LEGITIMATING THE MACHINE. THE EPISTEMOLOGICAL FOUNDATION OF TECHNOLOGICAL METAPHOR IN THE NATURAL PHILOSOPHY OF RENÉ DESCARTES

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Introduction

One of the salient features of early modern science is a conspicuous proliferation of mechanical imagery applied to all conceivable natural phenomena. These tropes are part of a complex historical shift, marking the emergence of a distinctly modern scientific attitude modelled in close partnership with craftsmanship and engineering. Metaphors of automata, artefacts and technical activity performed a varied range of explanatory functions, and are found in a number of analogical constructions: the world as machine, God as artisan, nature as handicraft, the world as rational design, the philosopher as engineer, etc. We can use the term 'machine metaphor' as a convenient way of referring to this multifarious constellation of images, conceptual approaches, explanatory devices, and rhetorical and pictorial strategies. All these discursive artefacts are interconnected in complex ways, finding their common source in the technocultural milieu of the early modern period; that is, on real artefacts. It is not my intention here to offer a comprehensive overview of this phenomenon, but to consider one momentous historical case: that of René Descartes (1596-1650).

Among his many considerable achievements, Descartes was the first to extensively and systematically introduce the machine metaphor into the life sciences, exploring the

poetic and conceptual possibilities of a mechanical theory of the living. But my main focus of interest here is the way Descartes set to legitimate the machine metaphor as an exemplary instrument of the new science, at a time when the role of analogy and other rhetorical tropes in natural philosophy was being intensely questioned. In this respect, Francis Bacon's attack on the excesses and vagaries of rhetoric and language (the 'Idols of the Market', in *The Great Instauration* [1620]) are well known.

A central aspect of the scientific revolution was a search for new rhetorical strategies; techniques of representation; and ways of presenting, circulating and advertising natural-philosophical knowledge. Descartes' case is unique because of the imaginative way in which he sought to ground heuristics on firm metaphysical and epistemological foundations. Descartes privileged technological images (machines, everyday artefacts, and the activity of engineers, artists and artisans) above all others, showing a keen fascination with the technology of his day; in particular, automata, the microscope, perspective representation, optical artefacts, mechanical illusions, and the textual and pictorial techniques of machine treatises and post-Vesalian works on anatomy.

Descartes' natural philosophy is an exemplary case of the alliance of systematic reason and technological practice that characterizes the technoscientific turn of the seventeenth century. Descartes articulated together many heterogeneous and disparate dimensions of technological experience; these 'ways of being' of technology cut across various technical, socio-cultural and discursive dimensions, where technology variously appeared as an object of rational knowledge; a site of spectacle and wonder; a symbol of certain kinds of knowledge and an emblem of the new science; as a practical problem for engineers, in a range of contexts; in the shape of new scientific instruments; as the abstract object of mechanics; and as the subject of illustrated technological treatises.

As a self-styled solitary traveller and observer, Descartes had access to a range of culturally and socially fragmented experiences; their creative incorporation actively and profoundly shaped the direction of his thought.

The intellectual milieu, however, was also pushing in this direction. We can briefly outline five *main* areas in which technological metaphors played an important role in the scientific revolution:

1 – As *structural* metaphors, where the arrangement of parts of a certain artifact is regarded as analogous to that of a natural object. Perhaps the most significant example is the analogy between the eye and the *camera obscura*.

In the notes to his edition of *Treatise on Man*, Thomas Hall argues that the gradual rise of modern optics was closely associated with certain technological developments.[1] First, the lens of the eye (the crystalline humour at its centre) had to be conceived as a refractor rather than a sensor. Once lenses began to be widely manufactured and better understood, the analogy was suggested, and buttressed by experiments that showed organic and technological lenses both behaved in the same manner. Simultaneously, the retina (from Latin *tunica reti similis*, 'membrane like a net'), began to be conceived as a *receiver* of the two-dimensional image, after refraction and conduction by the rest of the eye. The analogy developed in close connection to the *camera obscura*,[2] as the two elements of this

[1] Descartes R., *Treatise on Man,* transl. and annotated by Thomas Steele Hall, Prometheus Books (New York:2003), n. 90, 51-52.

[2] The first mention of such a device is by the Arab philosopher Alhazen (Abu Ali al-Hasan ibn al-Haitham, approx. 965-1041), in his *Kitab al-manazir* (*The Book of Optics*; Latin: *De aspectibus*). His experiments served to establish the fact that rays of light could pass through a very small hole without interfering with each other (Park D., *The Fire within the Eye: A Historical Essay on the Nature and Meaning of Light,* Princeton University Press [New Jersey: 1997], 83-4). Giambattista de la Porta popularised it in *Magia naturalis* (1589) and *De refractione* (1593). In his own *Optics*, Descartes repeats the *camera obscura* metaphor: '… the objects we look at do imprint very perfect images on the back of our eyes. Some people have very ingeniously explained this already, by comparison with the images that appear in a chamber, when having it completely closed except for a single hole, and having put in front of this hole a glass in the form of a lens, we stretch behind, at a specific distance, a white cloth on which the light that comes from the objects outside forms these images. For they say that this chamber represents the eye; this hole, the pupil; this lens, the crystalline humour, or rather, all those parts of the eye which cause some refraction; and this cloth, the interior membrane, which is composed of the extremities of the optic nerve' (Descartes R., *Discourse on Method, Optics, Geometry, and Meteorology,* transl. by Paul J. Olscamp, The Bobbs-Merrill Company, Inc. [New York-Kansas City: 1965], 91). Henceforth, all references to *Optics* are from Olscamp's translation, and

device (hole and screen) became functionally (and for Descartes ontologically) equivalent with the lens and retina, respectively.

