *world↔machine* and the *body↔machine* metaphors. Darwin was particularly influenced by the ideas of Paley, who had argued that nature and the body are "more artificial" and sophisticated than any other machine. According to Paley, the purposes of organs are more evident than the purposes of any other mechanism. The eyelid, for instance, protects the eye, wipes it and closes it in sleep. Paley pointed out that "The machine, which we are inspecting, demonstrates, by its construction, contrivance and design. Contrivance must have had a contriver, design, a designer." Finally, using the framework of the technological metaphor, Paley and the traditional philosophers concluded that the Divine Artificer designed the *world↔machine* and the *body↔machine* (Paley 1802: 14, 19, 36, 99). Nonetheless, the radical currents tried to transform the *Artificer* himself to a mechanism and Darwin was influenced by them.

Radical theories of transformism became very popular in Britain of the 1830s and the teleological explanation gradually declined, but most theories of transformism before Darwin were not entirely free of teleological thinking. Even Darwin himself did not entirely dispose of teleology, although he reduced it to a mechanism of efficient causes. Darwin's thought gradually detached from teleological thinking. He was convinced that the required solution to the problem of adaptation had to match the standards of the mechanical sciences and the *vera causa* principle. As an efficient cause the mechanism of natural selection can be summarized as follows:

<u>The mechanism of natural selection as an efficient cause</u>

- *Premise 1*: there is a variability of characters; over time new variations of characters may appear in different populations; the mutability of living beings and species.

- *Premise 2:* these characters are passed from parents to their offspring; the variations are hereditary.

- *Premise 3*: external conditions, such as permanent short of available resources (e.g. food, space, and mates), lead to competition among individuals; the "Struggle for Existence".

- *Conclusion*: "survival of the fittest" (as entitled later by Herbert Spencer and adopted by Darwin in a later edition of the *Origin*); the individuals which are the most fitted to external conditions will be able to survive and reproduce and their offspring will carry the favorable traits and become successful; as a result the most fitted characters will become more common in the population; eventually the unfitted individuals and the unfitted characters will have difficulties to survive and become extinct (natural selection of characters).

Darwin's approach was based on the mechanistic perception and on the characteristics of industrial society. The empirical data he gathered during the voyage of the *Beagle*

(1831-1836) and the developments in the science of his age helped him to establish a mechanistic framework of transformism and adaptation. In this context we can note the developments that occurred in comparative anatomy during the 1830s and the developments in paleontology and geology. Darwin, for example, was especially influenced by Charles Lyell's book *Principles of Geology* (published in three volumes between 1830 and 1833), which promoted the idea of *Uniformitarianism*: according to Lyell, geological evidence on the past should be explained by the same natural laws which can be studied in the present, and not thorough miracles or speculated laws which supposedly only existed in the past (Lyell 1872). We will see that the idea of natural selection manifested the political economy of industrial capitalism. The principles that guided Darwin in the construction of the theory of evolution included the principle of fragmentation, efficient causes, the Newtonian exemplar, the principles of artificial selection and the economic principles of Thomas Malthus and Adam Smith. Darwin was inspired, of course, by former theories of transformism, especially by the theories of Lamarck, Geoffroy, Buffon, and his grandfather - Erasmus Darwin. Finally, on the social-spiritual level Darwin was also influenced by the enlightenment idea of progress and to some degree by romantic ideas.

The mechanism of natural selection is based on efficient causes, as demonstrated above. Practically Darwin got rid of teleology, although residues of the first mechanistic phase still resonated in his view. Under the influence of the Newtonian philosophy he adopted the vera causa principle. For example, in the conclusion of the *Origin* Darwin criticized those who still offered explanations which are based on the "plan of creation". In doing so, claimed Darwin, they re-stated the facts about the adaptation of organisms without explaining the phenomenon. In this context, Darwin was puzzled by naturalists who believed that some species are the results of "special creations" while others are the results of "variations":

> Nevertheless they do not pretend that they can define, or even conjecture, which are the created forms of life, and which are those produced by secondary laws. They admit variation as a *vera causa* in one case, they arbitrarily reject it in another, without assigning any distinction in the two cases (Darwin 1872: 423).

Darwin rejected this hybrid explanation, which unlike his own explanation did not meet the standards of the vera causa principle. He compared his law of natural selection to Newton's law of gravity, and the criticism of his rivals to Leibniz's criticism on gravity. Wallace also compared Darwin to Newton and the theory of natural selection to the theory of gravity (Darwin 1872: 421 – 422; Wallace 1889: 9). Darwin adopted the Newtonian values through the philosophy of John Herschel and the philosophy of William Whewell. Let us examine other mechanistic and industrial aspects which were found in Darwin's outlook and work. The importance of artificial selection to the idea of natural selection was connected to the industrial revolution in Britain. A central part in the industrial revolution was the industrialization of agriculture and the development of breeding and selection techniques for increasing the production of crops, milk and meat. It should be noted that in the surroundings of Darwin, his uncle and father-in-law, Josiah Wedgwood II, was a breeder (Ruse 2004: 12). The technique of artificial selection served as an explicit model for natural selection in the *Origin*. According to Darwin's metaphor, in the struggle for existence certain individuals and traits are favored by the physical conditions in nature. In this metaphor nature takes the place of the human breeder who uses selection to increase the frequency of desirable traits in domesticated animals for his own benefit (even if sometimes he does so unconsciously). Nevertheless, unlike in the process of artificial selection, in natural selection purpose and a design by an intelligent being are absent or at least they are not required (Darwin 1872: passim).

Fragmentation was a key element of the industrial-capitalist approach. We will immediately see that under the influence of capitalist philosophers and the biologist Milne-Edwards, Darwin explicitly used in the theory of evolution the idea of specialization, i.e. the division of labor. In the metaphor of natural selection populations of organisms replicate the relationship of individuals within the capitalist-industrial society: these populations are decomposed into individuals who struggle against each other and against the external conditions. According to Darwin, intra-specific competition between members of the same species is one of the main driving forces of evolution and in fact competition is "*most severe between Individuals and Varieties of the same Species*" (Darwin 1872: 59).[74] Furthermore, Darwin started a trend in which the adaptation of the organism itself was broken into pieces, especially by the neo-Darwinians in the 20th century who tried to show that natural selection works on unitary traits (see, for example, the biological critique on neo-Darwinism in the famous article of the biologists Stephen Gould and Richard Lewontin (1979)). Fragmentation and specialization characterized Darwin's biological approach. In fact Darwin's program was part of the second mechanistic phase. For example, Darwin developed a theory of heredity which was intended to support the mechanism of natural selection. This theory was based on the reduction of heredity to atomic units, or *gemmules*, which work according to a mechanistic model (Darwin 1868, vol. 2: 357 – 404).

Darwin's outlook was materialistic and to some it was also characterized by determinism (although his theory was based on chance variations). For example, in a notebook from 1838 Darwin asserted that thoughts and especially desires are the result of the hereditary structure of the brain (Darwin 1987 [1838]: 291). In a note of irony, Darwin paraphrased the entreaty of the Scottish naturalist John Fleming to the materialist to read the ideas of the Scottish anatomist John Barclay on *life and organization* (Barclay 1822). This remark was probably related to the days Darwin spent in Edinburgh. Notice that in this passage Darwin expressed the view of the mechanists and materialists who developed the second mechanistic phase:

> Why is thought. [,] being a secretion of brain, more wonderful than gravity a property of matter? It is our arrogance, it our admiration of ourselves (Darwin 1987 [1838]: 291).

Elsewhere in his notebooks Darwin clarified again that passion, ill-humor and depression have bodily causes and that emotions, instincts and degrees of talent are hereditary. Materialism, he wrote, is evident even in the simple case of a glass of cold water which may cause the appearance of what is considered to be spiritual feelings. Furthermore, Darwin rejected the idea of free will: every action, he claimed, is determined either by heredity, or by the example of others and the teaching of others. In another collection of notes, Darwin defined thought as a function of an organ: thought is produced by the brain just as bile is produced by the liver. Darwin pointed out that this materialistic view does not have to be equated with atheism. Following Lamarck, Darwin proclaimed that the laws which govern the organic matter and the body differ from the laws which govern inorganic matter. In other words, like many other materialists and mechanists, he emphasized the autonomy of life sciences from the physical sciences (Darwin 1987 [1838-1840]: 524, 526, 533, 610 – 611, 614).

The political economy of industrial society had a great impact on Darwin's theory. One can find in Darwin's work of all of the main characteristics that Adam Smith described in his socio-economic model: fragmentation (division of labor/specialization), competition in the free market and the invisible hand (Smith 1981 [1776]). Darwin was practically influenced by the famous work of the English economist Thomas Malthus, *An Essay on the Principle of Population* (1817 [1798]). He read the book in 1838 before he conceived the mechanism of natural selection. In his book Malthus explained and predicted that the overpopulation of the earth will be ultimately balanced as a result of the limited availability of food and other recourses. According to Malthus, the population increases in a geometrical ratio while food increases by arithmetic progression only, and thus when there are not enough resources for the entire population death rate increases by starvation, epidemics and wars. He concluded that the results of these "struggles for existence" are death as a punishment of defeat and life as a prize of victory (Malthus 1817 [1798]: 136). Darwin adopted the doctrine of Malthus and applied it "to the whole animal and vegetable kingdoms". According to this metaphorical view, there is a constant "Struggle for Existence amongst all organic beings throughout the world, which inevitably follows from the high geometrical ratio of their increase". Darwin himself was partially aware that he uses the phrase "struggle for existence" in a "metaphorical sense" (Darwin 1872: 3, 50).

It is important to stress that Darwin was not exposed to the influence of a single work, but to an entire culture that began to shape his perception long before he read the book of Malthus. Charles Darwin was born to a family of industrialists, capitalists and men of the enlightenment who believed in the idea of progress. He was the grandson of Erasmus Darwin and Josiah Wedgwood. We already saw the connection of Erasmus Darwin to the mechanistic perception and to the industrial world. The other grandfather of Darwin, Josiah Wedgwood, was an important industrialist who contributed to the industrial revolution through the pottery business. He and Erasmus were members of the Lunar Society that endorsed social and scientific progress and the capitalist worldview in the spirit of Adam Smith. With regards to the scientific education of Darwin, we know that the young Darwin acquired knowledge in chemistry and that he dropped-out of the medical school in Edinburgh. At this stage of his life, he also studied zoology by himself and he was exposed to Robert Grant's ideas of transformism. Afterwards, he learned at Cambridge and was influenced by the conservative ideas of Sedgwick and Lyell, although one can find the idea of biological progress already in his earlier notes. Darwin thought that "There must be progressive development". He perceived the species as "living atoms" which are shaped by progressive development: this process directed the evolution of species from the infusorians, i.e. the oldest, simplest organisms that practically remained unchanged, to the mammalians, i.e. the youngest and most complicated living beings which were formed through greater number of "changes towards perfection". Like Chambers, he described a gradual development of the mind from the instincts of rodents, through dogs, elephants and monkeys, and to the human mind which is subdivided into the "unequally developed" brains of the different races of man. Yet the evidence on geographical isolation of populations, e.g. the case of the Galapagos Islands, influenced Darwin in the development of an evolutionary theory which was based on a branching tree model and not on the traditional uni-linear model of progression. Decades later, influenced by an article of Wallace, Darwin expressed in his writings racial and sexist Victorian values. For example, according to Darwin, the mind was modified in the later ages more than the body due to the struggle between the races of man; men are more courageous, aggressive, energetic and inventive than women because men were more exposed to sexual selection; women, on the other hand, are more caring than man and less selfish. Darwin also made a connection between the progress of "civilised countries"/"civilised races" and the positive effects of capitalism. The idea of progress was part of the Darwin-Wedgwood family's values (the values of his grandfathers, his uncle and father-in-law Josiah Wedgwood II and his older brother Erasmus), although Darwin was also influenced by philosophers like Auguste Comte. Finally, in 1838, the year Darwin conceived the mechanism of natural selection, he read not only Malthus, but also the work of the Scottish philosopher and mathematician Dugald Stewart, *Account of the Life and Writing of Adam Smith*, in which progress is directly linked with the values of the free market (Ruse 1996: 136 – 159).

Specialization and the division of labor can be identified in the heart of the mechanism of natural selection. Already at the end of the 1820s Milne-Edwards adopted the ideas of Adam Smith. He identified a biological progress which is based on the same principle as the "progress of human industry and technology: *the division of labour*". According to Milne-Edwards, the progress that characterizes the scale of being is the result of an increase in specialization: on the bottom of the scale one can find gross and imperfect organisms which are less specialized and on the top of the scale one can find elevated and perfect organisms which are more specialized. Darwin accepted the principle of Milne-Edwards and claimed that "No naturalist doubts the advantage of what has been called the 'physiological division of labour;'". He explained that under competitive conditions the species evolve through specialization and exploitation of different niches. Thanks to the division of labor the *economy of nature* is just as efficient as the physiological economy of organs and as social economy (Milne-Edwards 1863: 189 – 191; Darwin 1872: 59, 74, 89, 97; Ruse 2004: 13; Ruse 1996: 159 – 161). Darwin explained this in the *Origin*:

> The advantage of diversification of structure in the inhabitants of the same region is, in fact, the same as that of the physiological division of labour in the organs of the same individual body—a subject so well elucidated by Milne Edwards. No physiologist doubts that a stomach adapted to digest vegetable matter alone, or flesh alone, draws most nutriment from these substances. So in the general economy of any land, the more widely and perfectly the animals and plants are diversified for different habits of life, so will a greater number of individuals be capable of there supporting themselves (Darwin 1872: 89 – 90).

Darwin adds:

> If we take as the standard of high organisation, the amount of differentiation and specialisation of the several organs in each being when adult (and this will include the advancement of the brain for intellectual purposes), natural selection clearly leads towards this standard: for all physiologists admit that the specialisation of organs, inasmuch as in this state they perform their functions better, is an advantage to each being; and hence the accumulation of variations tending towards specialisation is within the scope of natural selection (Darwin 1872: 98).

Compared to his earlier view, Darwin had gradually adopted a softer version of the progressionist view of nature. Although he wrote in the *Origin* that natural selection works for the good of each being, he clarified that natural selection "does not necessarily include progressive development", but only a development which works for the adaptation of the living being in the conditions of its existence. Darwin explained that unlike Lamarck he did not need to use the special and unfounded assumption of spontaneous generation in order to explain the existence of lower forms of life: since Lamarck believed in the innate tendency of organic beings towards perfection, he had to assume a continuous production of simple forms by spontaneous generation, otherwise they would have disappeared. The overtly organic and teleological residues in the Lamarckian theory disturbed Darwin. He rejected Lamarck's idea on the innate tendency of organic beings towards perfection. Already in his notebooks from 1837 Darwin declined Lamarck's "willing doctrine" and called it "absurd". Indeed, Darwin provided an evolutionary role to the mechanism of inheritance of acquired characters: in the *Origin* he refers to the "use and disuse" of parts as a central force in inheritance and evolution, i.e. as a force which involves in the production of varieties and the production of distinct species. Nonetheless, in comparison with Lamarck, Darwin suggested a more mechanistic version of the inheritance of acquired characters, which was not based on an inner teleological mechanism. Darwin's version was based only on "direct and definite effect" of "physical conditions" on the use and disuse of organs. The blind animals that inhabit the dark caves of America and Europe were formed in this manner (Darwin 1872: 98, 415, 428; Darwin 1987 [1837]: 224 – 225).

Similar to Darwin, Wallace was influenced by the work of Malthus. The theories of Darwin and Wallace balanced the pessimistic conclusions of Malthus, and even reversed them, by the belief in progress. One cannot separate between social and biological progress in the views of Darwin and Wallace. Wallace wrote, for example, that, due to the effect of an unequal mental and physical struggle, the better and higher among the white race would increase and spread and the lower races (i.e. the Red Indians, the Tasmanians, the Australians and the New Zealanders) will inevitably die out. Darwin highlighted these passages and praised Wallace in a letter he sent him. As we have seen before, Darwin himself had similar thoughts on racial progress, and yet he was not absolutely sure that the noble Scotts will win in the struggle for existence against the inferior Irish. The connection between social and biological progress was evident in the worldview of other noted advocates of the theory of evolution. During the 1850s, for example, the English intellectual Herbert Spencer developed a proto-evolutionary theory that blended social and biological progress. The theory included references to the effects of the Malthusian pressure (i.e. the struggle for existence / the struggle over resources), and to the physiological advantages of the division of labor. Yet Spencer believed that transmutation of species takes place through the inheritance of acquired characters. Likewise, Thomas Huxley's outlook combined social and organic progress. When the earlier Huxley criticized Chamber's *Vestiges* he actually attacked the progressionist view. Later, when Huxley adopted the Darwinian Theory, he combined it with elements of the progressionist worldview. According to the updated view of Huxley, nature progresses from the formless to the formed, from the inorganic to the organic and from the blind force to the conscious intellect and will. Huxley thought that conscious intellect depends not just on the characters of the species, but also on the characters of the race and gender. In this context, he argued that although some black men are better than some white men, the average white man is superior to the average black man. For him, the struggle for existence was a law which governs both the intellectual and the physical spheres. For example, in 1863 Huxley wrote: "The advance of mankind has everywhere depended on the production of men of genius; and that production is a case of 'spontaneous variation' becoming hereditary, not by physical propagation, but by the help of language, letters and the printing press" (Ruse 1996: 160 – 161, 181 – 214).

