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Dossier Georges Canguilhem

Canguilhem and the Machine Metaphor in Life Sciences: History of Science and Philosophy of Biology at the Service of Sciences

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Abstract:
The metaphor is used in the construction process of scientific knowledge. There are, however, metaphors that do not suit the objects they should represent, which thus impacts the accuracy of the knowledge which derives from these objects. It is the case of the machine metaphor, when resorted to in the study of living organisms. Canguilhem has tackled problems it created in twentieth-century life sciences head on. In his criticism, he links the analysis of Descartes' work to his own philosophical thesis on "biological normativity". By doing so, he so sheds a light on the pitfalls, both historical and biological, over which the machine metaphor stumbles. He thereby orders sciences to periodically make sure of the relevance of their metaphors and explanatory models to their objects.

Keywords:
Metaphor; History of science; Philosophy of biology; Descartes; Scientific practices

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According to Ernst Kapp in *Principes d'une Philosophie de la Technique* (*Principles of a Philosophy of Technology*), the functioning of the human body can be subsumed within the metaphor of the complex machine, provided that one conceives the absolute priority of the organism over the machine (Kapp 2007). According to his theory of organic projection,[2] tools and machines are extension and/or externalizations of living bodies' activities. Indeed, the complex machine is the copy of a mix of forms and movements derived from the human

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[2] When formulating his theory of organic projection Kapp adopts a radical anthropocentrism: according to him, man is the center of the world, and there is no other world than the world man represents by means of his consciousness – it is perception that provides the consciousness with materials. However, it happens that the consciousness identifies dark areas in its representation of the world: thus, man gradually makes the world his own through art, because art is a faculty specific to man. However, according to Kapp, as a matter of principle, one can only give what one already has. Hence, productions of art are externalizations of the forms of human organs, i.e. of limbs and organs and of movements of the body. For example, the hammer results from the projection of the movement that the fist and the arm make together when hitting something.

organism. Besides, Kapp adds that "the use of mechanical laws to explanatory ends does definitely not turn organisms into machines, not more than the transfer of the organic movement and processes does turn machines into organisms". (Kapp 2007, 97) The complex machine, a copy of the organism, is technically speaking a representation of movements that indicates organic functions relying on the whole dynamic of the living organism; the movement of the machine relies on mechanisms, a motor and layout of solids that involve no suppression of the mechanism when the machine is set in motion. Indeed, for Kapp machine and organism are ontologically two distinct things. This circumscribes the use that could arise from the machine metaphor.

In usual sense the metaphor is a stylistic device based on the transfer to an entity of a term that designates another entity. To be accurate a metaphor requires the selection of a target-entity (a), of another entity (b) the referent of which will be transferred to (a) and the existence of attributes shared by (a) and (b). To insure the effectiveness of a metaphor, the attributes of (b) must be easily recognizable by the reader or the listener that will interpret the metaphor. The use of the metaphor in the construction of scientific knowledge became a fully-fledged study object from the 1970s, mainly under the impact of research in cognitive psychology (Lakoff 1980) and of works that can be linked to the new experimentalism in philosophy of sciences.[3] Daniel J. Nicholson has proposed a tripartite share of the uses of the metaphor in sciences: the theoretic use that consists in willing to know a fact through another known scientific fact; the heuristic use that allows to understand a fact thanks to e.g. hypothesis stirred by a known scientific fact; the rhetorical use that allows transmitting and even explaining a scientific concept, thanks to another better-known concept that allows for a distillation of the components of the first concept (Nicholson 2014).

To go back to Kapp, the reference to this tripartite share of the metaphor scientific uses and the ontological difference drawn by the author between the machine and organism allow the assertion that Kapp excludes the theoretic use of the machine metaphor. Yet he does not forbid though the heuristic use and one can herald he does not exclude the rhetorical use either. Georges Canguilhem does just the same and thinks the regularity of the functioning of the machine would not be viable in the medium term for the living thing (Canguilhem 2009). The least irregularity in the functioning would see the living thing fail and unable to re-establish stable state by himself – as a machine that requires the surveillance of a technician able to mend in due course. On the contrary, the living thing is able to compensate its failures and compromise with them because he owns his own normativity.