2 – Artifacts embodied a *mode of action*. The focus in this case was not so much on the physical structure of the machine but on the way in which it works. Aristotle had used images of mechanical puppets and other machines to illustrate the *efficient* mode of causation[3]. The key piece of technology here is the mechanical clock. The late medieval period was marked by the effort to reconcile and adapt the thought of pre-Christian thinkers like Plato and Aristotle to the framework of Christianity. During this period, science 'was transferred … from the ontological context of God as the first cause existing knowably within nature to that of God as the totally separate omnipotent and inscrutable creator of nature …'[4] With the assimilation of the clock image, the relationship of God-as-first-mover and the world was conceptualized in terms of machines that could move by themselves after an initial transfer of force. The rational, preordained design of the machine then ensured the continuation of harmonious motion. Thus, Marsilio Ficino (in his *Theologia Platonica* of 1576) describes an automaton Regiomontanus demonstrated in Florence in 1475, in which a single counterweight powered an arrangement of moving animals, singing birds and sounding trumpets: 'Thus God by his existence alone, which is the same thing as his intellect and his will, and which is the simplest of all centres from which … everything else leads like lines, with the easiest nod agitates whatever depends upon him.'[5]

In astronomy and cosmology, mechanical imagery came to represent the cosmos as a harmonious, skilful construction subject to determinable regularities. But moral, political and scientific meanings are impossible to disentangle, and the machine resonated with a significance previously reserved for natural and religious symbols. The political realm was

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marked 'O'.

[3] E.g.: *On the Motion of Animals*, 701b, 702a 20-703; *On the Generation of Animals*, 734b-735a 4.

[4] Crombie A. C., *Styles of Scientific Thinking in the European Tradition,* 3 Vols, Gerald Duckworth & Co. (London: 1994), vol. 2, 58.

[5] Crombie A. C., *Styles of Scientific Thinking* 468.

a microcosm of the heavens, and the clock acted as an image of both social and cosmic order. Otto Mayr sums up the kinds of contexts the clock appeared in: '… the clock was called upon to illustrate the attributes of God; the harmony of the universe; the joys of paradise; temperance, the highest of the seven virtues; the truth of the new science; and the effectiveness of absolute monarchy.'[6]

The machine metaphor married these two conceptual aspects: efficient causation and intelligent design. Johannes Kepler was arguably the first to transform 'one of the stock metaphors of astronomy into a functioning analogy in mechanics.'[7] In 1605, while searching for a true astronomical hypothesis (as opposed to merely saving the appearances), Kepler writes that his aim

> is to show that the celestial machine (*caelestis machina*) is to be likened not to a divine living thing but rather to a clockwork (*horologium*) … in so far as nearly all the manifold movements are carried out by means of a single quite simple magnetic corporeal force (*vis magnetica corporalis*), just as in a clockwork all the motions come from a single weight. Moreover I show that this physical cause (*ratio*) can be determined by numbers and geometry.[8]

Descartes' mechanistic physiology presents another stage in the transformation of the metaphor, as he banishes a fundamental Aristotelian principle: there are no 'movers' and 'moved' in nature; and consequently, no prime movers. Every particle is in motion, containing in itself the power to move others. As a consequence, the Cartesian automaton differs from the Aristotelian. For Descartes, as Des Chene writes, the machine is a self-mover mainly 'because some of its movements are comprised in self-perpetuating cycles: the periodic contraction and expansion of the heart, the depletion and replenishment of the blood, hunger and satiety, desiring food, seeking and obtaining it.'[9] Rather than a scheme of

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[6] Mayr O., *Automatic Machinery in Early Modern Europe*, John Hopkins University Press (Baltimore & London: 1986), 125.
[7] Kemp M., "Vision and Visualisation in the Illustration of Anatomy and Astronomy from Leonardo to Galileo", in Freeland G.- Corones A. (eds.), *1543 and All That: Image and Word, Change and Continuity in the Proto-Scientific Revolution*, Kluwer Academic Publishers, (Dordrecht-Boston: 2000), 43.
[8] Crombie A. C., *Styles of Scientific Thinking* 542.
[9] Des Chene D., *Spirits and Clocks: Machine and Organism in Descartes,* Cornell University Press (Ithaca-London: 2001), 25.

active and passive bodies, for Descartes *all* bits of the machine are active in a sense—they are 'moved movers'. Circular and circulatory motion is the underlying principle of Cartesian machines (cosmological, biological and in between), since motion must *produce its own cause*.

3 – The metaphor of God as *artifex*, as craftsman or technologist, also undergoes a transformation during the renaissance and subsequent periods. This metaphor encompasses a range of distinct constructions. For instance, as Daston and Park argue, the 'nature as art' metaphor conceived of the world as a pliable, somewhat passive object fashioned by the hands of God; whereas the 'nature as artisan' metaphor regarded nature as engaged in active deliberation and possessing a certain degree of autonomy.[10] We must also include here various conceptions of God as designer, architect, geometer, and so on. These metaphors were instrumental in determining the nature and reach of natural-philosophical knowledge.

4 – The activity of the natural philosopher became closer to that of the craftsman. Medieval thought grounded the distinction between scholar and craftsperson in certain theological schemes that drew categorical differences between manual labour and the contemplative life, mind and matter, and the heavenly and the sublunary. By the end of the seventeenth century, these key metaphysical distinctions had been worn away, leading to 'a drastic weakening of the art/nature distinction.'[11] The story is quite convoluted, beginning perhaps with the emergence of an experimentalist tradition in the late middle ages and the rise of the humanist 'rational artist' during the renaissance. The ancient sources include Plato's *Timaeus*, Aristotelian conceptions of art imitating nature and nature imitating art, and Vitruvius' remarks on the education of the architect at the beginning of his *De architectura*. The main point of contact here is the conception that in nature, as in art,

[10] Daston L.–Park K., *Wonders and the Order of Nature 1150-1750*, Zone Books (New York: 2001), 296-7.
[11] Dear P., *Discipline and Experience: The Mathematical Way in the Scientific* Revolution, The University of Chicago Press (Chicago-London: 1995), 151.

rational deliberation preceded material conception. By the late sixteenth century, the world of the craftsperson and engineer suggested a model of knowledge in which nature became like a manufactured object, a thing to be coaxed and scrutinized.[12]

5 – Finally, the mathematical approach to the physical world that lies at the core of modern science was shaped in part through the elevation of mechanics to a new, exalted status. Mechanics, like optics, was a *scientia media*, halfway between mathematics and physics. The early moderns began to regard the science of machines as an exemplary case of how mathematics can be applied to the understanding and modelling of physical phenomena. In his notion of mechanics Descartes conflated two distinct sources: the traditional sense of a branch of mathematics; and technological practice and engineering: the construction and study of machines.

All the dimensions outlined above provide the context to Descartes' own vision. What set him apart was his effort to provide a clear rationale for the development and application of tools of representation such as analogies, thought experiments, pictures, diagrams, etc. As we shall see, although a diagram and a metaphor are quite different things, they are connected by the same context.