The above analysis reveals the industrial-mechanistic origin of Darwinism and natural selection. Nonetheless I want to relate to a dispute between Ruse (2004; 2003) and Richards (2004; 2003) concerning the origin of Darwin's ideas. This debate is very much relevant to my argument on the hybrid development of scientific knowledge, which follows the hybrid development of techno-cultural environment as described by McLuhan. While Ruse contends that Darwin was mostly influenced by the capitalist-industrial environment of 19th century Britain, to which Darwin and his family were directly linked, Richards contends that Darwin was influenced by the romantic German thinking of his age. According to Richards, Darwin adopted a romantic view that defined nature as a purposeful, living super organism. Darwin embraced this view through reading and through personal influence of Romantic thinkers, such as the Prussian traveler and scientist Alexander von Humboldt and the English anatomist Richard Owen. Through the writings of von Humboldt, Owen, and Whewell, Darwin was influenced by the work of Goethe on morphology. Richards further remarks that in the third edition of the *Origin* Darwin credited Goethe, along with Lamarck and his grandfather Erasmus, for developing the idea of transformism. Thus Darwin constructed natural selection as a romantic force creatively and progressively working for the good.

Indeed Darwin admired Humboldt and was greatly influenced by his work. Darwin and Humboldt corresponded and Humboldt recognized the great importance of Darwin’s work. In his book *Cosmos* (Humboldt 1997 [1858]) Humboldt relied on the early publications of Darwin. Nevertheless, concerning this particular dispute between Ruse and Richards I tend to agree with Ruse, as can be understood from what I have already written about natural selection: more than anything else Darwin's theory of evolution and natural selection was based on the mechanistic metaphor and the industrial order. Furthermore, as a force that progressively working for the good, natural selection was based on the enlightenment idea of progress in general and not just on romantic ideas. But why should Richards' observations surprise us at all? Even Ruse himself does not entirely reject Richard's thesis and admits the presence of some *romantic* elements in Darwin's view. Ruse emphasizes that Darwin was influenced mostly by British natural theology rather than German Romanticism. For instance, among the traditional theories of transformism that influenced Darwin was the theory of his grandfather, Erasmus, “who linked his religious beliefs explicitly with his belief in an upward evolutionary process.” (Ruse 2004: 10).[75] We have seen that for Darwin progress was tightly linked with the political economy of industrial society, and as I have explained before, the idea of progress developed on the ground of print culture and the industrial revolution. Therefore, more than anything else, the Romantic notion of *progress* says something on the relations of the Romantic Movement and the industrial world. Humboldt himself was a student of Blumenbach and a colleague of Cuvier. Lenoir (1989: 17, 55 – 56, 70, 168) defines him as one of the teleo-mechanists.

- What, then, was Humboldt’s position on the mechanistic program? I would like to argue that not only Darwin was highly influenced by the mechanistic order, but also Humboldt: although Darwin's view was obviously more mechanistic than Humboldt's view, Humboldt himself did not hold an anti-mechanistic view, as Richard tries to portray him. Quite the opposite, Humboldt happily accepted the mechanical development and the industrial revolution.

Richards claims that during his voyage on the *Beagle* Darwin read and adopted “Humboldt’s Romantic conception of nature”. Humboldt developed his romantic conception under the influence of Goethe with whom Humboldt had close relations. The nature of Humboldt, according to Richards, was not “mechanically contrived”, but vitally alive, and it was full with aesthetic and moral values (Richards 2004: 31). Conversely, I would like to argue that Humboldt's romantic view was much more *heteroglotic* (If I may use the term of Bakhtin, which I mentioned in the previous part) and it contained the scientific, mechanical view of the universe. Humboldt, who was born in 1769 and died in 1859, articulated in his view the last breaths of the first mechanistic phase. We have seen it before in relation to the vitalists and we will see it now in relation to the romantic view of Humboldt: the growing impact of the mechanistic order and of the industrial society was deep and trans-paradigmatic.

I will use a famous book written by Humboldt to demonstrate this point (Humboldt 1997 [1858]). The five volumes of Humboldt's popular book, *Cosmos*, which were published between the years 1845-1862, contain the scientific knowledge of Humboldt's time, along with the impressions and knowledge he gained from his explorations around the world. First, it is interesting to note that God is not mentioned in *Cosmos* although the book is dedicated to a detailed sketch of the earth, of life and the universe. The absence of God from the book raised a controversy over the issue. Critics who held a traditional view wondered how someone could write a book on the creation without any reference to the argument from design or to the power and wisdom of the Supreme Artificer. Humboldt, however, adopted the approach of the new mechanical sciences in which God and the final causes were taken out of the scientific equation of the universe. In the French translation of *Cosmos* Humboldt explains that issues which are beyond the material world cannot be regarded as part of physics and therefore they should be discussed in their own terms (see N. Rupke review in Humboldt 1997 [1858], vol.1: xxiii – xxvi).

Humboldt was a student of Blumenbach and his work was part of the first mechanistic phase. The description of the universe, as it appeared in *Cosmos*, was based not only on a “romantic view”, but also on the industrial values and the mechanical sciences of Humboldt's time. In the introduction to the book, Humboldt declared that science has an inward aim, similar to philosophy, poetry and the fine arts. This inward aim of science is the ennoblement of the intellect. In fact, science, according to Humboldt, deals with:

…the laws and the principles of unity that pervade the vital forces of the universe; and it is by such a course that physical studies may be made subservient to the progress of industry, which is a conquest of mind over matter (Humboldt 1997 [1858], Vol. 1: 53 – 54).

These words articulated a romantic approach to the industrial revolution and the world of applied knowledge. In his book Humboldt praised the industrial and economical progress and the prosperity of the “mechanical arts” and described them as a result of intellectual and political progress. Humboldt contended that all branches of natural sciences are equally important to one another and to the industrial progress, including the study of living organisms, as the experiment of Aloysio (Luigi) Galvani on the frog's nervous fibers demonstrated. This experiment had eventually led Galvani's colleague, Alessandro Volta, to invent the voltaic pile (the first electric battery). Thus Humboldt tied together the study of the organic world and mechanical and industrial development (Humboldt 1997 [1858], Vol. 1: 52 – 54). His empathic approach to the mechanical universe is also evident in other sections of the book. Humboldt, for example, praises Pierre Laplace's famous model of the universe and the solar system which was purely mechanical. Laplace's work, according to Humboldt, is “an immortal work”. Humboldt was not concerned that “the structure of the heavens is here reduced to the simple solution of a great problem in mechanics” (Humboldt 1997 [1858], Vol. 1: 48). Recall the well known incident in which Napoleon wondered where exactly God is in Laplace's description of the universe? Laplace replied to Napoleon that he did not need God as hypothetical entity in order to construct a mechanical model of the universe. As I’ve already noted, a similar question was posed in relation to Humboldt's *Cosmos*. Moreover, Humboldt did not even seem to be bothered by the second mechanistic phase and by the industrial theory of the cell, e.g. the mechanistic explanations of Schleiden in relation to the physiology of plants (Humboldt 1997 [1858], Vol. 1: 340 – 342). In these pages too Humboldt ties together all branches of natural sciences. He reminds the reader that the structure of animals and the structure of plants are composed of the elements of earth, and then he adds:

A physical cosmography would therefore be incomplete if it were to omit a consideration of these forces, and of the substances which enter into solid and fluid combinations in organic tissues, under conditions which, from our ignorance of their actual nature, we designate by the vague term of *vital forces*… (Humboldt 1997 [1858], Vol. 1: 340 – 341).

These are surely not the words of an anti-mechanistic intellectual, neither in relation to science in general nor even in relation to biology.

Techno-cultural environments, theories, outlooks and beliefs are formed in a hybrid manner. Accordingly, the ideas of Humboldt and the older generation echoed in the industrial solution of Darwin. Indeed, Darwin's theory preserved residues of romantic ideas, but it also reduced the *romantic* progression via mechanistic forces. In the conclusion of the *Origin* Darwin wrote:

And as natural selection works solely by and for the good of each being, all corporeal and mental endowment will tend to progress towards perfection (Darwin 1872: 428).

The final cause in the Darwinian Theory became an end state of a series of efficient causes. A similar approach was already found in the work of Erasmus Darwin, but Charles Darwin articulated this view more clearly: unlike the semi-mechanistic theory of Erasmus, Charles Darwin's theory of evolution was based on a systemic industrial framework that explained the achievement of desirable end states through a mechanistic force, i.e. natural selection. One can notice that over time Darwin's perception had become more mechanistic. As Ospovat describes, between the 30s and the 50s, Darwin gradually detached from the teleological thinking. He rejected the approach of Cuvier and the approach of Natural Theology, which explained the "perfect" adaptation of living beings to the conditions of existence through purposeful forces and through the actions of the Divine Artificer (Ospovat 1981; Appel 1987: 230 – 232). In the famous passage that ends the conclusion of the *Origin*, Darwin describes the liveliness which characterizes nature, the great variety of plants which grow on the planet, the singing birds, the variety of flitting insects and the complexity of life on earth. This complexity, he clarifies, is produced by the laws of reproduction and inheritance (Darwin later developed the mechanistic theory of gemmules in order to account for the phenomena of reproduction and inheritance), variability (which is the direct and indirect result of the conditions of life and the use and disuse of organs), the struggle for life and natural selection: “Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows.” Darwin eventually became an agnostic, but in this paragraph he refers to laws which produced life as a mechanism which was “originally breathed by the Creator”. He emphasizes that the beauty and magnificence of life can be explained by these laws: due to them endless beautiful life forms are been evolved out of the simple beginning, while the planet continues to rotate regularly according to the fixed law of gravity. In another passage of the conclusion Darwin emphasizes again that selection is the force that brings beauty to the world. Following his grandfather, Darwin describes sexual selection, i.e. the competition between members of the same sex over members of the opposite sex, as the mechanism which is responsible for the remarkable colors, patterns and ornaments of males and females in many bird species, butterflies and other animals (Darwin 1872: 414, 429).

The impact of traditional values was more evident in the work of Wallace than in the work of Darwin. Wallace was motivated by traditional and spiritual views that prevented him from entirely reducing humans via the mechanistic law of natural selection. In his essay *The Limits of Natural Selection as applied to Man*, Wallace argued that certain characters of the human species cannot be explained in terms of natural selection, e.g. the size and complexity of the human brain, the specialization and perfection of the human hand and the hairlessness of humans in comparison with other apes. Thus he used the notion of *Supreme Intelligence* in order to account for the evolution of the human species (Wallace 1973 [1870]: chap. X). Nevertheless, twenty years later, in *Darwinism applied to Man*, Wallace suggested a softened version of this view. He now claimed that despite the great differences between man and other apes, the evidence shows that the human body was derived from the ape body, and therefore he rejected the idea of special creation. Moreover, Wallace clarified the even the physical structure of the more developed human brain can be explained in terms of natural selection and common descent of man and apes, but not the intellectual abilities of humans, morality and spirituality, mathematical, musical and artistic abilities. While Darwin argued that morality and other human mental faculties were derived from the faculties of lower animals and developed gradually, Wallace argued that the explanation to intellectual and moral faculties of humans should be sought in the "unseen universe of spirit". Wallace did not find any connection between the spiritual faculties of humans and the biological advantages needed in the struggle for existence (Wallace 1889: chap. XV; see also Huxley's response to the ideas of Wallace, in Huxley 1970 [1871], vol. 2: chap. V).

- In a review dedicated to "the hypothesis that animals are automata and its history", Huxley identified the 17th century as the era in which certain classes of vital actions were proven to be physical-mechanical phenomena, e.g. the circulation of the blood. He argued that over time the mechanistic conception "has not only successfully repelled every assault which has been made upon it, but has steadily grown in force and extent of application, until it is now the expressed or implied fundamental proposition of the whole doctrine of scientific Physiology" (Huxley 1970 [1874], vol. 1: 199 – 200).

It is not surprising that Huxley became the most distinguished advocate of Darwin's theory which provided an industrial solution to the problem of adaptation. Huxley believed that modern science developed as an integral part of the industrial revolution. He claimed that "It has become obvious that the interests of science and of industry are identical." His biological view was shaped by the *body↔machine* metaphor. Under the strong influence of the second mechanistic phase, Huxley scorned vitalism and promoted reductionism. He argued that just as the properties of water are the result of the nature and disposition of its component molecules, the properties of the protoplasm are the result of the nature and disposition of its component molecules. Historically speaking he identified the mechanization trend. According to Huxley's description, William Harvey's work on the circulation of the blood was the first paradigm that demonstrated how vital processes can be explained in physical terms. Furthermore, Harvey's model of fetal development was an early prototype of physical explanations in the discipline of embryology. Following Harvey, Descartes suggested mechanical explanations to the phenomena of motion and sensation. The work of Descartes influenced and anticipated the work of 18th century physiologists, e.g. the work of Haller. 19th century physiologists, such as Dubois-Reymond and Helmholtz, corrected and updated the basic ideas of Descartes (Huxley 1970 [1887, 1868 and 1874], vol. 1: 54 – 56, 153 – 155, 199 – 250).

Man, according to Huxley's outlook, is both a mechanical and a moral being. As a young person Huxley wanted to be a mechanical engineer, but eventually he studied medicine. He was interested mostly in physiology, or as he defined it the "mechanical engineering of living machines". In a sense he thought of himself as if he really was a mechanical engineer through his career. Influenced by Descartes' outlook, he saw animals as automata (Vaucanson's automata), or as a superior race of marionettes controlled by reflex actions. Social behavior and altruism, e.g. among ants or bees, are actually "the perfection of an automatic mechanism, hammered out by the blows of the struggle of existence". Consciousness, according to Huxley, is the only difference between man and other *animal↔machines*. Man can develop an "artificial personality" (or "the man within", in the terms of Adam Smith), which enables him to overcome the non-morality and ruthlessness of the natural world. Nonetheless, in abnormal state, when the human brain is injured, no difference can be found between the *human↔machine* and other *animal↔machines*: the machinery continues to work without the intervention of consciousness. Furthermore, Huxley claimed that consciousness is a complex phenomenon that gradually evolved, from the lower forms of consciousness which animals possess (feelings, but not language and thoughts) to the human brain. Huxley, therefore, minimized the differences between humans and animals and put them on a continuous scale (Mazlish 1993: 141 – 146; Huxley 1970 [1874], vol. 1: 226 – 250; Harman 2010: 26 – 33).

Similar to Darwin and Wallace, Huxley compared the new theory of evolution to the theory of gravity. Both theories, he argued, manifested the progress and maturity of sciences. In the early days of astronomy "the planets were guided in their courses by celestial hands", and yet the references to the Creator explained nothing: in fact they only indicated an ignorance of the mechanism behind astronomical phenomena, since every phenomenon must be explained as a particular case of a general law of nature.

The motion of planets, as well as the motion of a stone thrown by a schoolboy, is explained as a particular case of the law of gravity. Since the concept of special creation of species did not provide any natural law, it explains nothing in biology. Natural selection, on the other hand, is a general law of nature. Huxley looked around on the strong trend of mechanization and noticed that even social phenomena are explained through general laws which are confirmed by evidence. For instance, the solvency of large mercantile companies is based on laws which govern the seeming irregularity of human life: plague, pestilence and famine are not the result of the wrath of God, but of natural causes which largely depends on human activity. At this point Huxley asked rhetorically: “Shall Biology alone remain out of harmony with her sister sciences?” (Huxley 1970 [1860], vol. 2: 57 – 59).

The technological metaphor is multi-directional. In 1863 *The Press* newspaper in New Zealand published a short satirical essay, *Darwin among the Machines*, under the pseudonym Cellarius. The English author who wrote the essay was Samuel Butler. Inspired by the *Origin of Species*, Butler perceived the evolution of machines in terms of the evolution of life. According to Butler’s description, the mechanical world evolved from the “earliest primordial types of mechanical life” (the lever, the wedge, the inclined plane, the screw and the pulley) to the machinery of the most advanced steam ship - the *Great Eastern*. Compared to the “slow progress” of organic life, the mechanical world develops rapidly. As a writer, Butler tried to imagine how these developments will affect the future of mankind. Following the evolutionary debate on the organisms that will inherent mankind in the future, he wondered whether “we are ourselves creating our own successors.” New inventions will improve the self-motive and self-regulating powers of the machines. These powers will serve the machines as intellect serves the human race. Eventually the human race will become an “inferior race”. Indeed the machines will be indifferent to human passions and morality, but Butler assured his readers that the machines “cannot kill us and eat us as we do sheep”, because “they will not only require our services in the parturition of their young (which branch of their economy will remain always in our hands), but also in feeding them, in setting them right if there are sick, and burying their dead or working up their corpses into new machines… The fact is that our interests are inseparable from theirs, and theirs from ours.” Butler continued to discuss the interrelationships of humans and machines in other writings, such as *Lucubratio Ebria* and *Erewhon*, and he also corresponded with Darwin. In the essay *Lucubratio Ebria* he defined tools and machines as “mechanical limbs” (i.e. extensions) that influence the evolution of the human body. Butler claimed, for example, that following the use of sticks for millions of years the primate ancestors of the human race “became accustomed and modified to an upright position”. He added that the improvement of the body was followed by the improvement of the mind and concluded that “the new limbs were preserved by natural selection”. We are not only the children of our parents, but also the “children of the plough, the spade, and the ship; we are children of the extended liberty and knowledge which the printing press has diffused.” The Rothschilds, for example, “are the most astonishing organisms that the world has ever yet seen”, since rich people have a “whole army of limbs” to fulfill their desires and a “motive power of a thousand horses” (Butler 1921 [1863 and 1865]: 42 – 53; Butler 1968 [1872]: 189 – 219: Mazlish 1993: 146 – 155).