However, a look back on the history of science is enough to question the power of this argumentation against the machine metaphor. Through the ages, technical progress provides technical entities that revive the theoretical claims of the machine metaphor. For example, from 1991 to 2003, the complete sequencing of the human genome had been achieved under a large publicly funded research program, i.e. The Human Genome Project (HGP). It was expected that this research program would shed some light on the etiology of genetic diseases and would allow for the development of new diagnostic tests and treatments. Researches conduced within the era of HGP were based on what one called the central dogma if molecular biology, which Jacques Monod and François Jacob explained by the metaphor of the "genetic program". (Jacob, Monod 1961) The scientific idea behind this

[3] New experimentalism is a collateral effect of the "crisis of rationality" provoked by the publication of Thomas Kuhn's *The Structure of Scientific Revolutions* in 1962. Kuhn demonstrates in his book the historicity of sciences, i.e. that theories and concepts are rooted in particular practical and social contexts. New experimentalism thus states that until the 1960s-1970s, philosophy of sciences gave too much importance to theory and not enough to practice. Yet practice has a quasi-autonomous dynamic from theory and even play a part in its elaboration. Thus, according to the proponents of new experimentalism, if one wants to study scientific knowledge, one shall study scientific practices. About the use of metaphor in sciences, see Evelyn F. Keller, 2002 and Theodore L. Brown, 2003.

metaphor was that synthesis of a gene activator of protein can activate or deactivate other genes and so on, so that the activity of genes depends on the activity of other genes. The genome was considered a computer program. Moreover, each protein was thought to have only one gene partner because of its tri-dimensional structure. According to these premises, the failure of one gene equated the disruption of the entire program. Thus, the way of proceeding of researches that aimed to identify the etiology of genetic diseases within the era of HGP consisted in selecting a gene or a protein involved in the disease, and then reconstructing the cascades of molecular interactions.

The "genetic program" metaphor allowed for a better understanding of some monogenic diseases; but, more importantly, the study of the entire genome sequence produced a scientific fact: that about 98% the genome is non-coding DNA. Molecular biologists deduced from it that the activity of genes was not stereospecific.[4] As a result, HGP ended with the formulation of a model of "biocomplexity" which implied the disengagement from the metaphor.

The HGP example is a good case of the problems that can arise from theoretical use when constructing scientific knowledge: metaphors may lead scientists to favor the study of particular aspects of a phenomenon instead of others that may prove to be crucial to understand this phenomenon.[5] In his time and for similar reasons, Canguilhem grappled with the problem of the equation of the machine and organism.[6] In the last half of the twentieth century, indeed, behavioral psychology of John B. Watson and Benjamin F. Skinner; Jacques Loeb's physiology; Frederick W. Taylor' scientific management theory; molecular biology[7] and cybernetics of the 1950s all look in machines for models for the intelligence of structures and functions of the organism. However, Canguilhem's criticism of the machine metaphor does not resolve in the demonstration of an ontological difference between the machine and organism. In his paper "Machine et Organisme" ("Machine and Organism") from 1946-1947, he writes himself that this argument has a slight power of conviction.

As we will show in this paper, Canguilhem chose a roundabout way to address the issue of the theoretical use of the machine metaphor. In our opinion, he relates his history of science to his philosophy of biology to reinforce the argument of the ontological difference between the machine and organism, and more broadly to educate scientific use of metaphors.

Moreover, this study will highlight the continuous nature of Canguilhem's though on the living and the permanence of its justification by means of history of sciences throughout his work. According to us, Canguilhem's criticism of the theoretical use of the machine metaphor is rooted in a youthful text, i.e. the lecture "Descartes et la Technique" ("Descartes and Technology") he pronounced at the 9th International Congress of Philosophy in Paris in 1937 (Canguilhem 1982). Vincent Guillin writes that in this text, it is obvious that Canguilhem

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[4] That means that protein activity is not determined by genes alone.

[5] Such problems can also arise with the heuristic and rhetorical use of metaphor. In *La Formulation de l'Esprit Scientifique* (*The Formation of the Scientific Mind*), Gaston Bachelard admits metaphor among obstacles to objective knowledge he enumerates (Bachelard 2000). With regard to the HGP, we point out that factors additional to the theoretical use of the metaphor explain its failure, such as the need for researchers to use instruments acquired by laboratories that may have selectively oriented researches and results.

[6] As we will show in our conclusion, Canguilhem's criticism of the use of metaphor in sciences is sometimes politically motivated.

[7] In his paper "Georges Canguilhem et la Biologie du XXe Siècle" ("Georges Canguilhem and twentieth-century biology") Michel Morange shows that the attention Canguilhem paid to cybernetic models and informational metaphors prevented him from perceiving a change in the way biology considered living organism in the late twentieth century (Morange 2000). Biology began to consider living being in a way that was close to Canguilhem's rational vitalism.

is influenced by Alain's own reading of René Descartes.[8] Canguilhem set himself apart from Alain when he insists of the shift in the relationship between theory and practice in Descartes' thought, though. According to Dominique Lecourt, Canguilhem believes that he can convert this shift "into a thesis for his own use" (Lecourt 2016, 68): this thesis is that of the anteriority of the living over technology, which makes technology depend from biological normativity. The concept of biological normativity Canguilhem develops in *Le Normal et le Pathologique* (*The Normal and the Pathological*) (1943 – 1966) is of course to be found below this thesis.