This project of legitimation can be most explicitly reconstructed from Descartes' discussions on the nature of comparisons, the mechanisms of ideation and perception, and the nature and purposes of scientific knowledge. The Cartesian theory of analogy concerns mainly the relation between objects and cognitive impressions, and how our management of these impressions can lead to valid knowledge. It has a firm footing on Descartes' metaphysics of matter, and crosses through a number of dimensions of Descartes' thought, bringing together physics, the physiology of perception, the hierarchy of the sciences, and his views on human knowledge.

[12] See also Rossi P., *Philosophy, Technology and the Arts in the Early Modern Era*, Harper & Row Publishers (New York: 1970).

Descartes also demonstrates the explanatory promise of machine metaphors by *applying* them, showing mechanical modelling at work, and creatively transforming the technological milieu of his age into workable models.

The machine is, however, more than just a metaphor or model, and comes to inform Cartesian explanatory strategies at an intimate level, in the form of conceptual, rhetorical and pictorial structures derived from machine treatises, automata theatres, the microscopic imaginary, and other technocultural sources. I will call this level 'meta-analogical'. The machine is, for Descartes, a metaphysical thesis, coming to express a philosophical commitment about the ultimate nature of physical (extended) substance. This ontology or ruling metaphor is what ultimately threads together these various mutations of technology. The machine articulates a metaphysics of matter centred on the interaction of indivisible elements acting according to laws of motion, force and geometric figure. The corpuscularian conception of nature stood in stark contrast to previous models based on hidden correspondences and the belief in qualities or faculties inherent in substances. Descartes sought to restrict to a minimum the principles involved in the operations of matter, offering a model of local mechanical action in which corpuscles move as a result of direct contact or impact—this also being the main attraction of a plenarist metaphysics. Thus, in what respects the whole of the physical universe, Descartes, the famous dualist, is a radical monist. There is a principle of *immanence* to Cartesian mechanicism which postulates a single, continuous plane of material action, crossing the boundaries between natural, living and artificial. The machine, then, is a high-level concept connecting areas of knowledge as diverse as anatomy and cosmology, while also informing the application of particular artifacts in specific contexts.

Finally, the machine metaphor comes to inform the technological orientation of Cartesian science, the aim of which is to produce representations of the world that can facilitate manipulation and intervention.

In order to follow this transversal thread across Descartes' natural philosophy, I will leave aside some important aspects of the machine question. I have nothing to say, for example, about the incorporation of hydrostatics and hydrodynamics into Cartesian physics.[13] I also touch lightly on the role of the automaton metaphor in physiology and the theory of life, and the complications it encountered. The machine was also implicated in various theological and moral questions, such as free will, moral responsibility, and the nature of human judgment. The moral and religious aspects of bodily automatism were the most significant to Descartes' contemporary and future audiences, eclipsing to a large extent its scientific aspects. Lastly, this is not an essay about the history of technology, and the sources of these images and concepts (a fascinating area in its own right) will be addressed only cursorily. I will assume some familiarity with baroque technology, crafts and techniques. My main focus is how the machine metaphor is used to figure the cognitive activity of natural philosophy, how it shapes its nature and aims.

I begin with Descartes' philosophy of analogy in scientific method, then examine some concrete applications of analogies in physics. These analogies are then contextualized in terms of Descartes' wider philosophy of knowledge, where technological images come to represent some aspects of scientific activity. I argue that these images also shape the orientation of natural knowledge, which Descartes regards as consisting of provisory hypotheses that must have efficacy in the world. Then, I turn to more properly epistemological aspects, regarding Descartes' theory of perception and how analogical thinking fits into this. In this context, I highlight the role of optical deceptions in providing

[13] This has been exhaustively explored by Stephen Gaukroger. See, in particular, "The Foundational Role of Hydrostatics and Statics in Descartes' Natural Philosophy", in Gaukroger S.– Schuster J.–Sutton J. (eds.), *Descartes' Natural Philosophy,* Routledge (London-New York: 2000).

a model of how we perceive the world. Descartes, however, believed in the inherent rationality of the universe: our knowledge is not merely illusory and arbitrary, but rests on a proportionality between ideas, figures in the brain and the things of the world.

In the last two sections, I turn to *Treatise on Man,* Descartes' most extraordinary deployment of mechanical metaphor. I argue that this can be considered the last stage in the mechanization of nature: the point at which machines themselves are subsumed into Descartes' project of a mathematical physics, thus prefiguring modern notions of technology. Lastly, I focus on some aspects of the machine as a system of representation: how certain technocultural sources inform Descartes' techniques of visualization and pictorial representation.

One very last caveat concerns the use of terms such as 'image', 'metaphor', 'analogy', 'technology' and 'science'. For the purpose of this argument, and unless otherwise stated, I will use the terms 'metaphor', 'analogy', and 'image' as more or less synonymous. Part of my argument here is that Descartes' use of machine images exceeds easy classification, and that it is important to examine the phenomenon as a whole.[14]

'Science', 'technology' and their related terms are gross anachronisms when speaking of the seventeenth century. My main justification for using them is to draw certain historical continuities, to trace genealogies of concepts and practices that, in retrospect, bear

[14] Some examples might clarify the issue. In the *Treatise on Light*, the analogy of two boats travelling along two intersecting rivers illustrates how comets pass from one circulatory current to another, while planets tend to gravitate towards the centre [AT XI 57-60; Descartes R., *The World and Other Writings*, transl. and edited by Stephen Gaukroger, Cambridge University Press (Cambridge-New York: 1998), 38-9. Henceforth, all references to *The World* and *Man* are from Gaukroger's edition, and their page numbers are indicated with a 'G' after the AT reference.] Where this is clearly an analogy, another example a bit further on is a model: to explain how individual corpuscles exert force on each other, and how this affects the collective behaviour of matter in motion, Descartes employs the image of an arrangement of rows of balls, spaced at different intervals (AT XI 91-6, G 58-61). The line between analogy and model is thin at times, but the latter implies a more artificial set-up; in this case, a thought experiment that (it is assumed) can be carried out in practice. An analogy is a 'highly selective similarity', or 'a way of aligning and focusing on relational commonalities independently of the objects in which those relations are embedded' (Gentner D.—Jeziorski M., "The Shift from Metaphor to Analogy in Western Science", in Ortony A. [ed.], *Metaphor and Thought*, Cambidge University Press, [Cambridge: 1993], 448-9). The 'body as machine' image in the *Treatise on Man*, as we shall see, can be more accurately characterized as a metaphor, a comparison that is broader in scope, more 'vague'.

on science and technology as we know them. Science refers, in general, to the study of nature; while technology refers to the activities of artisans and engineers, to the universe of machines, techniques and surrounding cultural forms, and to a particular world-view that seeks (to use Descartes' words) the 'mastery of nature'. I apply the term 'technological' also to a certain attitude that regards explanations and forms of representation as having instrumental value, and subordinate 'true' knowledge to the aims of intervention. In the seventeenth century, this attitude is articulated through images of natural things as technical products or processes.