The social implications of Darwinism were dramatic. For example, among the promoters of natural selection was Francis Galton. The famous cousin of Darwin was a statistician, an important biometrician and the founder of the eugenic movement. Galton’s view combined hereditarianism and Darwinism. In his book, *Hereditary Genius*, which was first published at 1869, Galton argued that “a man's natural abilities are derived by inheritance, under exactly the same limitations as are the form and physical features of the whole organic world”. His conclusion was that similar to the production of dog and horse breeds with special running abilities, a “highly gifted race of men” can be produced through selective marriages during several consecutive generations. This formula was the basis of eugenics and of hereditary determinism. Biometrics as well manifested the triumph of the second mechanistic phase. The mechanistic program of biometrics was based on fragmentation, systematic measurement, quantification and statistics: first a visible character of an organism is isolated, measured and quantified and then the character is studied within a population through statistical analysis. Galton and his student Karl Pearson studied hereditary patterns of characters using the biometric method. A dispute about selection divided the biometricians between those who supported the gradual evolution of Darwin and those who believed in big evolutionary jumps. If Darwin is right, natural selection works on small variations of the hereditary material and leads to a gradual evolutionary change. Galton had statistically analyzed Darwin’s hypothesis and eventually came to a conclusion that large-scale variations of the hereditary material are needed in order for selection to be effective. On the other hand, many biometricians claimed that Galton was mistaken in his calculations and Darwin was correct. The theory of large scale variations was further promoted by the Dutch botanist Hugo de Vries and the English biologist William Bateson at the end of the 19th century and the beginning of the 20th century. Both of them had a major role in the adoption of Mendelism, the new mechanistic paradigm of the science of heredity. In any case, the rivalry between the competing theories manifested the supremacy of the second mechanistic phase with regards to the field of evolution and adaptation (Galton 1962 [1869]: especially page 45; Jablonka and Lamb 2005: 22 – 24; Allen 1978: 42 – 47).

Due to its social, moral, religious and ideological implications, Darwin's theory had caught the public's attention. The general public was not familiar with the details and with all the scientific and philosophical aspects of the debate over the theory of Darwin. The focus was rather on the debate over the descent of man and on the religious and social implications of this issue. Both Darwin and Chambers contributed to the reception of the idea of evolution by the general public: the popular book of Chambers was more appealing to the general reader, but on the other hand Darwin had much greater authority and much more intellectual allies in the scientific community. A few years after the publication of the *Origin*, the idea of evolution became more and more accepted by the scientific community and the general public. By the 1870s evolutionism, which became known as *Darwinism*, prevailed. Yet, most scientists in the last decades of the 19th century did not accept natural selection as the principal mechanism of evolution: many of them ascribed natural selection a minor role in evolution or searched for alternative explanations. Even Huxley had doubts about the validity of natural selection. He admitted that the law of natural selection was not well established and that its status would be determined only in the future by empirical evidence and experiments, e.g. selective breeding resulting in varieties infertile with one another. Neo-Lamarckian mechanisms were proposed in Britain, France, Germany and the US. The term *Neo-Lamarckism* itself was coined in 1885, but the "neo Lamarckians" were not able to develop a fundamental theory or a unifying paradigm. They agreed only on the basic principle that adaptation is produced by use and disuse and by the inheritance of acquired characters. Some neo

Lamarckians even believed in the existence of teleological, internal forces that make evolution a progressive process. The neo-Lamarckians failed to become a dominant force mainly because they did not have a convincing model of heredity (Ellegard 1990; Bowler 2003: 177 – 244; Huxley 1970 [1893], vol. 2: vi; Jablonka and Lamb 2005: 21 – 22; Gissis and Jablonka 2011).

Notice that in general the neo-Lamarckian theories detached from the "willing doctrine" and the inner teleological mechanism of transmutation which were found in the theory of Lamarck. The neo-Lamarckians were taking part in the gradual separation from the organo-mechanical perception. Biologists like Darwin or Ernst Haeckel suggested interpretations of the inheritance of acquired characters that were more mechanistic. Yet the mechanistic perception peaked only later when Mendelism and Neo-Darwinism took the principle of fragmentation one step further and separated between the influence of the environment and the action of hereditary factors. Already during the last decades of the 19th century, August Weismann laid the foundations of the new approach.

- The Darwinian Theory was supported by the leading German biologists who made the second mechanistic phase predominant. Darwinism helped to complete the materialistic view and to strengthen the mechanistic framework of the new biology.

Carl "monkey" Vogt became one of the most distinguished advocates of Darwinism. Before the publication of Darwin's theory of evolution, Vogt was unimpressed, to say the least, with the theories of transmutation: the idea of a Divine Artificer who creates, destroys and rebuilds the world was "repugnant" to him, but he admitted that he had no convincing explanation to the formation of species. The development of the Darwinian paradigm provided Vogt with a solid alternative which reinforced the mechanistic-materialistic framework. All organisms evolved from primeval singled-celled organisms through the laws of heredity, the struggle for existence and natural selection. In fact, natural selection produces the same results as artificial selection, but at a slower rate, because in artificial selection certain favorable conditions are constantly maintained by man in order to achieve a certain effect. Man, he emphasized, is not exceptional: even "the highest product of a progressive natural selection" is just a descended of the simians (Vogt 1864: 409, 446 – 469).

The impact of the techno-cultural environment was evident. Mechanistic, progressive, racist and sexist views continued to characterize biological and evolutionary theories. In his lectures Vogt specifically referred to the measurement of skulls made by researchers such as the German archaeologist Friedrich Welcker. He claimed that in many respects the female skull resembles the skull of infants and the skull of lower races. As slaveholders know, due to the infantile mentality of the *Negro* "slaves must be treated like neglected and badly brought up children". According to Vogt, the work of Welcker and others confirmed that the differences between the sexes increase as the race develops. Yet, he added, more observations are needed in order to prove with certainty that "the inequality of the sexes increases with the progress of civilisation". The characteristics of earlier stages of the race are preserved in the formation of the female head, and indeed females are the preservers of old customs, practices, traditions, legends and religion. It is important to emphasize that the progressionist outlook of Vogt was shaped by the characteristics of industrial society. He claimed that in cultures of lower *races*, e.g. the Australians and the Bushmen, there is no difference in the occupation of both sexes, while in the *civilised nations* "there is a division both in mental and physical labour". For him it was an indication that the mode of life has an influence on the development of the race in general and in this specific case on the development of the brain (Vogt 1864: 81 – 82, 171 – 202)

The popular work of the scientific materialists, Vogt, Moleschott and Buchner, had a great influence on the German public during the second half of the 19th century. Moleschott and Buchner supported Darwinism, although they thought that Darwin overstated the importance of natural selection. The scientific materialists believed that Darwinism opened new horizons that reinforced the mechanistic framework of biology and the materialistic worldview, on the expense of the teleological and theological thought. Their attitude towards natural selection was more complicated: it seemed to them that the mechanism of evolution cannot be reduced to natural selection because they believed that nature, evolution and society are directed by the principle of progress and not by pure chance (Gregory 1977: 38, 159, 175 – 188; Vogt 1864).

Darwinism was also promoted by the eminent students of Müller who made the reductionist approach in biology predominant, e.g. Schleiden, Helmholtz, Reymond and Virchow (see, for example, Virchow 1958 [1877, 1898]: 145 – 148, 220). Yet, Albert von Kölliker, one of the noted students of Müller, accused Darwin of being a "Teleologist" who believes that every part in the structure of the body was created for the benefit of the animal. Conversely, argued Kölliker, varieties appear according to the general laws of nature, with no relation to purpose or utility, and they may be useful, hurtful or indifferent. He called his hypothesis the "theory of heterogeneous generation". According to this theory, a general law determines the organism's course of development. Under certain circumstances an alternate generation may take place, thus producing new forms of organisms. Kölliker admitted that he does not know how the law of development operates and what factors exactly influence eggs and germs to produce the new forms. Yet, from Kölliker criticism on Darwin we can conclude that he aspired to develop an un-teleological theory of evolution within the mechanistic framework. Huxley was called to defend Darwin. He claimed that Kölliker misinterpreted Darwin, and in fact: "Teleology… had received its deathblow at Mr. Darwin's hands". Contrary to the interpretation of Kölliker, Darwin did not argue that organisms were purposely evolved to fit certain conditions. Huxley clarified that Darwin's view was un-teleological: out of a variety of organisms only those possessing advantages against competitors, and only those whose characters are adapted to the surrounding conditions, will continue to exist. The clash between the Darwinian metaphor and Paley's watch analogy was clear. According to Huxley, Darwin's solution made the argument from design, and Paley's watch analogy, irrelevant. In fact the theory of evolution demonstrated that the *watch* in Paley's analogy was not made by an intelligent being, but by a long process of modifications. At first there were only rudiments. Then simple forms evolved, but they were not similar to a watch. At a later stage, new structures evolved, but they cannot be defined as real watches since they had no figures on the dial and their hands were rudimentary. These structures were modified, until inaccurate watches appeared and then more accurate and complicated watches. All these changes are the result of (a) a tendency of the structure to vary indefinitely (b) a process of trial and error under certain conditions which create a preference for time accuracy. Evolution works through unintelligent agents, and therefore Paley's argument falls down and teleology becomes unnecessary. For the teleologist each organism is a bullet fired straight at a mark, but for Darwin organisms are grapeshot of which one hits something while the rest fall wide, e.g. cats that are better fitted than their competitors to catch mice (Huxley 1970 [1864], vol. 2: 80 – 98).

Karl Ernst Von Baer (1792-1876), the old representative of the first mechanistic phase, still tried to defend an updated version of transformism which did not deviate from the teleo-mechanical tradition. The young von Baer believed in the mutability of species and suggested a teleo-mechanical model of transformism. In his later days he was in opposition to Darwin. Von Baer was not able to break free from the traditional progressionist view of enlightenment, as he explained in a letter to the young German Darwinist Anton Dohrn:

> …I cannot deny mutability, in favor of which I expressed myself even before Darwin. However, I cannot declare myself at all in favor of Darwin's explanation of mutability, i.e., for the theory of selection, but I oppose it. It departs from the idea or thought that in nature reason cannot be effective; whereas I cannot break away from my old view that nature reasons and strives toward goals, whether immanently or transcendentally. If someone wishes to have circles drawn as correctly as possible, and chooses the best ones from millions of trials that have been drawn freehand, these will still not be as perfect as those done with a compass, that is, when with a purposive necessity a curve is guided in an always equal distance around a single point. The second method will therefore achieve its goal better than selection, which has to reject an immeasurable number of attempts (Von Baer 1875, in Baer and Dohrn 1993: 80).

Von Baer's criticism focused mainly on the mechanism of natural selection and on the claim that different classes, such as fish, birds, reptiles and mammals, share the same origin. He rejected the Darwinian view, since it was based only on chance variations and "the success of material influences", and stuck to the teleo-mechanical alternative. His theory was based on the connection between evolution and fetal development. Von Baer defined evolution as "a development, a progress toward a goal", or as "a process which leads to a determinate goal". According to his description, a strong productive force appears after conception and thus the early stages of development are characterized by numerous and rapid changes of form.

Eventually, at the following stages, the form of the main structures is fixed and stabilized. The evolution of species works in the same way: in the past the productive force was stronger and therefore many new forms evolved, while at the present age the productive force is weaker and therefore variations are small and new forms of life do not evolve. Moreover, according to Von Baer, the organization and correlation of parts constrain the evolution of species, i.e. adaptation occurs at the level of the organized machine and not at the level of separate parts. Consequently different classes had evolved separately and under certain conditions of existence. After their formation, classes quickly radiated into genera and species. Nonetheless, Von Baer did not deny the existence of intermediate steps between fish and reptiles and between reptiles and birds. He tried to defend his views against the new currents of the second mechanistic phase. In response to Haeckel's assertion that teleology and chance do not exist in nature, but only blind necessity of causes and effects, Von Baer reflected upon the critique of Kant and replied that indeed purpose as a conscious act does not exist in nature, but goal defined as a "prescribed result which can be achieved by necessity" does exist. The body, von Baer admitted, is a machine and a laboratory that operates in accordance with the laws of physics and chemistry, but at the same time the body is also the chemist or the mechanist who arranges, organizes and unites all the physical and chemical processes through a common goal. Only within a teleo-mechanical framework all the physical and chemical operations can form a harmoniously functioning *body↔machine* (Lenoir 1989: 236 – 275)

However, the study of evolution and development was already dominated by the new currents of the second mechanistic phase. The German biologist Ernst Haeckel (1834-1919) was probably the most influential evolutionist after Darwin. Haeckel promoted a "monistic view of the world" that was described by him "as mechanical or as pantheistic". Darwinism, and its implications on religious questions, was an important element in Haeckel's fight against conservatism. As a student of Virchow, his biological view belonged to the second mechanistic phase. He believed that the causes of matter and energy are always mechanical and chemical processes which can be decomposed through physico-chemical methods. As a mechanist and a monist Haeckel believed that even the mind and the consciousness are reduced to mechanical work of cells and to the physico-chemical reactions that take place inside them. Haeckel's theory of evolution combined Darwinism with neo–Lamarckism. In the

1860s he developed the theory of recapitulation which was based on the law of parallelism and on a linear, progressive model of evolution. The teleo-mechanists, Kielmeyer and Meckel, suggested this law in the early 19th century, under a strong influence of the idealistic philosophy that endorsed the idea of development and progress (although most of its supporters did not believe in transformism). According to the law of parallelism, the human embryo develops from the lower animal forms to the highest, i.e. from invertebrate, through fish, reptile, and mamma, until it becomes human. In the romantic thought, humans were at the center of universal progress. Accordingly, the basic formula of recapitulation theory asserted that ontogeny (the embryonic development of the individual) follows phylogeny (the evolutionary stages of its species). For Haeckel the meaning of this law was that "Phylogenesis is the mechanical cause of ontogenesis". The embryo drawings of Haeckel which were designed to prove the validity of the recapitulation theory are well known for the controversy they created: Haeckel was accused of fraud by his rivals, and even today the debate of biologists and historians on the drawings of Haeckel demonstrates how theoretical beliefs may shape empirical observations and interpretations (Haeckel 1912 [1897], vol. 1: especially 1 – 8; Haeckel 1914 [1868]; Haeckel 2004 [1892]: 3 – 4, 15; Bowler 2003: 122 – 136, 169, 187, 191, 227 – 240).

The mechanistic biology served as the foundation of the Darwinian Theory. Haeckel emphasized that natural selection is not based on unknown forces, but on inheritance and adaptation/mutability, which "like all other phenomena of life, are purely mechanical processes of nature, that is, they depend upon the molecular phenomena of motion in organic matter." Moreover, as a result of the limited availability of resources in comparison with the excessive growth of populations, the "struggle for life is a mathematical necessity". According to the theory of Haeckel, inheritance is the transmission of protoplasm or albuminous matter from parents to offspring: the hereditary material of each individual is characterized by a unique molecular motion that defines the vital actions of the protoplasm. Similarly, adaptation, or mutability, is the effect of external influences on organic material: external influences may produce changes in the inherited vital actions, that is, in the molecular motion of the albuminous particles (Haeckel 1914 [1868], vol. 1: 153 – 179).

In North America the noted botanist Asa Gray promoted the theory of natural selection through his famous collection of essays, *Darwiniana*. As a religious man Gray represented those who tried to reconcile natural selection with the belief in the Creator. In an article from 1860, entitled *Natural Selection not Inconsistent with Natural Theology*, Gray advised his friend Darwin to assume that “variation has been led along certain beneficial lines”. Gray admitted that monstrosities, impotent forms and failures of purpose occur sometimes, but he insisted that the slight and gradual variations on which evolution is based are “designed” and not accidental. Needles to say, Darwin opposed this interpretation that took the debate on evolution “out of the range of science” (Gray 1963 [1876]: 72 – 145; Ruse 1996: 245 – 251).

One of Gray’s articles was built as a dialogue, on the design of the *body↔machine*, between him and his atheist friend Daniel Treadwell who was an American physicist and an inventor of mechanical devices. The character that represented Treadwell argued that before Darwin there were only two alternatives to explain the creation of the *body↔machine*: chance or an intelligent action of design. Through the argument from design, philosophers such as Paley, or physicians such as the Scottish anatomist and theologian Charles Bell, tried to demonstrate that purposeful design is the only possible explanation: since the eye is an optical instrument, and the hand is a mechanical instrument, there must be a *watchmaker* or an *architect* who designed them. Yet the Darwinian Theory established a third alternative which asserts that the body and its organs are “the mere necessary result of natural selection”. Thus, claimed Treadwell, explanations based on purposeful and intelligent action of the Creator become irrelevant, and eventually the development of science will also account for the appearance of lower organisms from inorganic matter: “The atheist will say, Wait a little. Some future Darwin will show how the simple forms came *necessarily* from inorganic matter. This is but another step by which, according to Laplace, ‘the discoveries of science throw final causes further back’.” On the other hand, Gray was determined to prove that Paley’s argument from design and Darwin’s theory of natural selection are not contradicting. The industrial mind of Gray, on its religious adaptation, is manifested in the analogy that concludes the article. In Gray’s allegory a web of cloth is presented to a woman from the past and she is told that it was not made by manual labor. At first she may understand that the speaker tries to argue that the cloth was made without design, but then the speaker explains to her that the cloth was made by carding-machines, spinning-jennies and power-looms. The woman, wrote Gray, would continue to believe that the cloth is a result of design, but she would understand that the process is carried out indirectly by a complex mechanism. In Gray's analogy, then, the body is a fabric, God is a designer and industrialist, and the process of evolution and natural selection is the collection of machines which set in motion the textile industry. The Divine Artificer became the Divine Industrialist (Gray 1963 [1876]: 51 – 71).