First, we will bring to light in "Descartes et la Technique", the basis of Canguilhem's criticism of the theoretical use of the machine metaphor: this is the symmetrical relationship between theory and practice he discovers in Descartes. For "pure history",[9] Descartes is the forerunner of the theoretical use of the machine metaphor. Descartes, as Gilbert Simondon writes it, has been, indeed, "the first to formulate and transmute into philosophy the normativity and schematics contained in the pure and rational technologies of the Renaissance" (Simondon 2014, 103) i.e. the causal transfer without loss. But, as Canguilhem states it in "Machine et Organisme": "it is not possible to treat the biological problem of the organism-machine by separating it from the technological problem it supposes solved: that of the relationship between technology and science. This problem is usually solved by invoking the chronological and logical precedence of knowledge over its applications" (Canguilhem 2009a, 130) Before examining the relevance of equating the organism and machine, one shall demonstrate that technology can precede science: this is exactly what Canguilhem does starting from Cartesian philosophy, a few years earlier in "Descartes et la Technique".[10]

Secondly, we will argue that Canguilhem's reflections in "Descartes et la Technique" allow him to state that the living precedes technology and, thus, that they are ontologically distinct. This thesis, which Canguilhem asserts in particular in "Machine et Organisme" supports his criticism of Taylor' scientific management theory in "Milieu et Normes de l'Homme au Travail. (A Propos d'un Livre Récent de Georges Friedmann)" ("Human Milieu and Norms at Work. (About a Recent Book of Georges Friedmann)" (Canguilhem 1947). Canguilhem, thus, manages to put his history of sciences at the service of his own philosophy of biology, and of sciences that are contemporary with him.

The Symmetrical Relationship between Science and Technology in Descartes' Philosophy

Descartes Humanism: Technology, Based on Science, Makes us "Masters and Possessors of Nature"

In his Cartesian studies, Canguilhem ambition is not so much to challenge Descartes' philosophy as to question what one takes for granted in it. His approach is polemical: it is based on a close and erudite reading of the Cartesian corpus. He reveals its unapparent ambiguities – on which those who claim to be Cartesians about technology depends, without grasping the consequences of this affiliation. In this respect, Guillin points out that Canguilhem, like Alain, considered Descartes to be an exemplary figure in French classical philosophy, because:

[8] Jean-François Braunstein points out that Alain's thought deeply marked that of the young Canguilhem (Braunstein 2000).

[9] "Pure history" refers to what Canguilhem himself refers to by this term, as opposed to his epistemological history (Canguilhem 2009b, 13 – 14)

[10] We note that in "Descartes et la Technique", which first publication was in 1937, Canguilhem does not state that Descartes assumes an intellectualist conception of technology. He will do so in "Machine et Organisme" in 1946-1947.

> He thought back then that existed a *Philosophia perennis*, and that this philosophy was perennial because it faced with human problems that remains on time and places. It is this universality, and this humanity that makes great philosophies of Plato, Descartes or Kant, and that justify that one continues to teach them: even if their authors are dead, the thought that animates them remains very much alive. (Guillin 2015, 318)

"Descartes et la Technique" no less testifies about Canguilhem's interest for Descartes: for Canguilhem, Descartes is part of the first thinkers of technology, alongside with Leonardo da Vinci or Francis Bacon[1]. As for da Vinci or Bacon, "philosophical reflection on nature and value of technical activity is not accidental or secondary to Descartes" (Canguilhem 1982, 111): it is sustained by a humanist position that aims to restore man's power in the world and, ultimately, to make him "master and possessor of nature" through "knowledge of necessity" (Canguilhem 1982, 112). As Guillin suggests it, at this point, Canguilhem's reflections may be dependent on those of Alain: "Alain's emphasis on the moral and practical destination of Cartesian mechanism (which makes it possible for one to become 'master and possessor of nature' and of 'one's nature'; human problems, indeed) has certainly profoundly marked Canguilhem".

On this specific point, Canguilhem notices that "there is no doubt that Cartesian thought is aware of its redeployment". The "technician profession of faith" Descartes assumes in the sixth part of *Le Discours de la Méthode* (*Discourse on the Method*) (1637) and in *Les Principes de la Philosophie* (*Principles of Philosophy*) (1644) contrasts with the Stoic tone he adopts in the third part of *Le Discours de la Méthode*. Let us recall, with Canguilhem, that, because the Stoic doctrine admits a teleological conception of nature, it does not engage in the reflection on technology. Technology, indeed, is incompatible with the Stoic idea that humans are overwhelmed by necessity. According to Canguilhem, what allows Descartes to let in a "mechanical theory of nature and […] a mechanistic theory of art" in his thought, and to make technical progress a requirement is precisely the "negation of natural finality". (Canguilhem 1982, 112)