1 – Figures and clocks: Artefacts and the Cartesian theory of metaphor

Analogies play a central explanatory role in Descartes' natural philosophy, and he seized them 'as his principal tool of investigation',[15] seeking to employ them rigorously, as heuristic tools that would yield certain and useful knowledge. In Rule Fourteen of the *Regulae,* Descartes discusses the method of comparing two things to one another, arguing that human knowledge proceeds by abstracting common ideas from various subjects of observation:

> Indeed, it is by means of one and the same idea that we recognize in different subjects each of these familiar entities, such as extension, shape, motion and the like … This common idea is carried over from one subject to the other solely by means of a simple comparison, which enables us to state that the thing we are seeking is in this or that respect similar to, or identical with, or equal to, some given thing. Accordingly, in all reasoning it is only by means of comparison that we attain an exact knowledge of the truth.[16]

Descartes offers a working definition of analogy, announcing its centrality in his project. The comparison of two things yields a third term: universal abstractions that are (as

[15] Galison P., "Descartes's comparisons: From the invisible to the visible", *ISIS*, 75 (1984), 311.

[16] AT X 439, CSM I 57. 'AT' refers to Adam and Tannery's edition of Descartes' works. 'CSM' refers to the standard English translation of selected works: Descartes R., *The Philosophical Writings of Descartes*, 3 Volumes, transl. and edited by J. Cottingham, R. Stoothoff, and D. Murdoch, Cambridge University Press (Cambridge-New York: 1985).

we shall see) at once clear rational principles and the simplest features of matter, such as extension, shape and motion.

As Galison observes, most of the metaphors found in the philosopher's writings are, of everyday objects and phenomena; such as 'slings, canes, tennis balls, brambles, springs, clocks, robots, pulleys, pipes, organs, ships.'[17] As this list suggests, Descartes' favourite source domain consists of everyday artefacts, tools and machines. Despite Descartes' sceptical stance towards the evidence of the senses, in his investigative method these everyday objects play a friendlier role as maidens of knowledge. Descartes says in the *Discourse* that, regarding observations,

> … the further we advance in our knowledge, the more necessary they become. At the beginning, rather than seeking those which are more unusual and highly contrived, it is better to resort only to those which, presenting themselves spontaneously to our senses, cannot be unknown to us if we reflect even a little.[18]

However, as Brian Baigrie points out, these mundane images can help us procure true knowledge *only if* 'some of the properties of bodies of our experience are genuinely representational; that is, that we obtain genuine knowledge of bodies of mundane experience via sensation.'[19] This genuine knowledge consists in the simplest features of material nature: size, motion and figure. These principles remain the same regardless of how large or tiny the bodies are. In a letter to Morin, Descartes states:

> … in the analogies which I employ, I compare movements only with other movements, or shapes with other shapes; that is, I compare things that are too small to be perceived by the senses with other things that can be so perceived, the latter differing from the former simply as a large circle differs from a small one. I maintain, therefore, that analogies of this sort are the most appropriate means available to the human mind for laying bare the truth in problems of physics.[20]

[17] Galison P., "Descartes's comparions" 311.
[18] AT VI 63, CSM I 143.
[19] Baigrie B.S., "Descartes' Scientific Illustrations and 'la grand mécanique de la nature'", in Baigrie B. S. (ed.), *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, University of Toronto Press (Toronto-Buffalo-London: 1993), 113.
[20] AT II 367-8, CSM III 122.

Analogy has an ontological basis, as the comparison of two things that are of the *same nature*. The only differences between macroscopic and subvisible things are *size* and *complexity of arrangement*: strictly quantitative criteria. Thus technological analogies could be considered an exemplary case of figuring the microscopic by way of the macroscopic, serving as a heuristic tool to picture structure, force, and other features of matter in motion. A principle of geometric proportion ensures the equivalence and transferability of these features. In the Sixth Meditation, Descartes says that corporeal things

> … may not all exist in a way that exactly corresponds with my sensory grasp of them, for in many cases the grasp of the senses is very obscure and confused. But at least they possess all the properties which I clearly and distinctly understand, that is, all those which, viewed in general terms, are comprised within the subject-matter of pure mathematics.[21]

Geometrical reasoning as figuration (as distinct from geometrical reasoning as axiomatic-deductive thinking) pertains to *bodies*: 'corporeal nature … is the subject-matter of pure mathematics…'[22] These simple natures offer an epistemic link between the 'distinct understanding' *qua* language of ideas (innate in the mind) and the corporeal figures abstracted from everyday experience. As Galison explains, for Descartes the role of the imagination is to 'depict a macroscopic image to the rational soul',[23] while the role of its products (comparisons and analogies) is to 'bridge the gap from the invisible corpuscles of natural phenomena to visible figures in the brain.'[24]

The series of analogies offered in the First Discourse of *Optics* is an exemplary case in point. Descartes tells us that he does not need to explain the 'true nature' of light, only to 'explain how its rays enter into the eye, and how they can be deflected by the different bodies that they encounter …'[25]

[21] AT VII 80, CSM II 55.
[22] *Meditations*, AT VII 74, CSM II 51.
[23] Galison P., "Descartes's comparisons" 324.
[24] Galison P., "Descartes's comparisons" 311.
[25] Descartes R., Optics 66.

Descartes says he will 'make use of two or three comparisons' to help the reader conceive of light and all 'its properties that experience acquaints us with', and 'to deduce afterwards all the others which cannot be so easily observed.'[26]. He compares this method to that of astronomers, who use false or uncertain assumptions to draw 'many very true and well-assured conclusions.'[27]

The first comparison is that of walking at night with a stick, like blind people do to find their way around. This illustrates the first property of light: instantaneous transmission. A blind person can perceive differences between things solely by the medium of the stick; the same way we perceive colors by the diverse movements of matter. Descartes here insists on the lack of resemblance between cause and sensation, a topic that we shall encounter again soon.