Evolutionism prevailed in the American science of the second half of the 19th century. Yet, the study of evolution in America was directed more by the students of the Swiss-American zoologist Louis Agassiz, and the Naturphilosophie, than by the Darwinists. Agassiz himself continued to belief in the old views and rejected the idea of transformism even after the publication of the *Origin*. In fact he was the main opponent of Gray. Nevertheless Agassiz promoted the belief that parallelism is found in analogue phases of [a] the embryological stages of the animal (lower forms go only through earlier stages of development while human embryos go through fish, reptile and mammalian stages), [b] the place of its species among the classes (comparative anatomy; from lower classes to higher classes), [c] the order of appearance of life on earth (as evident in the fossil record). All this, argued Agassiz, was coordinated by the divine plan and was carried out through special creations of species in all the geographical areas which they inhabit. For him the connections between different parts of the divine plan were only intellectual and not material. Eventually, the emphasis of Agassiz's students was on the idea that the embryological stages of the individual follow the evolutionary stages of the species. Alpheus Hyatt, Agassiz's most distinguished student, suggested that just as individuals die from old age, members of a group can degenerate and the group become extinct. In 1872 Hyatt tried to persuade Darwin that evolution occurs through acceleration and retardation of development. He believed the mechanism of the inheritance of acquired characters is behind these phenomena: on the one hand the use of an organ produces heritable modifications, and on the other hand degenerative characteristics appear as a usual mode of development. According to this biological and social view, "progressive specializations" which increase the functional powers of the living being are eventually followed by degeneration (Ruse 1996: 111 – 117, 244 – 245, 251 – 257, 273 – 277; Bowler 2003: 121 – 124; Gray 1963 [1876]: 10 – 18, 95 – 99, 126 – 136; see also Hunter Dupree's introduction to Gray 1963 [1876]).

It is interesting to take a look at Karl Marx's reaction to Darwin. On the one hand, I have already pointed out in chapter 3 that Marx was a man whose perception and views belonged to the second order simulacra, i.e., he was a prominent intellectual of the industrial age and a secular materialist who focused on production and machines. Marx, as McLuhan and Baudrillard defined him, was "the spiritual contemporary of the steam engine and railroads" (Baudrillard 1981: 164; McLuhan and Fiore 1968: 4 – 5; McLuhan 1964: 38, 49; McLuhan and Nevitt 1972: 78 – 58). On the other hand, Marx was the greatest rival of capitalist philosophy.

- This is the point at which a low resolution analysis is extremely helpful. Despite all the differences, disagreements and contradictions, the two competing paradigms, the Capitalist paradigm and the Marxist paradigm, dealt with and articulated the industrial order: they shared a joint framework which distinguished them from pre and post-industrial thought. [76]

Thus, Marx was ambivalent towards Darwin: he admired Darwin and welcomed his ideas on evolution, but he also had some obvious reservations. For Marx, Darwin provided an important foundation to his outlook, that is, a materialist alternative to theology, teleology and to all other frameworks that conflicted with materialism and the industrial order. In December 19, 1860 he wrote to Frederick Engels on Darwin's *Natural Selection* that despite the "crude English way" of the Darwinian rhetoric "this is the book that contains the natural-history foundation for our viewpoint" (Marx 1979 [1860]: 139). In Similar words he wrote to the German socialist Ferdinand Lassalle:

> Very significant is Darwin's book and suits me as a natural-history basis of the historical class struggle. The crude English manner of development, one must naturally include in the deal. Despite all deficiencies, here for the first time, we have not only the death blow of "teleology" in natural history, but also the rational sense of the same explained empirically (Marx to Lassalle, January 16, 1861; in Marx 1979: 452).

As the greatest rival of capitalist philosophy, Marx could not have ignored the problematic elements in Darwin's theory which reflects the life, worldview and values of the bourgeois society. Therefore, he claimed, Darwin's ideas should be reinterpreted and modified:

> I'm amused at Darwin, into whom I looked again, when he says that he applies the "Malthusian" theory *also* to plants and animals, as if the joke with Herr Malthus did not consist of the fact that he did *not* apply it to plants and animals but only to human beings – in geometrical progression – in contrast to plants and animals. It is remarkable how Darwin has discerned anew among beasts and plants his English society with its division of labor, competition, elucidation of new markets, "discoveries" and the Malthusian 'struggle for existence'. It is Hobbes' *bellum omnia contra omnes* [war all against all], and it reminds me of Hegel's *Phenomenology*, wherein bourgeois society figures as a "spiritual animal kingdom", while in Darwin the animal kingdom figures as bourgeois society (Marx to Engels, June 18, 1862; in Marx 1979: 157).

In 1866, Marx argued that the theory of the French architect and intellectual Pierre Trémaux is an improved version of Darwin's theory of evolution although this theory too has its shortcomings. Marx identified some main points in the work of Trémaux. First, Trémaux claimed against the common view that crossbreedings do not create diversity but unity of the species. Moreover, Marx preferred Trémaux theory because the progress in the theory of Darwin is "purely accidental", while progress in the theory of Trémaux is a necessity due to the geological developments of earth. In addition, claimed Marx, Darwin could not explain the process of degeneration, while in the theory of Trémaux this process is easily explained. According to Marx, Trémaux also explains better than Darwin phenomena such as the rapid extinction of mere transitional forms and the slow development of species types. "In its historical and political application" Trémaux's work is also better than Darwin's, since Trémaux relates to the origin of different nations, ethnic groups and races. For example, Trémaux explains that the Russians are not Slavs but Tartars and that on the soil of Russia the Slavs "became Tartarized and Mongolized just as… the common Negro type is only a degeneration of a much higher one" (Marx 1979 [1866]: 215 – 216, 220).

Since we are trying to understand the impact of techno-culture on science, it will be interesting to examine the reaction to Darwin in nations which were much less industrialized, urbanized and individualized. Darwin's theory of evolution was based on the political economy of industrial capitalism. Struggle was everywhere: it was not just an inter-specific struggle (a competition between different species), or a struggle of living beings against the conditions of the environment, but mostly an intra-specific competition (a competition between members of the same species on resources). Perhaps for Darwin and Wallace the Malthusian metaphor was clear and self-evident, but for people from other cultures the Malthusian metaphor was not a common sense. During the last two decades of the 19th century Russian biologists and intellectuals suggested a new form of Darwinism. The noted Russian zoologist and intellectual, Peter Kropotkin, was of one of the leaders of the anarchist movement that aspired to build a society based on "voluntary associations" and "mutual aid". In his book, *Mutual Aid,* Kropotkin examined social cooperation in animals and in humans. The book was published in 1902, but the chapters of the book were already published during the 1890s (Kropotkin 1955 [1902]). According to Kropotkin, most Darwinists defined the competition between members of the same species as the main aspect of evolution and the struggle for life, although Darwin himself was sometimes more ambivalent regarding this subject. During his journeys to Eastern Siberia and Northern Manchuria, Kropotkin was impressed by two main aspects. On the one hand he identified "the extreme severity of the struggle of existence which most species animals have to carry on against an inclement Nature". On the other hand, even in the more populated areas, he did not identify an intense competition and struggle of existence between members of the same species. A competition between members of the same species does exist, but it is limited. Indeed a competition over food is more common in cases of catastrophe. However, in these cases the vigor and health of organisms severely deteriorates. Kropotkin came to a conclusion that "progressive evolution" cannot be the result of competition in harsh conditions between members of the same species. The relations between the biological and sociological aspects of intra-specific competition were explicit and Kropotkin rejected theories that emphasized its role in both fields (Kropotkin 1955 [1902]: iii – xiii; see also Todes 1987; Todes 1989; Harman 2010: 9 – 37).

Kropotkin and others complained that in many cases the Darwinian Theory was abused by crude popular misconceptions. In the 1914 preface to his book Kropotkin wrote that the struggle for existence became a favorite explanation among those who tried to excuse the horrors faced by the civil population in the ongoing war. Similarly, it was clear to Kropotkin that Spencer and other Darwinists adopted an unfounded myth: according to Hobbes, who defined this popular idea, the law of life in the primitive society was "war of all against all". As an alternative to intra-specific competition, Kropotkin suggested mutual aid as a *progressive* element in evolution and in the development of society. Kropotkin points out that a lecture titled "On the Law of Mutual Aid" made a great impression on him and on other Russian zoologists. The lecture was given by K. F. Kessler, the Dean of the St. Petersburg University, at a Russian Congress of Naturalists on January 1880. According to the theory of Kessler, in the struggle for life, and in the progressive evolution of species, the law of mutual aid is much more important than the law of mutual struggle. Kessler, claimed Kropotkin, did not invent a totally new idea, but only further developed the ideas which Darwin expressed in *The Descent of Man*. Kropotkin was exposed to the idea, and started working in this direction, in 1883. According to his testimony, the famous naturalist Henry Bates told him that his work, which was a critical reply to Huxley and other Darwinists, represents the "true Darwinism". However, Bates died before he could write a recommendation letter to the book. Kropotkin's theory was different from Kessler's. He did not accept Kessler's assertion that the primary source of the tendency towards mutual aid is based on parental feeling and care for progeny. Moreover, he argued, the sociability of animals and humans is not based on love and sympathy, but on a much wider and vague feeling of solidarity. A person does not rush to help a stranger in a burning house because he loves him, but due to a wider vague feeling, instinct or principle. The same inherited instincts motivate a herd of ruminants to form a ring in order to resist an attack of wolves, or motivate wolves to form a pack for hunting. Sociable habits provide animals a better protection from their enemies and better options to deal with the harsh conditions of existence. The institutions of mankind are the result of these social instincts: they enable mankind "to survive in its hard struggle against Nature" (Kropotkin 1955 [1902]: iii – xix).

Kropotkin tried to emphasize the ambivalence which is found in the work of Darwin. On the one hand, Darwin claimed in the *Origin* that the struggle for existence should not be taken in the narrow sense alone, i.e. as a struggle between individuals, but in a "large and metaphorical sense including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny". On the other hand, claimed Kropotkin, Darwin used the concept mostly in the narrow sense. Kropotkin praised Darwin for *The Descent of Man*: in this book Darwin recognized that in many animal societies *co-operation* and not *struggle* enabled the development of intellectual and moral faculties and facilitated the survival of the species. The followers of Darwin did not see eye-to-eye with Kropotkin. He had little expectations of economists who knew nothing about natural sciences except for vulgar versions of evolution theory, but even Huxley, one of the most important exponents of the theory of evolution, described the animal world, and the world of primitive men, as nothing more than a *gladiators' show* in which an eternal H*obbesian war* is taking place. Huxley's view of nature, argued Kropotkin, was the mirror image of the naïve view of Rousseau. Nature, then, is more than just a "field of slaughter" or a place of "love, peace and harmony". Huxley ignored the phenomena of co-operation and mutual aid, just as Rousseau ignored the beak-and-claw fight. Kropotkin admitted that "there is an immense amount of warfare and extermination" between many species, and especially between many classes, but within the same species, or at least within the same society, there is the same amount of mutual aid and mutual defense and perhaps even more. Sociability is a law of nature, and "most probably" it is far more important to the success of the species and to the evolutionary process than the law of mutual struggle. According to Kropotkin, Russian zoologists adopted Kessler's approach, while it had no impact on zoologists in Western Europe. Despite the reservations from the ultra-capitalist version of Darwinism, Kropotkin defined Russian zoologists as "followers of Darwin" and as "Russian Darwinists" (Kropotkin 1955 [1902]: 1 – 9).

In Kropotkin's outlook cooperation and mutual aid were the key elements of social organization. These elements, he argued, are even found among animals which are characterized by low degree of organization and perhaps even among micro-organisms. In one case, for example, he described how few crabs helped one of their members which fell on its back. Kropotkin noted that well known examples of cooperation are found in the social organization of termites, ants and bees. An ant is obliged to share swallowed, partially digested food with a hungry member of its community. Otherwise it will be treated as an enemy. Cooperation enables the small ants to fight successfully against large insects, e.g. grasshoppers, crickets, beetles, spiders and swaps, and to take over their holes and nests. Different species of ants or hostile nests tend to avoid each other and they may commit atrocities at war-time. Yet if an ant does not refuse to feed another ant from an enemy species, it will be treated as a friend. According to Kropotkin, cooperation in ants, bees and other animal societies is based on temporary "division of labour" in which every individual can carry out different kinds of work when necessary. Anthropomorphism and the reflection of social values become blatant when Kropotkin explains that natural selection works to eliminate "anti-social" instincts that exist in bees: part of the bees "prefer a life of robbery to the laborious life of a worker", but cooperation is much more advantageous to the species and thus "The cunningest and the shrewdest are eliminated in favour of those who understand the advantages of sociable life and mutual support" (Kropotkin 1955 [1902]: xii, 10 – 18)

Daniel Todes shows how Russian intellectuals and scientists, who held conflicting social and ideological views, were somewhat untied in their reaction to Darwin. They analyzed the metaphor of the struggle of existence and came to a conclusion that Darwin exaggerated on the importance of two Malthusian factors: (a) overpopulation as a cause of conflict (b) the consequence of intra-specific competition. According to Todes, there were two kinds of sources to the Russian reaction against the Malthusian metaphor. First, there was an anti-Malthusian reaction rooted in the culture and political tradition of tsarist Russia. Secondly, there was a non Malthusian reaction, partially rooted in the physical-geographical reality of wide Russia, that did not resonated with the Malthusian conflict of individuals in an overcrowded society.[77] From about 1840 the work of Malthus was highly criticized from all ends of the political spectrum: conservatives, radical Marxists, anarchists and even liberals. The work of Malthus was considered to be an expression of inhuman, soulless individualism. Nevertheless the *Origin* was a success in Russia and the majority of Russian intellectuals and scientists were ambivalent about the Darwinian Theory: they admired the work of Darwin and suggested a different interpretation to his theory. Yet, the Malthusian elements - competitive individualism and war of all against all (in the spirit of Adam Smith and Hobbes) - were considered to be the weakness of the theory. Instead of what they considered to be the product of the political economy of capitalist Britain, the majority of Russian scientists – transcending disciplinary, institutional and ideological boundaries –contended that intra-specific competition plays a minor role in nature, if any. The leading physiologist and psychiatrist, V.M. Bekhterev claimed that the universal rule in nature is not the intra-specific competition of individuals, but the struggle for existence against the physical conditions of nature. Many Russian scientists and intellectuals, like Kessler, eventually promoted theories of cooperation and mutual aid, according to which living beings of the same species cooperate with each other in order to survive, to reproduce and to struggle more effectively against the conditions in nature. Kessler admitted that overpopulation and the need for food may cause an intra-specific competition, but he thought that Darwin exaggerated the importance of these two factors. Russian zoologists tried to demonstrate the role of mutual aid and its selective advantages in species like ants, bees, birds and mammals (Todes 1987; 1989). Finally, it is important to note that Darwin himself did not dismiss the power of "community selection" in the evolution of social animals. After all, the industrial order did not conflict with social cooperation; it rather provided new forms of social cooperation, particularly the modern national-state.

Towards the end of the 19th century, Wallace was very optimistic concerning the fate of Darwinism. In his reply to the critique on natural selection Wallace observed that already in two decades the impact of Darwinism was vast and even "unprecedented": before Darwin the scientific consensus and the public opinion tended to accept the idea of special creations of distinct species; after Darwin the scientific consensus shifted and the idea of special creations was overpowered by the idea of common ancestors (the natural formation of species from other species). The importance and validity of the mechanism of natural selection remained in dispute until the appearance of the Neo-Darwinian theory which was the climax of the ultra-mechanistic program and the ultimate expression of the industrial order. This theory dominated the study of evolution and adaptation during the 20th century. Basically the Neo-Darwinian theory of the 20th century synthesized natural selection and neo-Mendelian genetics and its aim was to decompose the organism into unitary traits and discrete objects which, according to the theory, are optimally designed by natural selection. It was the noted German biologist August Weismann who already in the 1880's provided the foundation for the neo-Darwinian Theory. Weismann insisted that evolution occurs only through natural selection. Even Darwin himself did not go that far. In addition, Weismann rejected the mechanism of inheritance of acquired characters. He asserted that reproduction and inheritance are the unique functions of the *germ* cells. All other body cells, i.e. the *somatic* cells, are not involved in the transmission of hereditary characters from generation to generation. Hence, the acquired characters that appear in the somatic cells are not transmitted to the successive generations. Only direct effects on the units of heredity in the germ cells are transmitted to the next generations. Weismann speculated that random accidents modify these units and their ability to survive and multiply. Thus natural selection, or "germinal selection" in Weismann's terms, produces changes in the germ cells. Weismann's ideas were extremely influential, but on the short run they were rejected by many scientists (Wallace 1889: 8 – 9; Weismann 1893; Gould and Lewontin 1979; Jablonka and Lamb 2005: 16 – 21; Bowler 2003: 253 – 256).

During the 20th century the power of the industrial program in the study of evolution peaked. Nonetheless, in the last decades of the 20th century neo-Darwinism began to lose power, while post-mechanistic or electro-mechanistic alternatives began to flourish, such as the approach of Stephen Gould and Richard Lewontin or the paradigm of *Evo-Devo* which is based on the new developmental biology. My prediction is that 21st century evolutionary biology, along with the other fields of biology, will become more and more *electronic*.