Canguilhem mentions, nevertheless, that in many different texts, Descartes states that technical progress depends on the truth of knowledge, he even noted that "the development of a rudimentary art means that its rules are based on unconscious truths." (Canguilhem 1982, 111) For example, Descartes states in his preface letter to *Les Principes de la Philosophie* that "the whole of philosophy is like a tree. The roots are metaphysics, the trunk is physics, and the branches emerging from the trunk are all the other sciences, which may be reduced to three principal ones, namely medicine, mechanics and morals." (Descartes 1996, 14) Descartes, to this extend, occasionally castigate "craftsmen routines, that are ignorant of any knowledge of objects and phenomena they use" or "inventors without methods". In short, for Descartes: "the awareness of the technically possible is given to us by the knowledge of the theoretical necessity". For Descartes, technology extends sciences and, de facto, is made contingent upon it. This assumption makes it difficult to conceive exchanges between science and technology. According to Canguilhem, this exegesis of Cartesian thought is familiar to the reader: "So far, there has been nothing in Cartesian philosophy that, about technology, does not seem obvious to one; if one calls obviousness the long-lasting familiarity of Modern thought to a subject that, from da Vinci to Marx and passing through the Encyclopedists and Comte, has been the occasion of a development that became classico" (Canguilhem 1982, 114).

Canguilhem's proper historiography – of which Michel Foucault inherits and from which he develops his own historical method, the Archaeology – consists in working on the document "from the inside" and elaborating it in order to highlight elements and relationships between some of these elements that have remained hidden to "pure history". (Foucault 2016, 14) By applying this method to parts of the Cartesian corpus, Canguilhem discovers that Descartes came up against technical failure, and that the reflection he made up around it makes his thought about the relationship between science and technology more ambiguous than it seems.

The Consequence of Technical Failure on Descartes' Thought on Technology

Descartes' thought on technology derive from his scientific ontology. For him, science is foolproof: his Physics acts upon a homogeneous and infinite matter "without qualities", on a universe "without teleological hierarchy". (Canguilhem 1982, 112) Simondon confirms it: "The Cartesian continuum, the absence of void, is not only a metaphysical affirmation but the axiom, both ontological and axiological, which underlies this thought, whose basic schemes match those of pure technicity accomplishing a constructive operation". (Simondon 2014, 104) However, taking into account our daily experience of technology, it may seem questionable that technology, when sustained by a foolproof science, is itself foolproof: machines that broke down, technical objects that fails form part of our daily reality. According to Canguilhem, Descartes did not ignore the fallibility of technology, and this may account for his interest in many kinds of technical activities Canguilhem identifies:

> This short inventory of technical researches in which Descartes took interest in, as tiny as they may seem, had to be done; in our opinion, for not being averse to "debase his thought to the least of inventions of Mechanics", Descartes conceived between theory and practice relationships whose philosophical meaning seems important to us, both for the understanding of his thought and for any philosophical reflection. (Canguilhem 1982, 113)

According to Canguilhem, Descartes' keen interest in "recipes and practices" testifies of his finding: technology, unlike Physics, works in a matter that is not amorphous. Specifically, Canguilhem writes that: "Descartes sees very clearly that, in the passage from theory to practice, there remain 'difficulties' that the supposedly perfect understanding cannot solve by itself. All the possible and supposed given knowledge cannot, in some instances, get rid of a number of imperfections in the products of technology." (Canguilhem 1982, 114). Canguilhem then refers to three examples, in the Cartesian corpus, of what begins to emerge as a shift between theory and practice: Archimedes' mirror, a sewing thread numbering instrument i.e. the "*romaine*" and the astronomical telescope. Those are three technical objects that Descartes designed after theorizing reflection, the physical principles of leverage and refraction. According to him, when technology fails, the practice "shames the theory" (Canguilhem 1982, 115). This is indeed what happened in each example Canguilhem reports and, against all odds, Descartes admits from his failures that the application of knowledge includes experimental trial and error: "every technical synthesis, because it works on objects whose deduction cannot be complete, must include the unpredictable and the unexpected" (Canguilhem 1982, 115).

Canguilhem intends to radicalize Descartes' admission and, by continuing to rely on the Cartesian work, he states that Descartes consider that between science and technology, exists a relationship different from that which one usually attributes him i.e. that of the integral convertibility of knowledge into practice. It is a relationship where science and technology are symmetric, in which knowledge sometimes stems from the practice.

The Reversal of the Relationship between Science and Technology in Descartes' Thought

According to Canguilhem, there is indeed in Descartes' thought "another kind of relationship between knowledge and production than that which makes depend, even with restrictions, the latter on the former" (Canguilhem 1982, 115). This relationship is symmetric. Canguilhem refers to the example of the invention of binoculars i.e. the technical object behind Descartes' *La Dioptrique* (*Optics* or *Dioptrics*) (1637). The invention of binoculars results from an accidental experiment. This is, moreover, what Descartes writes in the beginning of *La Dioptrique* (Descartes 1937, 5-6):

By the shame of our sciences, this invention, so useful and admirable, is firstly due to experience and fortune. About thirty years ago, a man named Jacques Metius, from the city of Alkmaar in Holland and who had never studied […] had several lenses of various shapes. By chance, he looked through two of it, one of which was a little thicker in its middle than at its edges, and the other, on the contrary, was much thicker at its edges than at its middle; he put them so fortunately to both ends of a pipe that the first binoculars we are talking about were produced.