The second comparison is a vat full of half-pressed grapes at vintage time.[28] The vat has two holes at its bottom. Descartes argues that all the points on the surface will tend to go down simultaneously in a straight line towards these two holes. These 'tendencies to motion' (a key concept of Cartesian physics: the distinction between movement and the inclination to move) do not impede each other, but form lines of force that are transmitted across subtle fluids and hard bodies. The mixture of grapes acts as a microcosmic metaphor to illustrate how rays of light proceed from the sun, agitating the subtle material in interstellar space and forming rectilinear tendencies to motion that reach our eyes without impeding each other.

The third analogy is with tennis balls.[29] This is intended to explain deflection and refraction, since tendency to motion behaves in the same way as motion.[30] If we can imagine each particle as a ball bouncing off a surface, then different surfaces (smooth,

[26] Descartes R., *Optics* 66.
[27] Descartes R., *Optics* 67.
[28] Descartes R., *Optics* 69.
[29] Descartes R., *Optics* 70-4.
[30] Descartes R., *Optics* 70.

concave, rough, etc.) will deflect each of these balls in a different angle. Similarly, if we can imagine a ball entering a liquid body, we can get a mental picture of how rays of light lose some of their motion and direction of motion upon entering a liquid medium.

The main point is that each of these analogies illustrates one property of rays of light, and Descartes takes each of these both positively and negatively; i.e., he is quick to point out the limits of the image, and to draw attention to the mechanism of analogy itself. Each analogy is a provisory hypothesis, and illustrates something that the previous one lacks. The blind person's stick illustrates instantaneity of movement; the vat of grapes, tendencies to motion; and the tennis balls, refraction and deflection. In each of these cases, the analogue is of the same nature as the primary subject; in fact, each analogy can be understood as a thought experiment, an imaginary experimental set-up. The ordinariness of the analogue buttresses their evidential strength. Secondly, the analogue is a macroscopic image of a microscopic phenomenon.

Thus, these analogies are instances of a single analogical strategy, cutting cross Descartes' technocultural universe: the prosthetic enhancement of perception, the manufacture of wine, and an outdoor game. The machine metaphor is a transversal phenomenon: an abstract machine, a meta-physics, a meta-analogy that gathers and cements Cartesian physics. Each analogy will be a particular expression of the machine metaphysics. The vat of grapes indicates most clearly one of the sources of this abstract machine, in mechanics (hydrostatics). But it stretches far and wide, providing also the scaffolding for epistemology itself, as we shall see next.

3 - Knowing as making: The limits and nature of scientific knowledge

Technological analogies also serve another purpose: to figure the very activity of understanding. In a passage from *Principiae,* Descartes addresses the following objection:

how can the philosopher assign determinate shapes, sizes, and motions to invisible particles as if he had seen them? Descartes begins his response by alluding to his first principles. He says he considered clear and distinct ideas of things, and could find only shapes, sizes and motions, and the rules whereby these three things can be modified by each other (that is, the principles of geometry and mechanics). He continues:

> In this matter I was greatly helped by considering artefacts. For I do not recognize any difference between artefacts and natural bodies except that the operations of artefacts are for the most part performed by mechanisms which are large enough to be easily perceivable by the senses—as indeed must be the case if they are capable of being manufactured by human beings. The effects produced in nature, by contrast, almost always depend on structures which are so minute that they completely elude our senses. Moreover, mechanics is a division or special case of physics, and all the explanations belonging to the former also belong to the latter; so it is no less natural for a clock constructed with this or that set of wheels to tell the time than it is for a tree which grew from this or that seed to produce the appropriate fruit. Men who are experienced in dealing with machinery can take a particular machine whose function they know and, by looking at some of its parts, easily form a conjecture about the design of the other parts, which they cannot see. In the same way I have attempted to consider the observable effects and parts of natural bodies and track down the imperceptible causes and particles which produce them.[31]

This passage neatly articulates all the major areas in which technological analogy comes to play a part in Descartes' project. Firstly, we begin with an *ontological* assertion: the equivalence of natural bodies (both animate and inanimate), and artificial things. Secondly, the ontological leads to a *disciplinary* aspect, a rearrangement of the sciences: physics, concerned with natural bodies, is collapsed into mechanics, the science of machines. Although the latter is subsumed under the former, these two branches of knowledge deal with the same type of object; they are ruled by the same physical principles, and are not metaphysically (in their 'nature') distinct. This epistemological attitude is closely modelled on the activity of the technologist ('men who are experienced in dealing with machinery'), which becomes the key to elucidating the unseen structures and mechanisms beyond available observation.

[31] AT VIIIA 326, CSM I 288-9.

This attitude also extends to the nature and aspirations of knowledge. In the preface to the 1647 French edition of the *Principia,* Descartes proposes a reorganization of philosophy:

> Thus 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.[32]

In this schema mechanics encompasses the whole of the physical world; that is, the entirety of physics and biology. The three branches are the fruits of applying physics to the problems of human life: the betterment of our physical condition (medicine), the making of machines and rational improvement of techniques (mechanics), and the application of moral standards of conduct to everyday life (ethics). In Descartes' system (as *The Passions of the Soul* makes clear) both medicine and ethics depend heavily on the notion of the body-machine, as they depart from a mechanical understanding of bodily nature. Medicine and ethics have the same aims as mechanics: technological control with the aim of human utility.

> This will indeed be sufficient for application in ordinary life, since medicine and mechanics, and all the other arts which can be fully developed with the help of physics, are directed simply towards applying certain observable bodies to each other in such a way that certain observable effects are produced as a result of natural causes. And by imagining what the various causes are, and considering their results, we shall achieve our aim irrespective of whether these imagined causes are true or false, since the result is taken to be no different, as far as the observable effects are concerned.[33]

Manipulation and intervention are, for Descartes, the ultimate goals of scientific knowledge. Mechanical imagery, in this context, is a 'natural' expression of the technological orientation of Descartes' thought. As Peter Schouls explains, the 'abstract thinking required for pure science is, for Descartes, never to be an end in itself', having an

[32] AT IXB 14, CSM I 186.
[33] AT IXB 322, CSM I 289.