Conclusion

Human thought is anchored in metaphorical frameworks. Metaphors shape all forms of human discourse, from conventional everyday language to scientific theories. Additionally, as we saw in chapters 1 and 2, metaphors cannot be reduced to *literal meanings*. Temporary islands of literal meanings can appear within the metaphoric oceans, but they are not *literal* truths in the strong objectivist sense. All literal statements are abstract fragments that depend on a successful act of matching with truth conditions and phenomena. The problem is that the successful act of matching can be achieved only in a very narrow context. Literal statements collapse when they are examined in a broad context, because the statements and their components depend on grand-metaphorical frameworks. In broad contexts the anomalies and experiential failures of the metaphorical framework are revealed and the metaphorical framework itself is confronted with alternatives frameworks. For Aristotle, the description of a solid body (that is made of earth) falling towards its natural place, i.e. towards the center of the universe, is based on a literal statement which matches a simple observation. However, this simple literal statement is based on an inclusive cosmological view and on grand-metaphorical frameworks, such as the *telos* of each of the five elements in the Aristotelian Universe or the *macrocosm↔microcosm* metaphor. It is easy for us to reject the *literal truth* of Aristotle, because already in the 17th century the Aristotelian Universe became obsolete, as the Clockwork Universe began to take shape.

The differences between the objectivist-modernist approach and the non objectivist - postmodernist approach on which the thesis of the *Metaphoric Body* is based reflect the differences between *visual space* and *acoustic space*, as were defined by

McLuhan. The modernist-objectivist approach assumes that (a) statements can be dealt with by fragmentation and abstraction (b) metaphors can be reduced to literal statements. By contrast, the postmodernist - non objectivist approach assumes that (a*) statements depend on an inclusive context (b*) metaphors are irreducible. The modernist objectivist approach strives to achieve objective literal truths. Thus, according to the objectivist program, metaphors must be eliminated or reduced to literal statements (i.e. to abstract fragments). The phonetic alphabet, print culture, and the industrial-mechanistic approach, are the ground on which the objectivist approach developed. According to McLuhan, the phonetic alphabet promoted the principles of fragmentation and objectivity. Basically, the phonetic alphabet created one-to-one matching of sign and sound: instead of signs that express inclusive ideas, the phonetic signs represent abstract meaningless sounds. The movable type diffused, enhanced and modified the effects of the phonetic alphabet. Eventually, print culture promoted the standardization of languages and the mass production of standardized, homogenous dictionaries and *literal* definitions. Alternatively, the non-objectivist approach, which is presented in this work, is based on the electronic order, i.e. on totality/inclusive context and on reciprocal interaction/feedback. In the first part of this work, I have tried to demonstrate that metaphors cannot be reduced to literal definitions and that the metaphorical interaction includes much more than the matching of inherent similarities. The metaphorical interaction is active and reciprocal, fusing together and transforming both *source* and *target* domains.

Following McLuhan, I have argued that the technological metaphor is interactive. First, technologies are designed and used as functional extensions of the body: we project ourselves onto the world, thus creating a technological environment. At the same time the technological environment reshapes the body, the mind and society. As I have demonstrated in chapter 3, electronic prostheses are the ultimate expression of this reciprocal interaction. In the electronic world the two domains of the technological metaphor collapse into each other. The computer, for example, enhances the functions of the brain and at the same time it becomes a model for the brain and for other aspects of the body. In our time the brain is being physically redesigned using chips and electrodes, for example, the brain of humans and monkeys that control robotic arms via brain-machine interfaces (BMIs), or the visual cortex of the blind man that contains electrodes attached to external miniature TV camera, an ultrasonic sensor and a small computer. Therefore, with the appearance of the *cyborg*, the analogical relations of the *body↔machine* become more metonymic and synecdochic, that is, relations between parts of the same domain or the same system. Technology has become part of the physiological system and feedback mechanism of the body. Furthermore, through the cloning technique the body becomes an imploded prosthesis of itself.

The advantages of the non-objectivist approaches become evident when we examine the history of life sciences, from the pre-modern world and the organic order, through the modern world and mechanistic-industrial order, and to the post-industrial world and the electronic-cybernetic order. The non-objectivist approaches can explain how it is possible for scientific theories to reflect the impact of different techno-cultural environments. Moreover, the non-objectivist approaches can explain how it is possible that competing alternative theories may achieve empirical successes, and why despite their successes they eventually collapse. Metaphors, according to the non-objectivist approaches, are not arbitrary and each of them depends on an experiential basis. Thus truth values can be assigned to metaphorical frameworks, although each of them suffers from anomalies and struggles against alternative metaphorical frameworks. A good example of that is the *body↔machine* metaphor and the experiential failures of this metaphor that were discussed in part II.

Throughout the history of life sciences, If I may use McLuhan's aphorism, *the medium became the message*. In other words, in each era the characteristics of the techno-cultural environment reshaped the paradigms of life sciences. New media have a deep psychological and social impact: they create a new mode of perception, they modify basic assumptions and expectations, they modify the way that the body is perceived and experienced and they create new patterns of activity and new types of situations.

Techno-culture and the metaphorical perception of the body develop in a hybrid manner. Since the early modern age, the metaphorical perception of the body developed by organo-mechanical hybrids. Through the mechanical revolution and the appearance of industrial society, the grand-metaphor of the *body↔machine* had gradually replaced the grand metaphor of the *macrocosm↔microcosm*. The new framework served as the basis for the development of the mechanistic-reductionist approach in physiology during the last centuries. Even the vitalists took part in this process. Ironically, prominent vitalists were among the pioneers of the mechanistic approach. At the beginning of the 19th century, for example, the French vitalists from the Paris School were convinced that diseases are malfunctions which can be located in specific parts of the *body↔machine*. Although the members of the Paris School believed that the body is much more than a mechanical automaton, they decomposed it through the mechanistic approach. The tissue doctrine of Bichat and his colleagues was based on mechanical fragmentation. In this respect they were much more radical than the mechanists who preceded them and influenced their research program, e.g. Haller and Morgagni. Socially, their research program and goals were shaped by the characteristics and needs of industrial society. The new science of pathology was part of the bureaucratic-medical surveillance on populations, i.e. part of the systemic-analytic program of the modern industrial state. Even the new form of organization in the hospitals of industrial society resembled the organization in the factories that were described by Adam Smith in the 18th century. This new form of organization was based on fragmentation, specialization and standardization. Another example of the psychological and social impact of the new environment is the work of Linnaeus. On the surface of things Linnaeus did not take a significant part in the debate on the mechanistic view. However, the Linnaean program was based on the new mechanistic mentality and especially on the principle of fragmentation. Socially and psychologically, the Linnaean program depended on the characteristics of print culture: fragmentation, abstraction, standardization and the overload of data.

The *organic order* and the *macrocosm↔microcosm* metaphor were characterized by essence, wholeness, the telos, the soul or any other holistic force that regulates the body as a whole, and by the religious, mystic and animistic universe that resonated within the body. Through *hybrid energy* and *rear view mirrors* a new order was created in the modern age. The new mechanistic order and the *body↔machine* metaphor were characterized by fragmentation (reductionism, specialization and atomism), efficient causes, sequential operation, standardization (mechanical repetition of serial actions) and determinism. During the first mechanistic phase, the mechanical clock, pumps and other mechanical models inspired the research programs which were developed by mechanists, such as Descartes and Boerhaave.

Eventually, during the 18th century, mechanists such as Haller, Réaumur and Spallanzani realized that the *body↔machine* is not necessarily *mechanical* in a strict sense, but *mechanistic*. Another aspect that characterized the first mechanistic phase was the dominance of organo-mechanical solutions. Since the technological metaphor assumes the existence of an artificer, one of the main problems in the life sciences was to explain the development and organization of the *body↔machine*. During the first mechanistic phase the majority of scientists and scholars did not believe that the mechanistic approach in itself can account for the development and organization of the *body↔machine*. The Christian mechanists supported the theory of pre-existence, while Blumenbach and his disciples suggested a vitalistic theory which was based on a teleo-mechanical force. The strength of the mechanistic approach increased through the industrial-chemical program. By the mid 19th century, the second mechanistic phase became dominant. For example, Helmholtz, Virchow and their colleagues developed the *body↔engine* and *cell↔state* metaphors, while Darwin developed the industrial-capitalist metaphor of *natural selection*.

Industrialization and its impact on biology peaked in the 20th century, but when the electronic-cybernetic environment developed in the 20th century, the mechanistic approach was undermined and the *body machine* took a new form. The new electronic environment even revived, in a new form, *organic* characteristics, such as holism and teleology. Thus, from a historical perspective, the *industrialized body* is a manifestation of a techno-cultural order that is slowly fading away. In the mechanical-industrial age the organo-mechanical hybrids gradually became more and more mechanistic. Today the electro-mechanical hybrids are gradually becoming more and more electronic.

At this point, I would like to emphasize that the power of media is not deterministic or absolute. Otherwise we would have never been able to create new techno-cultural environments. In order to create a new environment we must be able to partially neutralize the power of the existing environment. To a large degree, individuals have the power to escape the impact of media, although they often have to pay the price for standing against the new trends. McLuhan himself was not a determinist. First, he did not define the medium as a closed container but as an open process. Moreover, he argued that "'Media determinism,' the imposition willy-nilly of new cultural grounds by the action of new technologies… is only possible while the users are 'well-adjusted' – sound asleep… There is no inevitability where there is a willingness to pay attention" (McLuhan and McLuhan 1988: 127 – 128). According to McLuhan, artists have a unique ability to deal with the existing environment by creating an *anti-environment*: "Environments are not passive wrappings, but are, rather, active processes which are invisible. The groundrules, pervasive structure, and overall patterns of environments elude easy perception. Anti-environments, or countersituations made by artists, provide means of direct attention and enable us to see and understand more clearly" (McLuhan and Fiore 1967: 68). In his work McLuhan wished to make his readers aware of the impact of media, to encourage them to use the technique of suspension of judgment and to learn from the artists "how to cope with the psychic and social consequences of the next technology…it is here that the artist can show us how to 'ride with the punch,' instead of 'taking it on the chin.'" However, "It can only be repeated that human history is a record of 'taking it on the chin'" (McLuhan 1964: 66).

If so, the dominance of new techno-cultural environments is not equivalent to a complete homogeneity of society. To some degree, old traditions may resist dominant trends that develop on a new technological ground. Vitalism, which maintained traditional organic principles, drew its strength from the experiential failures of the mechanical metaphor. With the development of the industrial world, vitalism became more mechanistic, until it was crushed by the industrial establishment. Yet the residues of the vitalistic approach were still found in the backyard of the industrial world. Between the last decades of the 18th century and the beginning of the 19th century, Samuel Hahnemann developed homeopathy as a reaction to the rise of *allopathic medicine*, that is, the industrial-mechanistic medicine. Homeopathy was based on the vitalistic approach and the organic traditions. Virchow, the representative of the mechanistic establishment, gave Hahnemann the credit for being the first physician who systematically studied the effects of medicaments on healthy people, although eventually "No conclusions for general pathology resulted from [homeopathy]". According to the description of Virchow, "Animal magnetism and homeopathy had arisen at a time when vitalism, particularly in Germany, still exerted almost sovereign power". The blame, according to Virchow, fell on those who promoted teleo-mechanism and Naturphilosophie between the end of the 18th century and the first decades of the 19^{th} century, including the “great masters” who preceded Virchow himself, e.g., von Humboldt and Müller. Finally, “Only with the greatest of difficulty and with the summoning up of all its powers was medicine able to guard against the onrush of Mesmerism and homeopathy” (Virchow 1958 [1895]: 181 – 183). The industrial establishment had thrown homeopathy into the backyard of the modern world (although the electronic, post-modern world and the neo-capitalist situation created a new niche for *complementary* medicine in healthcare services and in hospitals). Moreover, alternative medicine and traditional approaches were not immune to the effects of the dominant trends of modern science. Many ideas and concepts of modern science and medicine were adopted by alternative medicine, e.g., the concept of the *cell* that was developed by Virchow and his colleagues. Similarly, the great impact of the electro-mechanistic paradigm of genetics on traditional views is evident in metaphors, such as the “DNA of the soul”, which have become popular among modern spiritualists.

The ideas argued for in this work can be extended in several directions. One of the following steps will be to examine the electronic-cybernetic impact on 20^{th} century life sciences. In *Understanding Media* McLuhan defined the intersection of the mechanical and the electronic as the *peculiar drama* of the 20^{th} century (McLuhan 1964: 342). This historical trend also characterized the development of the life sciences. During the 20^{th} century new forms of the *body↔machine*, namely the electro-mechanistic hybrids, began to dominate the biological perception. The popular ideas of Richard Dawkins represent the electro-mechanistic hybrids and they are also a good example of the rear view mirror effect: Dawkins discusses the ultra mechanistic and industrial views of genetic reductionism and neo-Darwinism in terms of the digital age, as he tries to squeeze the totality of the electronic order into the industrial program (Dawkins 2000). Today we can identify the growing strength of the electronic perception and the decline of the power of the mechanistic perception.

There are many other aspects which connect the ideas of McLuhan to the history, philosophy and sociology of sciences. An interesting option is to try to develop a *total field* model of perception and knowledge based on the ideas and insights of McLuhan and the critiques of science. This model will demonstrate the complex interdependence and circular connections of all fields of knowledge to one another.

McLuhan observed that “the electric age gave us the means of instant, total field-awareness” (McLuhan 1964: 47). In contrast to the mechanistic-reductionist approaches, the electronic, post-mechanistic approaches, e.g. contemporary field and systems theories, are based on totality or holism. In his famous article, *Two Dogmas of Empiricism*, the philosopher W.V. Quine suggested an alternative theory to the reductionist and ultra-mechanistic principles of the logical positivists. Quine’s model was shaped by the grand-electronic metaphor:

> The totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man made fabric which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience (Quine 1961: 42).

The sociologist of science David Bloor argues that the force field model, which was developed by Quine and other philosophers, can ease the tension between the *social* and the *natural* elements of the cognitive system. In fact, Bloor and his colleagues, Barry Barnes and John Henry, proclaim: “…’the natural’ and ‘the social’ we see them as fused together.” Yet, as members of the Edinburgh School, Bloor, Barnes and Henry deal only with the social aspects of the cognitive system and they do not purport to analyze the *natural* aspects. As Bloor clarifies, “Without denying their reality I shall leave the biological contribution aside and confirm myself to the socially generated coherence conditions” (Bloor 1984: 58, 60; Barnes, Bloor and Henry 1996: 53, 75 – 76). Quine, on the other hand, ignored the social aspects of the total field. He related only to evolutionary epistemology, that is, to the *natural* aspects of the field (1969b; 1969c). In practice, then, the complex interrelationships between the *social* and the *natural* aspects of knowledge are ignored. The *total field* model will shed light on the circular connections between the *social* and the *natural*.

Notes

Notes to Chapter 1

1) Mary Hesse, for example, identifies the anti-metaphoric outlook with the philosophy and thought of modern scholars, such as Thomas Hobbes. She points out that the primacy of literal language over metaphors is closely related to the birth of modern science in 17th century (Hesse 1993: 49; see also Johnson 1980: 47 – 48; Hoffman 1980; Lakoff and Johnson 1980: 95 – 209). The tension between the metaphorical thinking and modern science is obvious, since metaphors conflict with the myth of objectivity. As the objectivist philosopher, Jerry Fodor proclaims:

> When you actually start to do science, the metaphors drop out and the statistics take over (cited in Ruse 2005: 290).

Nevertheless, in this work I will argue that science depends on metaphorical frameworks and techno-cultural environments.

2) Mac Cormac and Lakoff argue over the definition of *metaphor*. As Indurkhya notes, they disagree on whether everyday conventional language (or "dead metaphors") are metaphors. Mac Cormac, who focuses on the novelty of metaphors, would tend dismiss many of Lakoff's examples. Lakoff, on the other hand, would refuse to define *conventional* metaphors as non–metaphors. Nonetheless, Mac Cormac and Lakoff's views both rely on Black's interaction view (even though Lakoff does not accept the idea of bidirectional interaction). Furthermore, Mac Cormac's basic definition of *metaphor* is not so different from Lakoff's definition: "I argue that metaphor results from a cognitive process that juxtaposes two or more not normally

associated referents, producing semantic conceptual anomaly… (Mac Cormac 1985: 5). Elsewhere, Indurkhya notes that “the two schools of thought are closer than either one might be willing to admit” (Indurkhya 1992: 296).

3) Basically, according to the non-objectivist views, a metaphor makes the two domains similar, analogical or correlated in certain respects. But what does it means to *make* something similar to something else? If A was made similar to B, then B was made similar to A as well. To infer that A is similar to B is to infer that B is similar to A. Clearly, the effects on both sides do not have to be identical or symmetric. Yet Indurkhya assumes that only one of the two domains is affected by the interaction. The degree of the bidirectional influence is less relevant, since the question is whether or not it exists (of course, the degree of the influence depends on how much the metaphor is convincing; for example, do people really think about the Star of David as a set of triangles?).

4) See, for example, the following news report on the incident. CNN News, 18-2-2004: http://www.cnn.com/2004/TECH/ptech/02/17/polaroid.warns.reut/index.html

5) In this line of argument, Forceville inaccurately asserts that the work of Malgady and Johnson (1980), Verbrugge (1980), Connor and Kogan (1980) “reject the idea that the two terms of a metaphor are symmetrical (or bidirectional)”… Indeed their arguments confirmed that the relationships between the metaphoric domains are asymmetrical, but they did not disprove the existence of a bidirectional influence. Moreover, Verbruggue, as I’ve quoted him before, explicitly supports Black's interaction view. He claims that although metaphoric interactions are usually asymmetric, the subsidiary subject (or the source domain) is modified during the interaction.