This rather basic invention was then imitated and became widespread without the optical principle on which its functioning is based being theorized, so that it did not improve and only revealed a few phenomena. Descartes, therefore, assigns to *La Dioptrique* the task of formulating optic laws in order to allow for the improvement of binoculars. According to Canguilhem, this task is significant: it means that "knowledge of nature, thus depends doubly […] on human technology. First, in this sense that the instrument […] helps discover new phenomena. Second, and above all, in this sense that technical imperfection provides the 'opportunity' of theoretical researches because it reveals 'difficulties' that must be resolved". (Canguilhem 1982, 116) Following Descartes, the role Canguilhem assigns to technology in the construction of science refers to Gaston Bachelard "phenomenotechnics". Unlike Canguilhem, Bachelard believes that Descartes could never have conceived that practice takes part in the construction of knowledge (Bachelard 1966) In *Le Nouvel Esprit Scientifique* (*The New Scientific Spirit*) he restates Descartes' wax argument, i.e. where Descartes demonstrates that things do not have properties attached to them,[11] in order to justify his rationalism. In Bachelard's wax argument, between the observer and the drop of wax, there is a monochromatic X-ray beam. According to Bachelard: "one knows that latest spectrograms, those of Van Laue, renewed crystallography by allowing for the inference of the internal structure of crystals. Similarly, the study of the drop of wax renews our knowledge of material surfaces." (Bachelard 1966, 170) Technical mediation discloses properties of things whose study enables the construction of knowledge.

However, this modality of the role of technology in the construction of science is not essential for Canguilhem. What is essential, according to him, is that technical failure draws science's attention on new research pathways and allows the construction of knowledge that improves technology.

It is significant that Canguilhem lays the emphasis on this second modality of the dependence of knowledge on technology in Descartes' thought: this is precisely that which enables him to introduce his thought on biological normativity. According to Canguilhem, indeed, the precedence of technology over science is justified by what is life: life is creation. Life does not wait for science to be mature to launch itself in practice: "the technical initiative

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[11] The wax argument appears in the Second Meditation of *Méditations Métaphysiques* (*Metaphysical Meditations*) (Descartes 2009). Before being melted, the piece of wax has certain qualities, i.e. flavor, smell, etc. Once melted, it is just wax. This is, for Descartes, the demonstration of the fact that properties are not attached to things, but that is in understanding and its operations that one must seek to understand qualification.

forms part of the demands of the living" (Canguilhem 1982, 116) Simondon, whose philosophy of technology inherits from Canguilhem's teachings, writes in "Les Limites du Progrès Humain" ("Limits of Human Progress") that technology refers to "elaboration and satisfaction of biological needs themselves" (Simondon 2014a, 270). This is exactly what Canguilhem means: "The final irreducibility of technology to science, of constructing to knowing and the impossibility of a total and continuous transformation of science into action, thus, would be equivalent to assert the uniqueness and precedence of a 'power'." (Canguilhem 1982, 116)

Without wishing to anticipate on our next reflections, let us simply state that for Canguilhem, technology is a universal biological phenomenon: thanks to technology, the living can adapt to its environment and can add to its organs exogenous parts.[12] This precedence of the biological over the technical no longer permits the equating of biological with the machine: what ontologically distinguishes the latter from the former is its normativity. Hence, the analysis of the relationship between knowledge and practice in Descartes' thought in "Descartes et la Technique" leads to the assertion of the existence of a biological normativity, which is a significant objection against the theoretical use of the machine metaphor. Canguilhem makes it a weapon that he points, in particular, on Taylor' scientific management theory, in which "a mechanist and mechanistic vision of physiology" reflects, that makes Taylor's theory "a province without autonomy of the energetics". (Canguilhem 1947, 128)

For an Enlightened Use of the Machine Metaphor in Twentieth-Century Sciences

Legitimacy and Limits of the Machine Model, from Antiquity to the Renaissance

Even if the theoretical use of the machine metaphor rests on a logical error, one can only note that it has a long history in the sciences: one can find it in Descartes texts, but also in Aristotle's. In "Machine et Organisme", Canguilhem points out that setting an analogical relationship between the organism and machine is only allowed by the existence a specific type of machines. Aristotle was able to equate the movement of limbs with mechanisms because automatic siege machines existed in his time. As for Descartes, his animal-machine theory depends of the Renaissance's machines, particularly of automata. The biological and the mechanical can only be brought closer together by the existence of machines whose movement is automatic – automation can be achieved by exploiting physical milieu or thanks to the conservation of mechanical energy and its transformation in kinetic energy, as is the case with the mechanical watch:

> For a very long time, kinematic mechanisms received their energy from human or animal muscular effort. In those days, it was obviously tautological to explain the movement of the living by its equation to the movement of the machine, for this movement depended of the muscular effort of the living. Hence, the mechanical explanation of living functions historically presupposes [...] the construction of automata. (Canguilhem 2009a, 133)

The mechanical explanation of organisms could appear when automata were

[12] Canguilhem does not restate Kapp's thesis: unlike Canguilhem, Kapp does not address the issue of norms and normative conflicts. According to Canguilhem, if life is creation and if technology too, then technology produces norms that can interfere with those of living organisms. See Canguilhem, 1947.

invented. But should it have appeared? Canguilhem's answer is positive: it must have appeared, precisely at times when a limited knowledge of the living and a rudimentary technology do not allow for extensive physiologic researches. Descartes' though on the genesis of the living in *La Description du Corps Humain* (*Description of the Human Body*) (1667) – a thought that many scholars at that time shared and that has been refuted by studies in experimental embryology – is a shining illustration of Canguilhem's claim:

> If one knew well all parts of the seed of an animal species, man, for example, one could deduce directly from this knowledge, thanks to certain and mathematical reasoning, the form and the conformation of its limbs as, reciprocally, by knowing several particularities of this conformation one can deduce which is its seed. (Canguilhem 2009, 152)

What is noticeable is that in the classical age, the theoretical use of the machine metaphor is a physiology by provision that enable scholars to understand the man already built, for lack of the means to understand how he is formed. This is confirmed by Canguilhem in "Modèles et Analogies de la Découverte en Biologie" ("Models and Analogies for Discovery in Biology") (1961-1963); referring to history of physiology, he writes that: "Physiology first have been and remained for a long time an *anatomia animata*, that is a discourse *de usu partium* that seemed based on anatomical deduction, but that, in fact, drawn knowledge of functions from their equation to uses of tools or mechanisms recalled by the form or the structure of corresponding organs." (Canguilhem 2015a, 306) The analogical use of the machine metaphor was, then, well suited to an emerging physiology: "In the 16th and 17th century, the systematic use in biology of references to mechanisms analogous to organs – inspired by Galilean and Cartesian sciences and the new picture of the world they spread – cannot be credited with much more decisive discoveries in biology." (Canguilhem 2015, 308) Canguilhem adds that: "Even when it became rigorous in its principles, mechanics has not become more fruitful in its analogical applications." After the Renaissance, even if machines improved and became more complex, thanks to advances in mechanics, they were still insufficient to the understanding of the living. Moreover, no machine, whatever is the technical and scientific principles by which it functions, represent a sufficient model for explanation in biology:[13]

> Adrian's remark doesn't just apply to the kind of research it targets: 'What we can learn from the machines is how our brain must differ from them!' [...] Elsasser since drawn similar conclusions from his study: an organism does not fulfill by itself any of the stability conditions an electronic machine requires for functioning properly. (Canguilhem 2015, 314)

For these two reasons, the persistence of the theoretical use of the machine metaphor in the study of the living in the twentieth century – at a time when means of scientific investigation are much more extended than those of the Renaissance – exasperates Canguilhem:

> We came to the point where recent apologists of heuristic efficiency in biology – especially in neurology –, of cybernetics automata and of feed-back models, consider the construction of standard automata as the effect of a fad without scientific interest

[13] Descartes recognizes it: in *Les Ecrits Physiologique et Médicaux* (*Physiological and Medical Writings*) the use of a mechanical model for modeling embryological processes is no longer mentioned (Descartes 2000).

> and as recreation: standard automata do not have adaptive feedback organ. They can stimulate animal behavior or human gestures, but within the limits of one or more rigid programs. (Canguilhem 2015, 308)

The Living Organism is the Model of the Machine

Canguilhem confronts this trend with an abrasive argument in "Machine et Organisme": "the mechanism can explain everything if machines are given", yet, he points out that there is no spontaneous generation of machines. The machine is a mean that man constructs for an end: "a machine is made by man and for man, for some end to achieve, as an effect to produce". (Canguilhem, 2009a, 146) Nevertheless, according to him:

> Mechanist philosophers and biologists reflected on machine as given or if they have studied its construction, resolved the problem by invoking practical reason. [...] They were abused by the ambiguity of the term "mechanics". They noticed, in machines, only solidified theorems, exhibited *in concreto* by a minor operation of construction, which is the simple application of a knowledge aware of its scope and certain of its effects. (Canguilhem 2009a, 130)

As Canguilhem demonstrated it in his lecture on Descartes in 1937, machine is not the result of a calculation, of a direct transposition of knowledge into practice. Technology precedes science and, consequently, is as close as possible to the biological. According to Canguilhem, this is evidenced by the fact that Cartesian mechanism cannot account for the construction of machines (Canguilhem 2009a, 147) Canguilhem even draws from the study of Descartes' *Traité de l'Homme* (*Treatise of Man*) the idea that "the construction of the living machine [implies], if one reads this text well, the obligation to imitate a given organism. The construction of a mechanic model presupposes an original." (Canguilhem 2009a, 144)