'instrumental value only, [in] that it serves to lay the foundations for mastery.'[34] Thus, we must move 'from abstract thought to useful, practical knowledge as soon as this is legitimate, that is, as soon as abstract thought is sufficiently advanced to serve as proper foundation.'[35]

There is a tension here between the heuristic and the metaphysical, between metaphor and literality: technological images are, on one hand, a provisory explanatory tool; yet, on the other hand, they are constitutive and foundational. Our reasoned analysis must pass through theories and analogies—yet a certain type of image provides the very condition of possibility of this process. Without these metaphors, it would be impossible to conceive of the universe and the activity of natural philosophy. So, rather than a subset of a larger analogical strategy, the machine is in fact the very precondition of that strategy.

We can also glimpse another tension between reason and imagination, understanding and corporeal figuration. The complex and imperceptible business of nature cannot be directly presented or represented to the senses, but only grasped through reason. The task of representation is to extract certain essential features from the tumult of matter, make them available to reason through the imagination. We shall return to this in a moment.

The wider, moral-theological dimension of Descartes' philosophy of knowledge is founded on the notion of the inscrutability of God. As Harry Frankfurt explains,

> The Church insisted that only God's word could authoritatively reveal the design of the world …, while Galileo maintained that this design could be discovered by the use of natural reason in scientific inquiry. Descartes, on the other hand, leaves God's truth to God and claims for science only a truth sufficient for man.[36]

[34] Schouls P.A., *Descartes and the Possibility of Science*, Cornell University Press, (Ithaca and London: 2000), 128.
[35] Schouls P.A., *Descartes and the Possibility of Science* 129.
[36] Frankfurt H.G., (1970) *Demons, Dreamers and Madmen: The Defense of Reason in Descartes'* Meditations, The Bobbs-Merrill Company Inc. (New York: 1970), 184.

Descartes saw the reconciliation of certain natural-philosophical and theological demands as crucial to the success of his system. In the words of Dennis Sepper, for Descartes '[t]he notion of God's absolute power undermines any significant analogy or proportionality between his being and that of his creatures.'[37] Our knowledge can never be absolute, or pretend to equal that of the Creator. The progress of philosophy may serve to enhance our sense of reverence for the Designer of the universe; indeed, this is one of the moral dimensions of Cartesian science. Yet this moral dimension is subordinate to the real mission of science, which is the betterment of the human condition (moral, bodily and material). Descartes advertises his project with the prospect of great utility, and puts a passionate and persuasive case for the value of this collective enterprise.[38]

The mastery of nature requires a previous step: its representation. To put it simply, the task of natural philosophy is to manufacture representations that *work*. These representations must be understood in the context of a view of knowledge as provisory, dealing in probable, working hypotheses:

> … although this method may enable us to understand how all the things in nature could have arisen, it should not therefore be inferred that they were in fact made

[37] Sepper D.L., *Descartes's Imagination: Proportion, Images, and the Activity of Thinking*, University of California Press (Berkeley: 1996), 215.

[38] In particular, in the *Discourse on Method*. Descartes maintained that these rational foundations must be laid by one person (i.e., Descartes himself), and hence the metaphors of architecture and town planning to refer to this aspect of his project. In what respects observation and experimentation, Descartes recognizes it is a collective task. The most eloquent expression is given in the following passage from the *Discourse,* which deserves to be quoted in full again: 'I believed that I could not keep them [i.e., the principles I had discovered] secret without sinning gravely against the law which obliges us to do all in our power to secure the general welfare of mankind. For they opened my eyes to the possibility of gaining knowledge which would be very useful in life, and of discovering a practical philosophy which might replace the speculative philosophy taught in the schools. Through this philosophy we could know the power and action of fire, water, air, the stars, the heavens and all the other bodies in our environment, as distinctly as we know the various crafts of our artisans; and we could use this knowledge—as the artisans use theirs—for all the purposes for which it is appropriate, and thus make ourselves, as it were, lords and masters of nature. This is desirable not only for the invention of innumerable devices of innumerable devices which would facilitate our enjoyment of the fruits of the earth and all the goods we find there, but also, and most importantly, for the maintenance of health, which is undoubtedly the chief good and the foundation of all the other goods in this life. For even the mind depends so much on the temperament and disposition of the bodily organs that if it is possible to find some means of making men in general more wiser and more skilful than they have been up till now, I believe we must look for it in medicine. … all we know in medicine is almost nothing in comparison with what remains to be known, and that we might free ourselves from innumerable diseases, both of the body and of the mind, and perhaps even from the infirmity of old age, if we had sufficient knowledge of the causes and all the remedies that nature has provided' (AT VI 61-3; CSM I 142-3).

> in this way. Just as the same craftsman could make two clocks which tell the time equally well and look completely alike from the outside but have completely different assemblies of wheels inside, so the supreme craftsman of the real world could have produced all that we see in several different ways. I am very happy to admit this; and I shall think I have achieved enough provided only that what I have written is such as to correspond accurately with all the phenomena of nature.[39]

Again, the machine image demonstrates the very character of scientific activity. In this case the metaphor of the clock (or rather two clocks) is closely associated with that of the craftsman. The function of this craftsman analogy is, in turn, double; representing both God's and the philosopher's endeavour. While designing and making the world is the prerogative of the creator of the universe, the philosopher must find working models that allow more effective explanation and manipulation. In both cases the craftsman image encompasses a range of elements: the specific mindset of the technologist, and activities such as designing, constructing, and empirical, on-the-spot problem-solving.

Laurens Laudan labels Descartes' general attitude as 'probabilism', and traces its influence on later natural philosophy, particularly in England.[40] According to Laudan, Descartes does not claim that the whole of natural philosophy can be deduced from first principles, and neither does he believe that truth in the sciences can be derived purely from empirical observation, unaided by any a priori or metaphysical suppositions. He advocates instead the hypothesising of principles of 'intermediate generality',[41] and despite his proscription to deduce physics from first principles, 'he never offers any deduction which does in fact exhaustively or uniquely explain some particular in terms of these very general principles.'[42]

These provisory images can be considered as 'morally certain', that is, 'as having sufficient certainty for application to ordinary life, even though they may be uncertain in

[39] AT VIIIA 327, CSM I 289.
[40] Laudan L., "The Clock Metaphor and Probabilism: The Impact of Descartes on English Methodological Thought", in *Annals of Science*, Vol. 22, #2 (1996).
[41] Laudan L., "The Clock Metaphor and Probabilism" 79.
[42] Laudan L., "The Clock Metaphor and Probabilism" 78.

relation to the absolute power of God' (AT VIIA 327, CSM I 289-90). Our hypotheses must have technological efficacy in two senses:

(a) They must be able to address the internal, technical problems of the sciences, coherently explaining and integrating various observations, as well as solving issues of representation. As we shall see, these representations should aspire to clarity and economy, and be closely in synch with the mechanisms of human perception and reasoning.