6) The Nazi regime is a widely-used source domain. Robert Proctor points out, for example, that pro-tobacco advocates portray anti-tobacco activists as “NicoNazis” or “health fascists”. In an advertising campaign of *Philip Morris* from 1995 a map of Amsterdam presented a “Smoking Section” near the traditional Jewish quarter with the headline: “Where will they draw the line?” The smokers, then, were described in

the campaign as ghettoized persecuted Jews. Proctor claims that this kind of analogies diminishes "the genuine extremity of the Nazi experience" (Proctor 1999: 271).

7) For the prevalence of the "Affection is Warmth" schema see this chapter, section: "metaphors and experience"

8) In relation to issue of asymmetry in metaphors, Barnden and his colleagues contend that asymmetries do not make the transference between the metaphoric domains unidirectional. They agree that the main transfer is from source to target (Barnden et al. 2002; Barnden 2001). Furthermore:

> … asymmetry arises for four reasons: (i) the direction of main transfer is switched, (ii) a particular transfer that happens to be involved both in a use of a metaphorical view and in a use of a reversed view will have different roles in the two cases, (iii) uses of "A AS B" and "B AS A" views in particular discourses can deal with different aspects of A and B, and (iv) even when they deal with the same aspects, the way aspects of A are linked to aspects of B can differ (Barnden et al. 2002: 44).

9) Blending is comprised of three basic processes. The first process is *composition* or the projection of features, elements and frames from the input spaces to the blend space. As a result, new relationships appear and fusions could occur between elements from the source input space and the target input space, for instance the person who performs the operation fuses together the surgeon and the butcher. I think that this process coincides with the condensation and transformation phenomena which Verbrugge described. The second process is *completion* or the usage of background conceptual structure and knowledge on subjects, in order to understand and to make sense of the scenario in the blend and to complete the composed structure. For instance, the new feature of incompetence arises in the blend by the interaction of input elements because we know how destructive a butcher can be in an operating room. The third process is *elaboration* of the imaginary event in the blend space. For instance, the scenario of butchering the patient could be extended to the packaging of his organs as expected in the space of butchery. In summary, the blend and the fusion of elements from different mental spaces promote the formation of new features and frames which are not found in the scenarios of the input spaces (Grady et al. 1997: 107; Fauconnier and Turner 1998: 144).

10) Lakoff and Johnson distinguish *metaphor* - which according to their definition, is a general conceptual mapping between two fields - from a single metaphoric phrase which results from that mapping.

11) See also the arguments of Barnes, Bloor and Henry (1996: chap.3) on the indeterminacy of concepts' meanings and references in relation to empirical data and the *outer* world.

12) See also Indurkhya's critique on the experientialist synthesis: (Indurkhya 1992: 294, 300). Indurkhya developed his own interactionist model to overcome the tension between *subjective* and *objective* features of knowledge and metaphors (see Indurkhya 1994a; 1992).

Notes to Chapter 2

13) See, for example, Wittgenstein (1953). See also the following theses in the history and philosophy of science: Fleck (1979), Kuhn (1970) and Hanson (1958). It may be argued that born infants experience perceptual metaphors, e.g. synesthesia, before they acquire language skills (Marks 1996), but then a new question is added to the debate over the definition of *metaphor*: can metaphors be created without a language?

14) See, for example, Havelock's analysis of the impact of phonetic alphabet on the rejection of oral perception, the creation of a solid, non polyphonic self and the development of the idea of objectivity (Havelock 1963; McLuhan and McLuhan 1988: 13 – 21). See also the work of Ong (1982), who summarizes some of the mental effects of phonetic writing and print. McLuhan and Ong identified the linear model of communication (i.e. the conduit metaphor) as a model which reflects the mechanistic approach and the characteristics of print culture (Ong 1982: 176 – 177; McLuhan and McLuhan 1988: 85 – 87; Willmott: 1996: 72). As we have seen, Lakoff and Johnson also reject the conduit model and recognize the influence of writing on the

transformation of the word into a static object and the creation of an experiential basis for objectivism (Lakoff and Johnson 1980: especially page 204).

15) Similarly, Ferdinand de Saussure wrote: “Without language thought is a vague uncharted nebula. There are no pre-existing ideas, and nothing is distinct before the appearance of language” (in McLuhan and McLuhan 1988: 186).

16) McLuhan relies on his colleague E. Carpenter and refers to his book (1959).

17) In oral cultures blindness was attributed to prophets and wise men, like Homer. Generally, the senses in oral cultures are not dominated by the visual sense. Modern Western people, on the other hand, often use visual metaphors even on vocal context: we say “see” or “look”, when we want someone to listen (and understand) to what we have to say. McLuhan and his colleagues attribute the rule of visuality in the West to phonetic writing and print technology. This historical trend continued until the electronic age. The new electronic environment puts an end to the rule of visuality and it creates a new sensory balance. See, for example, Howes 2005b. See also the article of Bernard Hibbitts (1999), who reviews the end of the dominance of *visual* metaphors and the rise of *acoustic* metaphors (such as polyphony and dialogue) in the American legal system.

18) The above mentioned literature often identifies McLuhan's *acoustic space* (or *audile-tactile space*) with the sense of hearing *in itself* and it often interprets McLuhan as a theoretician who claims that the ear dominates oral cultures. This interpretation is not wrong, but McLuhan’s position was much more complicated. McLuhan's writings on the subject are sometimes ambivalent and sometimes misleading the reader. Yet it should be emphasized that, according to McLuhan, in the acoustic space of the preliterate there was a harmonious balance of the senses, compared to the separation of the visual sense from the other senses which occurred under the influence of phonetic alphabet and print. *Visual space* was created through the characteristics of the phonetic alphabet (see the discussion below) and it should not to be confused with the visual sense *in itself*. As McLuhan clarifies, visual space is far from the non-phonetic writing (e.g. the Chinese ideogram), which “affords none

of the separation and specialization of sense, none of the breaking apart of sight and sound and meaning which is the key to phonetic alphabet" (McLuhan 1996: 241). Similarly, television was defined by McLuhan as a medium which creates a neo *audile-tactile space* and not as a medium which supports the *visual space*.

19) Tools and technologies amplify and extend the abilities of organs and bodily functions. According to Hans Hass, their main advantages are as follows:
(a) They have no need of constant nourishment, thus saving energy.
(b) They can be discarded or stored rather than carried (a further saving of energy).
(c) They are exchangeable, enabling man to specialize and to play multiple roles: when carrying a spear, he can be a hunter, or with a paddle he can move across sea
(d) All of these instruments can be shared communally.
(e) They can be made in the community by 'specialists' (giving rise to handicrafts) (Hass 1970: 103 – 104; cited in McLuhan and McLuhan 1988: 95).

Despite the advantages, McLuhan also identifies the dangers of the interaction between *Man* and his extensions. He argues that (a) people tend to become servomechanisms of the technological environment they use (b) people are usually not aware of how the technological environment reshapes them. The response to the technological shock is *numbness*/*narcosis*/*closure*/*amputation* that is imposed on our perception and consciousness (McLuhan 1964: chap. 4 and chap. 7). McLuhan and McLuhan also refer to the ideas of A. Simeons, K. Storr and D. Lorenz - concerning the dangers of technology (McLuhan and McLuhan 1988: 95 – 96).

20) According to the Book of Genesis, the entire world was created by the words of God. Furthermore, people can create things using magical words, e.g. the Aramaic phrase *abra cadabra* (creating through speech).

21) The *tetrad* is based on the four "laws of media", which are a set of guiding rules that allow to explore and understand artifacts (*hardware*), words and ideas (*software*) as part of dynamic processes and not as inactive products. In the tetradic structure each idea or artifact is translated into the aspects it *enhances*, *retrieves* and *obsolesces* and also into the aspects which eventually *reverse* its characteristics. The model of

this dynamic is the dynamic between *figure* (the small area of attention) and *ground* (the much larger area of inattention), as described in Gestalt psychology. Tetrads, then, reveal that words and things share a common dynamic structure (see McLuhan and McLuhan 1988; McLuhan and Powers 1989). We will see below that McLuhan explained the idea that *the medium is the message* according to the dynamic of *figure* and *ground*.

22) http://en.wikipedia.org/wiki/Memory_storage_density

23) Watt's regulating mechanism consists of two balls which are attached to pendulum rods. The balls swing on opposite sides of a rotating shaft. Two forces act on the balls. The first force is either the weight of the balls or a spring which drags the balls down. The second force is a centrifugal force which depends on the angular velocity of the shaft. Now, the mechanism is attached to the engine's cylinder and it regulates the steam intake valves of the cylinder. When the engine slows down the balls fall and cause an increase of speed by opening the intake valves. When the engine accelerates, the balls rise up and cause a decrease of speed by closing the intake valves (Wiener 1948: 97; Mayr 1970: 2 - 4, 109 - 113; Mayr 1971: chap. 2). The steam engine itself became obsolete after the appearance of the electric spark and the gasoline engine (McLuhan 1964: 220).

24) Feedback loops enable a machine or a system to regulate itself by linking its input and output in a circular fashion: the output signal of the system is fed back to the system as information, and therefore the system can react properly in different situations. There is a distinction between negative feedback and positive feedback. A negative feedback mechanism can maintain a desirable pattern of activity in varying conditions: the system uses its own output to detect deviations and neutralize undesirable effects. Watt's governor is a simple, limited prototype of the negative feedback mechanism. A positive feedback mechanism, on the other hand, does not reduce the deviation but increases it: the initial deviation is fed back to the system and as a result the deviation increases, while the system continues to generate larger deviations due to the circular reaction (in some cases this process is called “vicious circle”). Systems that are based on feedback mechanisms can become more flexible

and sophisticated if their feedback loop is “open”, that is, if they can regulate themselves according to additional environmental data other than their own output. For this purpose the system needs sensors, chips and computational abilities.

25) Mayr, for example, points out that Hero's book, *The Pneumatics* (written around 60 B.C.), was translated into Latin in 1575 and was eagerly received in Europe. However, the parts of the book which describe “feedback” mechanisms were totally ignored. Moreover, from the 12th century to the 18th century the float valve regulators were completely absent from the relevant literature on technology (Mayr 1986: XVI; 1970: 46 - 48).

26) On Newtonianism, and its impact on Smith and his intellectual milieu, see, for example: Montes 2008; Hetherington 1983.

27) The division of labor and functions has a long history, which, according to the description of McLuhan, begins in the transition from the world of the nomads and food-gathering hunters to the world of the settlers and villagers. See, for example: McLuhan 1964: chapter 10, esp. page 97.

28) According to Levinson, McLuhan's *rear view mirror* is not only a metaphor, but a metaphor that expresses an important essence of metaphors: to perceive, understand and explain the new/the unknown/the less known /the unclear by linking it to the more familiar (Levinson 1999: 175).

29) Some researchers, such as Coulson and Teenie Matlock, argue that despite the differences between the creation of literal meanings and the creation of metaphorical meanings, in certain respects there is a continuity between them. Similar processing appears in the comprehension of both literal and metaphorical meanings: space structuring, mapping and blending. Additionally, empirical data concerning “event related brain potential” (ERP) suggest that the same brain regions are involved in the construction of both literal and metaphorical meanings (Coulson and Matlock 2001). Alternatively, McLuhan and McLuhan (1988: chap. 2) suggest that the differences between the metaphorical and the literal correspond to the differences between the

right and the left hemispheres of the brain. The equilibrium of the hemispheres is dynamic. The literal perception is characterized as analytic, linear and continuous (a bias towards the left hemisphere), while the metaphorical perception is characterized as contextual, resonant and discontinuous (a bias towards the right hemisphere).

30) For a review on the attempts to define literal meanings in absolute terms and on their failures see: Gibbs 1994: chap. 2.

31) As Gibbs describes the relationship of literal meanings and context:

The conventional interpretation of an utterance presupposes some context of use perhaps so widely shared that we think that context has no role in determining that meaning. Literal meaning cannot be *uniquely* determined, since our understanding of situations will always influence our understanding of sentences. To speak of a sentence's literal meaning is already to have read it in light of some purpose, to have engaged in an interpretation. What often appears to be the literal meaning of a sentence is just an occasion-specific meaning where the context is so widely shared that there doesn't seem to be a context at all (Gibbs 1994: 71).

The philosophers Hans Gadamer and Mary Hesse also argue that literal meanings depend on an ongoing evolution of the metaphorical language (Gadamer 1975; Hesse 1993; Fox Keller 2002: 119). Metaphors, according to their view, are not produced as deviations from the "original" literal meanings. On the contrary, literality (i.e., the matching of words, phrases and sentences with phenomena via truth conditions) is a local, temporal, undetermined and unstable state of metaphoric language.

Notes to Chapter 3

32) TV screens and monitors are defined by McLuhan as media that belong to the audile-tactile space. Basically, television enhances the abilities of the sense of sight and sense of hearing and it enables us to see and to hear from anywhere in the planet. Nevertheless, McLuhan claimed that TV screens and monitors are based on a *reverse perspective*, since they project the objects on the user (*light through*). The experience

of watching TV screens and monitors is closer to the way we hear and touch and is more involving in comparison to the detached and distant way of viewing objects by a reception of the reflected light (*light on*). Thus “We are the television screen”. Furthermore, colors are defined by McLuhan as tactile, a phenomenon that is manifested, for instance, in the texture of paintings (see, for example, McLuhan 1964; see also the interpretation of T. Schwartz 1973). Later, McLuhan translated his claims regarding the differences between the audile-tactile space and the visual space into neuropsychological claims regarding the equilibrium between the right and left hemispheres of the brain. In this context, McLuhan refers to the experiment of Herbert Krugman, who tested the effects of television and print on the brain, in order to disprove McLuhan's assertion that “the medium is the message”. However, according to Krugman himself, the results of the experiment supported McLuhan's hypothesis (McLuhan and McLuhan 1988; McLuhan and Powers 1989). See also Baudrillard's interpretation of the connection between the “tactile and the digital” (Baudrillard 1983: 115 – 138). It should be noted that the ideas of McLuhan on the connection between the electronic technology and the nervous system were inspired by the neurophysiologist J. Z. Young, one of the participants in the Macy conferences in which the new cybernetic program developed. Biology was one of the many fields which were influenced by cybernetics.

33) Simulators of virtual reality, especially flight simulators, can enhance even the kinesthetic sensation and they can create the feelings of G loads (Hayles 1999: 26 – 27). For a discussion on McLuhan and Virtuality see: Horrocks 2000.

34) See also: BBC News, 18 January, 2000: “Electronic eye for blind man”:
http://news.bbc.co.uk/2/hi/science/nature/606938.stm
Wired News, 17 January, 2000: “Computer Helps Blind Man 'See'”:
http://archive.wired.com/science/discoveries/news/2000/01/33691

35) See also: BBC News, 31 March, 2005: “Brain chip reads man's thoughts”:
http://news.bbc.co.uk/2/hi/4396387.stm
Wendy Lawton: “Controlling movement through thought alone”, George Street Journal, Brown University, 19. 11. 2004, updated 12.7.2006 :

http://brown.edu/Administration/News_Bureau/2006-07/06-002.html.

More information can be found in:

http://www.braingate.com/

http://www.youtube.com/watch?v=TJJPbpHoPWo

See also the project of the University of Pittsburgh School of Medicine and UPMC Rehabilitation Institute. Around October 2011, Tim Hemmes, a quadriplegic patient who participate in this project, learned to control a robotic arm using his mind and a grid of electrodes implanted in the surface of his brain (Electrocorticography - ECoG):

ABC NEWS, 10 October, 2011; "Paralyzed Man's Thoughts Move Robotic Arm: Tim Hemmes touches his long-time girlfriend using mind-controlled robotic arm":

http://abcnews.go.com/Health/video/paralyzed-mans-thoughts-move-robotic-arm-14706821

See also: Pittsburgh Post-Gazette, 10 October, 2011; David Templeton: "Brain linked to robotic hand; success hailed"

http://www.post-gazette.com/local/city/2011/10/10/Brain-linked-to-robotic-hand-success-hailed/stories/201110100221

36) Kevin Warwick's homepage: http://www.kevinwarwick.org/

For links and videos on the subject of RFID see:

http://en.wikipedia.org/wiki/RFID#Human_implants.

37) Generally, *Understanding Media* (McLuhan 1964) is a satirical criticism on the way people and societies understand and deal with techno-cultural changes, but the book also contains some statements that sound utopian. Nonetheless, as I pointed out in the previous chapter, McLuhan's analysis of media and culture is non-moralistic (i.e. an analysis which does not stem from a fixed point of view regarding history and culture). Later he commented "…I brought the bad news with aches and pain, and am branded as a Utopian" (McLuhan cited in Gordon 1997: 99).

38) According to Searle, computer programs, unlike the brain, do not attach meaning to symbols, and thus a formal-syntactic manipulation of symbols using a computer program is not a sufficient condition for the creation of semantics, mind and consciousness. Searle's argument is based on a thought experiment or an allegory in

which a system that manipulates symbols becomes a *Chinese room*. The person (the *computer*) inside the Chinese room doesn't know the Chinese language, but he receives notes with Chinese symbols and he has a rule book (the *computer program*) that instructs him how to manipulate the symbols. His replies would be meaningful to the people who wrote the questions (the *programmers*) but not to him; he would still not understand Chinese. According to Searle, computational models of mental activity are not “real”, just as computational models of weather or any other natural phenomenon are not “real”. Searle asserts that certain biochemical processes and structures which characterize the biological brain, or equivalent systems and processes, are needed in order to create semantics and mental content. Against Searle's argument, the Churhlands suggest the “luminous room” argument. In the allegory of the Churhlands, a magnet that is pumped by a person appears to produce no light, and therefore, allegedly, one might argue that electromagnetic forces are not sufficient for the production of light. The Churchlands claim that this experiment is misleading: the frequency of oscillation of the magnet is too low and therefore the eyes are unable to detect light (in response, Searle claims that the luminous room is a false analogy that does not disproof his argument)… The issue will be decided empirically, but the Churchlands believe that it is unlikely that one would be able to create a conscious, intelligent machine using the principles of classical artificial intelligence. They suggest that a new kind of systems would, probably, be able to simulate the activity of the brain / central nervous system more efficiently. These systems will include parallel processing that simulates the activity of nervous systems and an analog response to signals (instead of digital response) that will simulate the activity of neurons. Additionally, similar to the connection between groups of biological neurons, the artificial neurons should be connected by feedback loops (adaptability of a flexible, learning system; e.g. neural networks). Similarly, McLuhan believed that a precondition for simulating consciousness is the creation of a “total field”. The problem with computers today, he noted, is that “…they are highly specialized” (McLuhan 1964: 351).