This thesis enables Canguilhem to reverse the prevailing relationship between the organism and mechanism in explanation in biology: if, "the model of the living-machine is the living itself' (Canguilhem 2009a, 145), then mechanist model is tautological, for invoking it is "explaining the organ by the organ". (Canguilhem 2009a, 144) Rather than explaining organism by machine, one must explain machine by organism. Thus, according to Canguilhem, ethnologists are the closest to the constitution of organology, which he calls for in the beginning of "Machine et Organisme":[14] reflections of Alfred Espinas, André Leroi-Gourhan and Kapp are all articulated to a theory of organic projection that, somehow, intersects with Canguilhem's reflections, without overlapping them.

Living Being's Normativity does not Allow one to Equate it with the Machine

In addition to the research pathways in philosophy of technology, the assertion of the uniqueness and precedence of living things over machine makes it possible to affirm forcefully the ontological difference of living things and machine. Indeed, if it becomes possible – and even recommended – to explain the machine by living things, yet it is no longer possible to explain living being by machine. Living being is revealed in all its specificity, which, as a last resort, depends on its normativity.

[14] One can consider that Simondon's philosophy of technology – he was Canguilhem's student – concretizes this wish. Simondon's concept of technical invention, in particular, was inspired by Canguilhem's thought on norms. See Guchet, 2015.

In "Machine and Organisme", when comparing the features that organism and machine share, Canguilhem highlights some of the specificities of living beings. The feature that allows for a split between those entities is not their respective capacities to self-regulate or not. Canguilhem notes, however, that "a machine shows a neat functional rigidity, a rigidity which is increasingly brought out by the practice of standardization" (Canguilhem 2009a, 149). Actually, the arrangement of the parts of a machine is designer for a particular functioning. This arrangement can produce side-effects when machine functions, as it is often the case when the properties of the parts are not completely known. However, standardization of parts tends to reduce the probability of unexpected side-effects. On the contrary, living being is labile and, therefore, normative: it can renew its own living norms in order to live in other conditions i.e. environmental or biologic ones.

Canguilhem's comparison of intrinsic finalities of the machine and the organism reinforce this idea: is there, Canguilhem writes, "more or less finality in the machine than in the organism?" (Canguilhem 2009a, 150) In machine, the finality is "rigid and univocal, univalent". Each part of the machine has a specific role in its total functioning. On the contrary, each part of living being is multipurpose. Canguilhem calls it "vicariance of functions". In order to reinforce his statement, Canguilhem refers to an experiment realized by Robert Courrier (1895-1986), who was professor of biology at the *Collège de France* from 1938 to 1966: this experiment consisted in grafting the placenta of a rabbit on its intestine. Courrier observed that the placenta fed normally and even survived to the removal of the rabbit's ovaries, so in the absence of *corpus luteum*. Thus, Canguilhem concludes: "Here is an example where the intestine behaved like a uterus and, one might even say, more victoriously". (Canguilhem 2009a, 151) In short, "the living organism acts empirically. Life is experimentation, that is improvisation, use of opportunities; it is an attempt in every direction". (Canguilhem 2009a, 159)

Science Must Reconsider its Models and Metaphors: The Case of Taylorism

The thesis of the normativity of living beings, from now on justified by history of sciences, enables Canguilhem to defeat the theoretical claims of the machine metaphor in sciences in the last half of the twentieth century. His criticism of Taylorism is a shiny example of his condemnation of the theoretical use of this metaphor. In Taylorism, the wish to reduce the organism to machine is explicit, as Canguilhem writes in "Machine et Organisme" (Canguilhem 2009a, 162): "With Taylor and the first technicians of the rationalization of worker's movements, we observe the human organism aligned, so to speak, on the functioning of a machine. Rationalization is, strictly speaking, a mechanization of the organism so far as it aims to eradicate unnecessary movements".