(b) These explanations must guide effectively the manipulation of nature for human ends. Their usefulness and 'fit' with reality must be vouched by application.[43]

Things and thoughts, nature and our explanations, neither transparently reflect nor logically resemble each other. Knowledge (to define it negatively) does not adhere to a correspondence theory of truth. In the Cartesian schema, our ideas, opinions and observations must undergo an unforgiving methodical examination before they can be called 'knowledge', let alone truth. And the first obstacle to overcome is the illusory, misleading nature of our perceptions; a theme in which machine imagery also plays a defining role.

4 – Illusion, appearance, the automaton

Descartes maintains that our sense impressions are confused, and in no way resemble their objects. Yet they are congruent with them, in a manner to be examined soon. His model of perception is closely modelled on the machines of illusionism. This association of visual representation with optical illusion is crucial, and plays a role in the general distrust of sense perception that kicks off the process of hyperbolic doubt in the *Meditations*.

[43] Schouls writes: 'God, for Descartes, could have brought about certain effects in various ways, and our human faculties cannot reveal the way they were in fact brought about. However, if our scientific theory has as a consequence that it explains the effects we want to explain, or produces the effects we want to produce, then that *may have been* the way God in fact made things to work, and it is certainly a way in which things can and do work.' Schouls P.A., *Descartes and the Possibility of Science* 141.

The account of vision offered in the *Optics* and the *Treatise on Man* is based on the instruments and techniques of perspective representation. 'Perspective in art is an active, ongoing analogy for Descartes, not just a passing comment.'[44] The *Optics* is peppered with various analogies with engravings and perspective:

> For example, you can see that engravings, being made of nothing but a little ink placed here and there on the paper, represent to us forests, towns, men, and even battles and storms, even though, among an infinity of diverse qualities which they make us conceive in these objects, only in shape is there actually any resemblance. And even this resemblance is a very imperfect one, seeing that, on a completely flat surface, they represent to us bodies which are of different heights and distances, and even that following the rules of perspective, circles are often better represented by ovals rather than by other circles; and squares by diamonds rather than by other squares; and so for all other shapes. So that often, in order to be more perfect as images and to represent an object better, they must not resemble it.[45]

In *Man* Descartes uses the metaphor of painting to describe how light rays form a pattern on the retina: 'The change of shape that occurs in the crystalline humour allows objects lying at different distances to paint [*puissant peindre distinctement*] their images distinctly on the back of the eye.'[46] This image of an oval offers a counterpoint, at once contrasting and complementary, to the image of the big circle and little circle examined previously. Whereas in everyday perception we perceive a circle as an oval, reasoned knowledge must compare circles to circles.

For Descartes, as Maull writes, 'the only intelligible and true information to be had about bodies is geometrical.' To begin with, this requires establishing a distinction between a mechanistic explanation of the perception of *magnitudes* and that of *colours*;[47] to which we can add a third parameter: *intensity of light*, which gives the soul cues for degrees of shadow, light, and also textures. Descartes 'wanted the case for colour-perception to be

[44] Newell Decyk B., "Cartesian Imagination and Perspectival Art", in Gaukroger S.– Schuster J.–Sutton J. (eds.), *Descartes' Natural Philosophy,* Routledge (London-New York: 2000), 478.
[45] AT VI 113. Descartes R., *Optics* 60.
[46] AT XI 156, G 128. In addition, this metaphor appears in Kepler's *Paralipomena*, and is most likely the source for Descartes' own use. See Gorman M.J., "Projecting Nature in Early-Modern Europe" www.stanford.edu/~mgorman/ publications/ProjectingNature.pdf (Accessed 05/09/2005).
[47] Maull N.L., "Cartesian Optics and the Geometrization of Nature", in S. Gaukroger (ed.), *Descartes: Philosophy, Mathematics and Physics*, The Harvester Press (Brighton: 1978), 27.

very different from the awareness of figure.'[48] Whereas perceptions of size, distance, and shape (magnitudes) can be easily represented through projective geometry and perspective representation, other perceptual registers (such as colour, sound, and pain) imply a certain incommensurability between figure and judgement. In Discourse Eight of the *Meteors*, for example, Descartes develops an account of colour perception in terms of differences in the rotary motions of second element particles—that is, it arises from certain dynamical properties of matter. In the *Optics*, Descartes maintains that intensity of light is a result of the *force* of the movements in the brain, whereas colour is the result of their *character*.[49] In other words, colour bears an immediate causal relation to a physical/primary property. Intensity of light, on the other hand, seems an intermediary case: it implies a continuous transfer of force running from tendencies to motion to its translation into internal movements of fibres and spirits.

Size, *shape*, *distance* and *position* (or *location*), the four kinds of 'primary' information we obtain about objects, according to Descartes, are not 'proper' to sight, because our awareness of these arise later, as it were, in the brain. They are the result of the interaction of light and our perceptual system, rather than being causally contained in the qualities of matter. As such, they are relative to the observer and require a certain 'processing'; whereas colour derives from a primary quality and bears a more immediate relation to the idea it occasions (however difficult it is to picture this incommensurable leap).

Everything Descartes says about primary magnitudes can be understood in the context of perspective representation. The first striking feature of these parameters, as described in *Optics* and *Man*, is that they are static elements of composition. Descartes models visual perception on the analogy of someone looking at a picture. Once we subtract

[48] Maull N.L., "Cartesian Optics" 29-30.
[49] Descartes R., *Optics* 101.

intensity of light and colour from an image, all we have left is a bare, schematic representation of edges, surfaces, and basic salient features, all of which could be theoretically constructed out of geometrical figures. Nowhere does Descartes explain the perception of *motion,* for example. We can reasonably assume that perception of motion arises from differential changes in these parameters; nonetheless the absence is telling.