39) see also: http://www.ric.org/bionic/.

40) For a review of the current state of stem cell therapy, see for example: Abdelwahid et al. 2011; Chien 2004; R. Schwartz 2006; Rosenthal 2003.

41) From a historical perspective, for example, one of the inventors of the telephone, Alexander Graham Bell, was raised in a family who developed a technique of teaching speech for the deaf. He worked at schools for the deaf and opened his own school. Similarly, many of the early typewriters were developed for the blind.

42) The world of photographs itself produced visual archives. Each item in the visual archive refers to other items in the matrix. Furthermore, many photos in newspapers, journals and websites are used as *illustrations*. Photos from albums that are divided into categories and videos are sold by companies for this purpose and for any other purpose, e.g., TV programs or movies. Thanks to graphics software like Photoshop and video editing software, the photos and videos in the digital archives are subjected to endless manipulations. The play of empty signs with no *real* referents can be seen in *ghost websites*, such as search-wise.net, which exist only to be used in movies. In other words, they function as virtual signs that circularly refer to other virtual signs in the matrix. Notice that the signs of popular postmodern culture - from the content of commercials and video clips to T-shirts with meaningless logos, slogans and images - are a mixture of free signs and images that mostly *represent* the third order. The religious Jewish settlers who protested against the Israeli disengagement from Gaza have adopted the orange color from the Ukraine's “orange” revolution. The orange color had nothing to do with the subject at hand or with the cultural roots of the protesters. In the global trade of images, the identifying mark of the campaign was an empty sign that referred to another empty sign.

43) When a documentary film crew came to the house of the philosopher Jacques Derrida to film his “everyday life” at home, he pointed out that due to presence of the camera and the film crew he does not dress and behave as usual. Media do not merely “mediate” or “represent” reality, but they rather transform reality and society. Eva Illouz, for example, shows how media images of romance shape our concepts of love and romance (Illouz 1997). The gathering of protesters in front of the TV camera is a simple phenomenon that demonstrates how the presence of media shapes the events.

The protesters, who wait for the beginning of the live broadcast from their location, shout and protest only for the camera. Once the broadcast is finished the action is stopped. In a similar way, global trends and manias like the Sudoku *fever* are not only "reported" by the media but are created by the media.

44) Haaretz Newspaper, 9 January 2009: Salvatore Aloise, "Cosa Nostra's Facebook Stirs up Italy"; Telegraph.co.uk, 24 March, 2003: Charles Laurence, "'Tony Soprano' Mafia boss sings to the judge"; Haaretz Newspaper, 25 April, 2008: Yam Hameiri, "A Yiddishe Mafioso", originally published in Le Monde Newspaper.

45) Recombinant DNA technology is based on slicing DNA sequences (e.g., genes) from the genome of one organism and recombining them into the genome of another organism (e.g., from a human genome to a plasmid DNA of bacteria).Cloning is the replication of *identical* copies: molecular cloning of DNA fragments, cloning of cells, cloning of an entire organism and natural cloning in asexual reproduction. Recombinant DNA can be created through molecular cloning: genes or other DNA fragments are sliced and inserted into a vector (e.g., a plasmid or a virus) and then numerous copies of the fragment are replicated in host cells. One can also amplify copies of DNA fragments in test tubes through the PCR (polymerase chain reaction) method.

46) A photo of Droz's automata:
http://en.wikipedia.org/wiki/File:Automates-Jaquet-Droz-p1030472.jpg

47) He writes, for example:

The truth is that science is organized, like any other discourse, on the basis of a conventional logic, but it demands for its justification, like any other ideological discourse, a real "objective" reference, in a process of substance… Science accounts for things previously encircled and formalized so as to be sure to obey it. "Objectivity" is nothing else that that, and the ethic which comes to sanction this objective knowledge is nothing less than a system of defense and imposed ignorance, whose goal is to preserve this vicious circle intact (Baudrillard 1983: 114 – 115).

48) See an interview with Edgar Morin; by Ana Sánchez: Mètode, 2011, issue- *Science is Culture*:

http://metode.cat/Annual-Review/Monographs/Human-nature/Interview-with-Edgar-Morin

49) Richard Lewontin and Stephen Gould are among the prominent biologists who in the last decades criticized the reductionist models in genetics and evolution and promoted alternative views (Lewontin 2000; Gould and Lewontin 1979). Field models, computers and cybernetic systems influence the new developmental biology. See, for example, the review and theoretical analysis of Gilbert (Gilbert et al. 1996), Jablonka (2004) and Jablonka and Lamb (2005), and the historical analyses of Fox Keller (2002; 2000b; 2000a; 1995) and Doyle (1997).

50) Fractals are geometric, non-Euclidean patterns, natural or computerized, that contain endless, non-identical copies of themselves. In this framework, for example, blood vessels and trees are perceived as objects composed of geometric patterns that are similar to one another and to the overall geometric pattern of the object.

51) Loeb 1964 [1912]; Pauly 1987. The term *synthetic biology* was coined by Stéphane Leduc (Leduc 1911).

52) cited in guardian.co.uk, 14 January 2012: Adam Rutherford: “Synthetic biology and the rise of the 'spider-goats'”:
http://www.guardian.co.uk/science/2012/jan/14/synthetic-biology-spider-goat-genetics

53) See also an interview with the head of the group, Esmail Zanjani: Reno Gazette Journal, 30 March, 2005: Lenita Powers “Stem-cell work raises hope for organ transplants”:
https://www.ryze.com/posttopic.php?topicid=826820&confid=1031

54) For an interview with Stewart Newman see: PBS, online interview, July 2005:
http://www.pbs.org/newshour/bb/science/july-dec05/chimeras_newman-ext.html

See also an interview with Eugene Redmond whose team (Bjugstad et al. 2005) creates human-monkey hybrids: PBS, online interview, July 2005:
http://www.pbs.org/newshour/bb/science/july-dec05/chimeras_redmond-ext.html

See also: ABC News, 7 February, 2005: Amanda Onion: "Mixing Humans and Animals for Science" (including interviews with on the one hand Jeremy Rifkin, and on the other hand Irwin Weissman, a researcher from Stanford University whose research team creates human-mouse hybrids):
http://abcnews.go.com/Technology/Health/story?id=465202&page=1

For another interview with Weissman see:
The Stanford Daily, 17 October, 2005: Dianna Bai, "Prof. plans to put human cells in mouse brains":
http://www.worldhealth.net/news/prof_plans_to_put_human_cells_in_mouse_b/

Notes to Chapter 4

55) As defined by *Oxford* and *Merriam-Webster* dictionaries, the term *organic* can signify: "an organic whole"; "forming an integral element of a whole"; "(of the elements of a whole) harmoniously related", etc. This term also has a pre-industrial or post-industrial meaning in relation to food: "not involving or produced with chemical fertilizers or other artificial chemicals". In the context of our discussion, we cannot ignore that *organic* also means something which relates or derived from living matter; "relating to or affecting a bodily organ or organs", etc.

56) Havelock suggests that the new form of communication, and the "separation of the knower from the known", were behind the extensive use of the method of dialectic since the 5th century BC. The dialectic technique challenged the technique of poetic memorization and identification. In its simplest form, dialectic demands from the speaker to repeat his claims, to rephrase, to clarify and to defend them. This technique disturbed the mimetic process of learning and transformed the poetic into the prosaic. Instead of "me identifying with Achilles" a new alternative was formed: "me thinking about Achilles". Plato took the method of dialectic one step further. His method was based on logical chain-reasoning. In addition, Plato called to use arithmetic in the

non-mimetic process of learning. Arithmetic deals with problem-solving. It presents a challenge to the autonomous psyche and disturbs the mimetic process:

He is not asking for a repetition of the same series of symbols in fixed order, but rather the establishment of simple ratios and equations. This can not be a mimetic process; it involves not identification with a series or a list of phenomena, but the very reverse. One has to achieve personal separation from the series in order to look at it objectively and measure it (Havelock 1963: 210).

57) In spite of that, Martha Nussbaum contends that the conventional interpretation of the Aristotelian view is wrong (Nussbaum 1978). Nussbaum raises an important point: teleology does not have to be cosmic, mystical and intentional. She argues that Aristotle adopted a moderate view of teleology. In this moderate view there was no need to invoke mysterious or supernatural agencies to guide things towards certain goals. She further claims that (a) Aristotle ascribed teleology only to living beings and to the heavenly bodies which he considered to be alive; he did not ascribe teleology to non-living natural bodies, including the four elements which reach their natural state in accordance with material causes only (b) Aristotle gives no evidence that he believed in a universal teleology of nature. However, in my opinion, Nussbaum is trying to defend Aristotle from a modern point of view and she tries to portray him as if he was a *modern* scholar. Aristotle was still between the two modes of perception: *acoustic space* and *visual space*. In other words, he modified the organic perception, but he was still caught in it. The mechanistic approach achieved its maturity and became dominant only in the modern age. The citation above, and Aristotle's notion of the prime mover of the universe (Zeus or God - a supernatural agency), demonstrate that at least to some degree his universe was working with the guidance of cosmic teleology. Moreover, as I've noted before, he also accepted the *macrocosm↔microcosm* metaphor. In one point in the article Nussbaum herself makes a similar reservation about her modern interpretation of Aristotle (Nussbaum 1978: 68; f.n. 12).

58) McLuhan defines Descartes and Locke as two of the main advocates of visual space. We will see that Descartes was the forerunner of the mechanistic program in the study of life. His contribution to the *body↔machine* metaphor was indispensable.

Locke, on the other hand, was more hesitant in applying the mechanical metaphor in relation to some aspects of the body: the organization of the living machine and its power source. In the course of this work I will try to explain how the mechanists dealt with these issues.

Notes to Chapter 5

59) The lungs, for instance, are produced by airy particles, which according to Descartes are not extremely active or extremely solid in comparison to the particles of animal spirits. Similarly, Descartes divided the particles composing the blood into four, and assigned to each of them unique, specialized functions. Ramified particles, for instance, are responsible for forming the arteries and the veins, a process which occurs during the flow of the blood through the body. Nonetheless, his pioneer attempt to apply the imagination of the mechanist on the issue of generation encountered problems and it was too abstract (Descartes' deductions from principles). Most mechanists of the second half of 17^{th} century and the first decades of the 18^{th} century, e.g. Gassendi, rejected the attempt of Descartes to replace the explanation based on the Divine Artificer (a teleological design of the machine by a supernatural cause) with a pure mechanical explanation based on reducing the generation of the complex machine, on its functional adaptations, to a series of efficient causes. In fact, most mechanists of that age preferred the organo-mechanical hybrid of pre-existence. Even the disciples of Descartes did not follow him on the issue of embryology. As Malebranche said, "a machine can only work when it is finished". He finally became one of the prominent advocates of pre-existence. Descartes himself thought that he do not have satisfying solutions to some of the problems, as the determination of sex (Roger 1997: 118 – 123; Pyle 2006).

60) The term *res extensa* refers to the physical/mechanical world, and the term *res cogitans* refers to the mental being and to the spiritual world.

61) See also the essay which La Mettrie wrote, *The Natural History of the Soul*: La Mettrie 1961[1748]: 153 – 161.

62) The translator of the book, Gertrude Bussey, notes that the German-French philosopher Baron d'Holbach further developed the mechanistic view of La Mettrie on sensations: d'Holbach denied free will altogether and he argued that external causes control and modify the man-machine from the moment of his birth. Thus the man-machine "is but a passive instrument in the hands of necessity" (La Mettrie 1961 [1748]: 133 – 134, 173 – 174, 199).

63) Dualist views are not necessarily compatible with vitalist views. Descartes, for example, was a dualist who believed in the existence of the soul, but he also believed that the body functions only according to the mechanical laws. On his view, animals and the human body are no more than mechanical automata. The vitalists did not accept the complete reduction of the body which characterized the Cartesian system.

Notes to Chapter 6

64) From ancient times the heat of the body was considered essential to life. Studies on the role of respiration in the production of body heat were already made in the 1780s by researchers like Lavoisier and Laplace. Lavoisier and Laplace developed together an instrument for measuring the quantity of heat evolving in the body of laboratory animals in a given period compared to the CO_2 which is produced during the respiration process (the quantity of heat was calculated by measuring the quantity of melting ice). According to Lavoisier, the respiration process is based on chemical combustion: the body takes oxygen from the air and transforms it to CO_2 while releasing heat to the organs of the body through the blood. Lavoisier thought that the combustion process takes place within the lungs, but in the 19th century researches such as Helmholtz concluded that the process takes place in the muscle tissues, after the oxygen arrives to the tissues through the blood. The heat itself passes to different organs also through the blood.

65) From the work of Thomas Kuhn, writes Rabinbach (1990: 54), we learn that the energy conservation law is a prime example of "simultaneous discovery". In the fourth decade of the 19th century more than a dozen scientists worked on the idea at the same time, not necessarily knowing about the work of one another (but this does not mean that they did not work in a similar techno-cultural environment, that they were not influenced by similar phenomena or that they did not participate the same "communication network"). Kuhn counts three combined aspects that influenced the formulation of the energy conservation law in that period: (a) The steam engine demonstrated on a daily basis the conversion of heat into mechanical work and it served as exemplar of converting energy into force. According to Coleman (1979: 122), in addition to the steam engine other phenomena were taken as evidence for the conversion which occurs between natural forces through the conservation of energy: chemical reactions produced electric current which served to produce heat and light; the inter-convertibility of electricity and magnetism and the inter-convertibility of mechanical work and magnetism (b) The *Naturaphilosophie* - a German philosophical current which relied on the idealist philosophy of Scheling and Hegel. This philosophical current highly influenced Helmholtz (c) The engineering tradition in early 19th century France.

Notes to Chapter 7

66) The term scrofula relates to a variety of skin diseases. Today the term is especially identified with tuberculosis which affects the lymph nodes and the appearance of abscess on the neck.

67) See in N. Chomsky and M. Foucault, 1974, Human nature: Justice vs. power; in F. Elders (ed.), Reflexive water: The basic concerns of mankind, London: Souvenir Press (pp. 135-197). In Foucault's opinion, the medical revolution at the end of the 18th century was great: compared to the previous generation Bichat and his colleagues produced a different type of knowledge. Moreover, even the approach which

Morgagni developed around 1760 was very different from the approach of the new generation, whose representatives felt that they rediscovered pathological anatomy. The perceptual change they promoted, i.e. the shift from analyzing the functions and pathologies of organs to analyzing the functions and pathologies of tissues, included a new system of classification and new *geographical* divisions of the body. As a result new pathological categories were formed and new connections were discovered between diseases which appear in different organs but in tissues of the same kind (Foucault 1973: 126 – 130).

68) For example, Josef Skoda and Carl von Rokitansky, two distinguished followers of the Paris school who became the leaders of the "new school of Vienna", criticized some aspects in Laennec's method. Skoda published a work on percussion and auscultation in 1839. In this work he rejected the attempt of Laennec to characterize diseases by definite stethoscopic findings. Skoda and Rokitansky emphasized the utmost importance of demonstrating anatomical changes in patients. For them the job of the stethoscope was only to indicate the presence of these changes and not to *hear* diseases or definite signs of certain diseases (Faber 1923: 55 – 57).

Notes to Chapter 8

69) Following the works of McLuhan, Foucault and others, a new field of study, that deals with *visual culture* and *scopic regimes* in the modern age, has appeared; see for example Martin Jay (1988) and Jonathan Crary (1994).

70) Although Kant took the idea of transformism more seriously over the years, Ruse doubts that he accepted the idea of common descend. Perhaps, he only referred to ideal connections of species and not to their actual connections. On Kant's teleological view, any hypothetical transmutation of living beings may cause fatal disruptions to the holistic organization of the body, i.e. to the adaptation of organs to one another and to their purposes. He did not believe that a mechanical explanation

can circumvent this problem (Ruse 2006). As we will see below, the noted zoologist Georges Cuvier developed a similar argument.

71) It should be noted that even the traditional belief in the power of parental imagination was given mechanistic interpretations, although in general this belief did not fit the mechanistic approach (Roger 1997: 172 – 173).

72) Unger himself changed his mind towards 1852. He claimed that since the number of new species increased over time, as the evidence of paleontology demonstrates, we should have expected more and more occurrences of spontaneous generation, but we do not see these occurrences in our period. As an alternative, Unger suggested a transformist theory based on inner forces rather than on external conditions. The formation of the first cell was not explained by the theory of Unger, but he perceived the totality of plants as an organism purposefully striving for perfection. Accordingly, the appearance of new races is a purposeful act aimed at achieving an adaptation to the next cosmic period.

73) In this chapter I'll use the sixth edition of the *Origin* which contains Darwin's responses to the public and scientific discussion of his ideas.