In "Milieu et Normes de l'Homme au Travail", Canguilhem enlists his thesis of biological normativity in order to prove the absurdity of Taylorian rationalization. He brings to the attention of the reader that Taylorian rationalization claims to provide a standard of the amount of work a worker can done in an interval, but in doing so, it struggles with a difficulty: which worker should be used as a basis for establishing what the standard is? Actually, according to Canguilhem, the standard drawn from the study of a worker cannot make sense for another worker, "understood in the biopsychic totality of its existence" (Canguilhem 1947, 132). According to Canguilhem, biological normativity, which is underpinned by living being's lability, enables the living organism to establish new vital norms when faced with changes in its milieu to which it must adapt in order to survive. Once living thing has adapted to its milieu, it behaves normally (Canguilhem 2013). In "Milieu et Normes de l'Homme au Travail", Canguilhem's concept of "milieu" includes the psychic and sociological dimensions, in addition to the physic and biological aspects, so, if each worker adapts to its own milieu, each worker has a unique biopsychical life. Thus, to go back to Taylorian rationalization, the claim that the normal state of a worker can be equivalent to that of another worker is disputable. The norm is no longer a concept which refers to a statistical reality i.e. the standard or the average, but a concept which refers to an individual metastable balance. Canguilhem refers to studies that have shown that laboratory animals developed behaviors which they would never have adopted in nature: the organism adapts to the milieu of the laboratory. According to Canguilhem, the same is true for human guinea pigs whose performances are involuntarily stimulated by the scientists observing him. The standard that Taylorian rationalization of work draws from the study of workers, hence, will never be universalizable: the "ambition of treating man like the object of rationalization and management comes up against resistance from the vital aspect" (Canguilhem 1947, 123) In the case of man, it comes up against additional difficulties: it is the psychic and sociologic aspects, which make that "worker's behavior reveals as a given, set against forecast and calculation". (Canguilhem 1947, 134)

In Canguilhem's own words, there is "primacy of the vital over the mechanical, primacy of values over life" that make vain any attempt to equate machine and organism. The demonstration of the specificity of living beings, and its justification by the work of the very one of which the "mechanics" claim themselves, enjoin life sciences to get rid of the theoretical use of the machine metaphor. More generally, Canguilhem's criticisms of the machine metaphor prove the need for sciences, if solicitous of the relevance of the knowledge they construct, to periodically make sure that their metaphors and explanatory models are appropriate for the type of object they study and to replace them when necessary.

In that, the fact that Canguilhem, in "Milieu et Normes de l'Homme au Travail" warmly salutes what he recognizes as an effort to make up a human management theory based on biopsychical individuality,[15] in Georges Friedmann's *Problèmes Humains du Machinisme Industriel* (*Human Problems of Industrial Machinism*) (1946) seems to us significant of the pedagogical destination of his criticism of the machine metaphor in life sciences.

Conclusion: On the Scientific and Politic Purposes of Canguilhem's Criticisms of Metaphor

Canguilhem's insistence on analyzing the misuse and use of some metaphors in sciences and the fact that he questions them by history and philosophy of science reveal the purposes Canguilhem assigns to his practice of these two disciplines: education of scientific uses of metaphors and, Jean-François Braunstein adds, politics.

In his essay *Canguilhem, Histoire des Sciences et Politique du Vivant* (*Canguilhem, History of Life Sciences and Living Policy*), Braunstein shows that Canguilhem enlists history of sciences in order to shed a light on contemporary debates. The paper "Le Problème des Régulations dans l'Organisme et dans la Société" ("The Problem of Regulations in the Organism and in Society") (1955) offers a shiny example of this tendency. Canguilhem, with the help of his thesis in philosophy of biology, examine the relevance of the equation of society to the organism in political theory and sociology (in particular, in Henri Bergson's philosophy and in the sociology of cybernetician Walter Cannon) and in the lay public representation. As far as political and sociological sciences are concerned, the problem is not new: "one must note that there has always been exchanges of good or bad practices between sociology and biology". (Canguilhem 2010, 104) It is above all the lay public

[15] It is a theory where machine adapts to the individual and where this is no longer the individual that must adapt to machine, as in Taylorism.

representation resulting from political and sociological theories which excuse Canguilhem's analysis of the metaphor: "I would like to show […] that if we place ourselves […] from the point of view of lay public representation, the correcting of this metonymy is urgently required". (Canguilhem 2010, 105) The equation of society to an organism suggests, on the one hand, that, like the organism, society self-regulates and then, that crises resolve by themselves and that society tends towards cohesion. On the other hand, it results in the idea that social ills can be treated by a social therapy i.e. a reform. Canguilhem demonstrates that the metaphor is not relevant: in a sick organism, it is difficult to determine the etiology of the pathology, but it is simple to know where this organism should tend towards i.e. to know the purpose of therapy. The aim of therapy is the healthy organism, which is the ideal state of organisms, given during its existence. On the contrary, in society, men easily agree on the causes of crisis but can hardly see a remedy to it, for society has no purpose and therefore no regulatory ideal; society is merely a means. Consequently, society "presupposes and even calls for regulations; there is no society without rules, but there is no self-regulation in society. In society, regulation is always, if I may say so, added on and precarious" (Canguilhem 2010, 121).

The analysis of the organism metaphor in "Le Problème des Régulations dans l'Organisme et dans la Société" thus takes a political coloration. Through it, Canguilhem seems hoping for awaking politically his contemporaries: that society does not self-regulate, he writes, is "the reason why I believe there is an essential link between the idea that justice is not a social apparatus and the idea that, until now, no society has been able to survive without crisis and with the mercy of these exceptional beings one calls heroes" (Canguilhem 2010, 124).

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