74) Of course, the modern idea of individuality does not mean the rejection of social cooperation. The industrial order encourages the formation of new social forms, e.g. the national state which breaks tribalism, localism and unifies different ethnic groups by centralization and standardization. Thus, beyond the selection of the individual there still can be a selection on the level of the group. As Robert Richards points out, Darwin did not dismiss the power of "community selection" in the evolution of social animals. Therefore, according to Darwin, social patterns of cooperation can create advantages for the group in competition with other groups (Richards 2004: 35 – 36).

75) See also: Robert Young's *Darwin's Metaphor: Nature's Place in Victorian Culture* (1985), in which Young analyzes the Malthusian influences on Darwin.

76) McLuhan himself identified the existence of a techno-cultural link between Darwin and Marx. According to his interpretation, both Darwin and Marx suggested post-Newtonian worldviews which superseded 18th century thinking and the

clockwork cosmos. Their analysis was the peak and the reversal point of the industrial age:

> …Darwin's evolutionary approach opened the closed, self-regulating systems to a cosmic process of innovation that was totally environmental. This new approach had lurked in the Romantic idea of all-presiding time spirit or *Zeitgeist*… Charles Darwin's "missing link" opened up the closed system that has stood adamant for centuries. His "gap in nature" began a new interface of rapid change and breakthroughs that still resonates. That *the gap is where the action is* is now acknowledged as the basis of chemical and physical change. At first, however, the gap spurred the archeologists and anthropologists to world-wide explorations. Whereas Darwin (1809-1882) had flawed the mechanisms of the scientists, "Chunk" Marx (1818-1883) found the same chink in 'the iron law of wages" (McLuhan and Nevitt 1972: 60 – 61).

77) Todes refers to Russian intellectuals who responded to the work of Malthus before and after the publication of the *Origin*. The ideas of Malthus on overpopulation, limited resources and limited space did not seem be relevant in the Russian reality. Kropotkin claimed that the differences between Darwin and Wallace on the one hand, and Russian zoologists on the other, stemmed not just from the Malthusian thinking, but also from the fact that Russian zoologists studied vast continental regions in which the struggle against physical conditions of nature was more evident, while Darwin and Wallace studied coastal zones of tropical lands in which the population density is usually higher.

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בחלק זה אדון בטענות ובנושאים הבאים:

- מטאפורת *מכונת הגוף* והגידול בכוחה של הגישה המכניסטית; מן הסדר האורגני אל הסדר המכניסטי;
- ההתפתחות ההיברידית של המסורות המדעיות;
- הפאזה המכניסטית הראשונה, או הגישה המכנית המוקדמת;
- הפאזה המכניסטית השנייה, או הפרוגרמה הכימית-תעשייתית;
- הויטליזם כאוסף של גישות מכניסטיות רכות;
- ויטליסטים בולטים כחלוצי הגישה המכניסטית;
- הכשלים ההתנסותיים של מטאפורת *מכונת הגוף*;
- עיצוב *מכונת הגוף*

סיכום חלק II: המעבר מהתפישה האורגנית של הגוף אל התפישה המכניסטית

בחלק השני של העבודה אבחן כיצד *המדיום הפך למסר* במדעי החיים, או כיצד סביבות טכנולוגיות-תרבותיות ומסגרות מטאפוריות גדולות, בתקופות שונות, עיצבו את הגוף כמכונה. נעקוב אחר המעבר מהעולם הפרה-מודרני ו-*הסדר האורגני* אל החברה התעשייתית ו-*הסדר המכניסטי*. על אף שהתיאוריות של מקלוהן ועמיתיו מתוארות לעיתים כתיאוריות המציגות מהפיכות חדות, אציע פרשנות שונה לרעיונותיו של מקלוהן. בהתאם לכך, אטען כי הסביבות הטכנולוגיות-תרבותיות, כמו גם המסורות המדעיות, מתפתחות באופן היברידי. כמו כן, אחשוף את הגידול בכוחה של הגישה המכניסטית ואראה כי עם הזמן אפילו הויטליזם הפך ליותר מכניסטי.

חלק II עוסק בהיבטים שונים של המסגרת המכניסטית בהיסטוריה של מדעי החיים: שורשי מטאפורת *מכונת הגוף*, הפיסיולוגיה והארגון של מכונת הגוף, התפתחותן של הגישות הכימיות-התעשייתיות, פתולוגיה, תיאורית התא, אדפטציה, טרנספורמיזם ואבולוציה (בשל מגבלות מקום, פרק העוסק בהיסטוריה של מדע התורשה וההתפתחות הושאר מחוץ לעבודה). באופן כללי, אזהה ואתאר את ההבדלים בין *הסדר האורגני*, *הפאזה המכניסטית הראשונה* ו- *הפאזה המכניסטית השנייה*.

בין הנציגים הבולטים של הפאזה המכניסטית הראשונה ניתן למנות את:
Rene Descartes, Herman Boerhaave, Albrecht von Haller,
.Julian Offray de La Mettrie, Lazzaro Spallanzani and Georges Buffon

בין הנציגים הבולטים של הפאזה המכניסטית השנייה ניתן למנות את:
Hermann Von Helmholtz, Matthias Schleiden, Theodor Schwann,
.Rudolf Virchow, Charles Darwin and Ernst Haeckel

בנוסף, אראה כי הגישות הויטליסטיות היו קשורות קשר הדוק לפרוגרמה המכניסטית ותרמו להתפתחותה. בין הויטליסטים הבולטים המופיעים בעבודה זו ניתן למנות את:
John Hunter, Johann Blumenbach, Xavier Bichat, Jean Corvisart,
.Rene Laennec and Friedrich Tiedemann

העבודה מורכבת משני חלקים:

❖ ***סיכום חלק I: מטאפורות, טכנולוגיות וגוף האדם***

בחלק הראשון של העבודה אבחן את הבסיס המטאפורי של המחשבה האנושית ואת האלטרנטיבות לתפישה האובייקטיביסטית. בנוסף, אבחן את יחסי הגומלין בין טכנולוגיות ומטאפורות. אראה כי מטאפורת *מכונת הגוף* היא מטאפורה אינטראקטיבית שבה שני התחומים משפיעים אחד על השני.

בחלק זה אדון בטענות ובנושאים הבאים:

- המחשבה האנושית מבוססת על תפישה מטאפורית;
- היחסים בין תחומי המטאפורה (תחומי המקור והמטרה) הדדיים, דו-כיווניים ו-א-סימטריים;
- לא ניתן להעמיד מטאפורות על משמעויות מילוליות;
- למטאפורות יש בסיס התנסותי;
- מעבר להיבט הלשוני, למטאפורות יש היבטים גופניים ופיסיקליים,
- רעיון האקסטנציה, או הסביבה הטכנולוגית כפרוטזה מטאפורית של הגוף;
- הדינמיקה של המטאפורי והמילולי;
- תיאורית המדיה והמטאפורות של מקלוהן;
- *אנרגיה היברידית* ו- *מראות אחוריות*;
- המכני כנגד האלקטרוני;
- הצטופפות (implosion): הפרוטזה האלקטרונית, הסייבורג והשחזור הפיסי של הגוף; מיחסים אנלוגיים ליחסים מטונימיים וסינקדוכיים;
- פרוטזות והסימולקרה של באודריאר;
- הצטופפות בין מינית;
- ד.נ.א ומטאפורת האינפורמציה: דוגמא הממחישה כיצד הסביבה האלקטרונית-קיברנטית מעצבת מחדש את האופן שבו הגוף נתפש וממושג.

בהכרח או כקישוטים לשוניים אשר ניתן להעמידם על טענות מילוליות. מסגרות מטאפוריות מייצרות *אמיתות יחסיות* התלויות בבסיס ההתנסותי של המטאפורה ובקונטקסט טכנולוגי-תרבותי. יתרה מזו, בהשוואה לתפישות מודרניסטיות מופשטות (כגון, פוזיטיביזם או ריאליזם נאיבי), התפישות הפוסט מודרניסטיות (כגון, תזת *הגוף המטאפורי*) מכירות במרכזיותן של המטאפורות במחשבה האנושית והן יכולות להתמודד בצורה טובה יותר עם שני היבטים מרכזיים בהתפתחות המדעית: (א) ההשפעה ה- "חוץ מדעית" של סביבות טכנולוגיות-תרבותיות על תיאוריות מדעיות ועל הנחותיהם וציפיותיהם של אנשי המדע (ב) הדינמיקה ההיסטורית של המדע, כלומר ההצלחה היחסית של תיאוריות סותרות להסביר נושא מסוים וההופעה התדירה של אנומליות וכשלים החותרים תחת תקפות התיאוריות עד לקריסתן והחלפתן בתיאוריות חדשות.

לבסוף עולה השאלה מהי הסביבה הטכנולוגית-תרבותית או המסגרת המטאפורית הגדולה המעצבת את תפישתי? כממשיך דרכו של מקלוהן, עבודתי מבוססת על התפישה האלקטרונית. כמו כן, גישתי היא פוסט-מודרניסטית. המטאפורות המקלוהניסטיות הבסיסיות המעצבות את התזה שלי כוללות, בין היתר, את *החלל הויזואלי*, *החלל האקוסטי*, *השדה הטוטאלי*, *אקסטנציות*, *הצטופפות* (*implosion*), *אנרגיה היברידית* ו- *מראות אחוריות*. גישתי מבוססת על דחיית התפישה האובייקטיביסטית כמו גם על דחיית הדיכוטומיה הברורה בין ה- *חברתי* ל- *טבעי*. המדע הוא חלק משדה טוטלי שבו גורמים חברתיים, תרבותיים, מדעיים וטכנולוגיים משפיעים אחד על השני. במילים אחרות, מטאפורות מעצבות את כל סוגי הידע האנושי ועל כן עלינו להכיר בחשיבותן. אף על פי כן, איננו יכולים להתעלם ממחירה של הפוריות המטאפורית. העולם האלקטרוני הפוסט-מודרני התפתח מתוך העולם המודרני ולכן ניתן לזהות את השפעת הגישות המודרניות הביקורתיות על הגישות הפוסט מודרניסטיות. במובן זה, תזת *הגוף המטאפורי* אינה מאמצת גישה נאיבית ובלתי ביקורתית למטאפורות אלא מכירה במגבלות ובבעיות האפיסטמיות הנובעות מן המחשבה המטאפורית, אשר לא ניתן להגדירה כ- *אובייקטיבית* ו- *מילולית*.

תזת *הגוף המטאפורי* מבוססת, בראש ובראשונה, על רעיונותיו של Marshall McLuhan (1911-1980). בעבודתו, מקלוהן התמקד בחקר המדיה והטכנולוגיות ובהשפעתם על התפישה והחברה האנושית. הוא זיהה את הסביבה המלאכותית כ- *אקסטנציה* או *פרוטזה* של הגוף. רעיון ה- *אקסטנציה* נדון כבר במאה ה- 19 על ידי אינטלקטואלים כגון Ralph Emerson, Samuel Butler ו- Henri Bergson וביולוגים כגון Thomas Huxley. אולם מקלוהן היה האינטלקטואל הראשון אשר החל לנסח תיאוריה מקיפה המגדירה את האינטראקציה בין שני התחומים, הגוף והסביבה המלאכותית, כאינטראקציה מטאפורית דו-כיוונית.

תזת *הגוף המטאפורי* מרחיבה ומעדכנת את התיאוריה של מקלוהן ומיישמת את הגישה המקלוהניסטית ביחס להיסטוריה של מדעי החיים. אחת ממטרותיי היא לפתח גישה חדשה המשלבת בין תיאורית התקשורת של מקלוהן לבין גישות ביקורתיות חדשות למדע ולסביבה הטכנולוגית-תרבותית. בהשראת אחד הרעיונות המרכזיים בהגותו של מקלוהן, *המדיום הוא המסר*, אנסה לזהות דפוסים היסטוריים במדעי החיים. עבודתי משלבת מקורות מהתחומים הבאים: מדעי החיים, היסטוריה של המדעים, פילוסופיה, חקר התקשורת, ומחקרים בפסיכולוגיה ובמדעים קוגניטיביים העוסקים במחשבה המטאפורית.

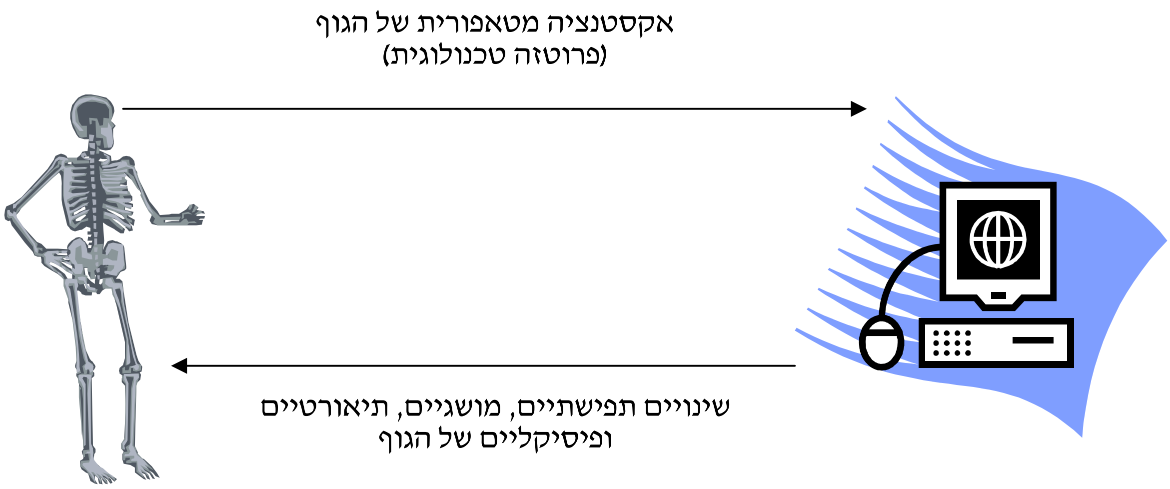
עבודה זו כוללת ניתוח מפורט של כמה מהפרדיגמות המרכזיות בהיסטוריה של מדעי החיים וניתוח ב- *רזולוציה נמוכה* של מגמות ודפוסים היסטוריים (1600 - 1900 לספירה). אשתמש בניתוח ברזולוציה נמוכה, במקום להתמקד בתקופה מסוימת או דיסציפלינה מסוימת, כדי לזהות מגמות ארוכות טווח במדעי החיים. באופן בסיסי, אראה כי התפתחותן של הסביבה המכנית, מטאפורת *מכונת הגוף* והחברה התעשייתית הובילה לשקיעת התפישה ה- *אורגנית* הפרה-מודרנית ולעליית התפישה המכניסטית במדעי החיים. במהלך העבודה אטען כי לאורך ההיסטוריה המודרנית ניתן לזהות עלייה בכוחה של הגישה המכניסטית ובנוסף אראה כי אפילו הויטליסטים, אשר לכאורה דחו את הגישה המכניסטית, לקחו חלק בבניית הסדר המכניסטי במדעי החיים. אף שעבודה זו מתמקדת במעבר בין הסדר האורגני לסדר המכניסטי, אתייחס גם לעליית הסדר האלקטרוני במאה ה- 20, אשר הפך את הקערה המכניסטית-תעשייתית על פיה ויצר *מכונת גוף* חדשה. שינויים היסטוריים אלה, כפי שנראה, לא התרחשו באמצעות שברים אפיסטמיים חדים או פרדיגמות חסרות קנה מידה משותף אלא באמצעות מה שמקלוהן הגדיר כ- *אנרגיה היברידית* ו- *מראות אחוריות*.

אחת ממטרותיי המרכזיות תהיה לזהות את הקרקע המטאפורית החבויה של המדע, או במילים אחרות, את פוריותן ונחיצותן של מטאפורות במחשבה המדעית. בניגוד לתפישות האובייקטיביסטיות המודרניות, אטען כי לא ניתן להתייחס למטאפורות כאל טענות שקריות

תזת הגוף המטאפורי

בעבודה זו אחקור את יחסי הגומלין בין מטאפורות, סביבות טכנולוגיות-תרבותיות ותיאוריות במדעי החיים. ביסודה, תזת *הגוף המטאפורי* עוסקת במטאפורה אינטראקטיבית דו-כיוונית. על פי הטענה המרכזית של התזה, טכנולוגיות הן פרוטזות אשר מחד מבוססות על הגוף ומאידך מעצבות מחדש את הגוף מבחינה תפישתית, מושגית, תיאורטית ופיסית (ראו איור 0.1). התפישה האנושית תלויה במסגרות מטאפוריות גדולות: מצד אחד, סביבות טכנולוגיות-תרבותיות נוצרות באמצעות המחשבה המטאפורית; מצד שני, אותן סביבות מעצבות מחדש את התפישה המטאפורית. המדע הוא חלק אינטגרלי מתהליך זה, הן כגורם חשוב בהתפתחות הטכנולוגית-תרבותית והן כתחום ידע הנמצא תחת השפעת הסביבה הטכנולוגית-תרבותית.

האינטראקציה ההדדית בין שני התחומים של מטאפורת *מכונת הגוף*



איור 0.1: סיכום סכמאטי של תזת *הגוף המטאפורי*

עבודה זו נעשתה בהדרכתם של

פרופ' ימימה בן-מנחם

ד"ר עתניאל א. דרור

התיאוריה של מקלוהן וההבניה המטאפורית של הגוף במדעי החיים

חיבור לשם קבלת תואר דוקטור לפילוסופיה

מאת

שמעון עמית

הוגש לסנט האוניברסיטה העברית בירושלים

אוקטובר 2012