Descartes applies geometrical means of representation to *relations* among points—the overall patterns that emerge from the transmission of pressures and tendencies to motion from the points at which rays of light are refracted by objects and transmitted to the eye, nerves and the machinery of perception. His diagrams and explanations focus on transversal figures, geometrical lines of action passing *across* the various realms involved in the perceptual process (light, surfaces, plenum, lens, etc.), as they would appear to an outside observer. These relations are macroscopic effects arising from the primary qualities of extension in motion, and their geometrical tractability confers a central status on various forms of mathematical diagrammation. Despite the fact that the brain is a three-dimensional object, and despite the figural complexity of the nerve openings, Descartes never really seems to abandon the notion of two dimensions, of traces on surfaces. This is because visual pictures are first received by the lens of the eye; the third dimension is only inferred from this information, and from the fact that the eye must alter focus to look at nearby or faraway objects. The figures on the pineal and the ventricles are also two-dimensional.[50] Most of our ideas of position and distance are derived from *internal cues* of the body, such as muscle location, configurations of nerve openings, and differential position of the eyes.[51] So, again, this information is not contained *in* the picture received by the eye.

[50] In the *Regulae*, Descartes presents an early version of his theory of perception. The point is quite clear here: All sensory information is transformed into geometrical figures. In this early version, colour is also a geometrical pattern.
[51] Descartes R., *Optics* 104-113.

Lastly, these four qualities are relative to the observer. Shape itself is a function of the edges and contours of an object as seen from a particular angle, and is not a real feature of objects. The magnitudes are also relative to each other. Descartes, for example, writes that

> … the soul will be able to tell the size and all other similar qualities of visible objects simply through its knowledge of the distance and position of all their points, just as, conversely, it will sometimes judge their distance from the opinion it has of their size.[52]

Hall notes: 'A crucial feature of perception, whether of shape or distance, is comparison; perceptions are based on the drawing of distinctions.'[53] This fits squarely with the role of the observer in perspective representations, where the viewer is the ordering function of the pictorial elements, a fixed geometrical point grounding their relative positions.

By Descartes' time, the significance of perspective representation to optics had been amply recognized. Optical puzzles, for example, were of great interest to Kepler and Galileo, and a prominent preoccupation of the baroque. Besides, the mathematization of vision is inseparable from its instrumentalization, the becoming-machine of the eye. Perspective and illusionist representation is heavily dependant on the use of geometrical instruments, mirrors, grids and other artefacts such as the *camera obscura*. Newell Decyk argues that the Cartesian imagination itself can be understood as an instrument of this kind, 'a master mathematical decoder for various transformations of images.'[54]

The question is: how can we obtain certain (or at least reliable) knowledge from this elaborate deception?

For Descartes, observation trades on surface appearances, while 'real' knowledge deals with the imperceptible business of inside mechanisms. Like touch, vision can only

[52] *Man*, AT X 160, G 133.
[53] In Descartes R., *Treatise on Man*, n. 106, 61.
[54] Newell Decyk B., "Cartesian Imagination" 474.

perceive *surfaces*. Descartes elaborates this point during an intricate discussion of transubstantiation in the Fourth Set of Replies:

> … I am convinced that what affects our senses is simply and solely the surface that constitutes the limit of the dimensions of the body which is perceived by the senses. For contact with an object takes place only at the surface, and nothing can have an effect on any of our senses except through contact …[55]

Descartes reformulates the ancient battle between reality and appearance, truth and illusion, in terms of automata and illusionist machinery. There is a peculiar logic to the process of seeking explanations, a logic also based on the spectacle of machinery.

> I shall lay before your eyes the works of men involving corporeal things. After causing you to wonder at the most powerful machines, the most unusual automatons, the most impressive illusions and the most subtle tricks that human ingenuity can devise, I shall reveal to you the secrets behind them, which are so simple and straightforward that you will no longer have reason to wonder at anything made by the hands of men. I shall then pass over to the works of nature …[56]

Knowledge is conceived in terms of a spectacular demonstration, structured around a series of tensions or plays between appearance/reality, obscurity/clarity, wonder/knowledge, deception/truth, observer/observed, surface/inside, visible/invisible, spectator/stage, macroscopic/microscopic, and mind/body. Illusionist machines (by far the most common type in Descartes' writings) are the paradigmatic example of this logic; in particular, the lifelike automaton, a machine that simulates living things.

This pedagogical narrative has a temporal dimension comprised of two main stages. We begin in a state of wonder, the source of all philosophy. Wonder is a passion, a bodily affair before which the soul is passive. For a moment we forget we are watching a trick and become seduced by surface appearance, falling into the spell of the technological sublime.

Then there follows a process of unveiling and explanation: the banishment of wonder, as the conjurer-scientist comes to explain the mechanisms behind the trick. This is the final moment in the unmasking of appearance, and comprises the main bulk of natural-

[55] AT VII 249, CSM II 173.
[56] *The Search After Truth,* AT X 505, CSM II 405.

philosophical activity.

The mechanical sublime is found in the context of a culture of wonder (admiringly documented by Daston and Park, and Stafford and Terpak,[57] among others) that emerged in Western Europe in the late medieval period. Descartes sought to incorporate these passions into natural philosophy, harnessing them for productive ends. In the words of Daston and Park: 'Descartes was wary of a sensibility of frozen astonishment and a science of nature that wallowed in secrets and rarities for their own sake'.[58] Wonder is not completely banished from Cartesian science; only a *certain kind* of wonder is undesirable: untamed, unreflective, confused wonder. As Galison says, Descartes tried to prove that '[e]ven if our naïve impressions were deceptive, our reasoned analysis of experience would be reliable.'[59]

Descartes conceives the automaton as an optical trick with an underlying rational structure—and this is precisely why it is such an attractive metaphor. As Dalia Judovitz writes: 'Illusion is presented as a mechanical effect, whose optical-mathematical character underlies even its most fantastic and magical apparitions.'[60] Technologically produced illusion depends on a concrete, knowable set of mechanisms. Thus, the automaton (as a subset of the optical trick—in many ways, the ultimate piece of sensory trickery) plays both a positive and negative role, as both the model of confused wonder and the means for dispelling it.

But the philosopher-scientist is not merely a conjuror or trickster. The Cartesian scheme advocates more than a metaphysically uncommitted 'save the appearances'

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[57] Daston L. – Park K., Wonders and the Order of Nature 1150-1750; Stafford B. – Terpak F., Devices of Wonder: From the World in a Box to Images on a Screen, Getty Research Institute (Los Angeles: 2001).
[58] Daston L. – Park K., *Wonders* 292.
[59] Galison P., "Descartes's Comparisons" 318.
[60] Judovitz D., "Vision, Representation and Technology in Descartes", in Levin D. M. (ed.), *Modernity and the Hegemony of Vision*, University of California Press (California: 1993), 65. Cavaillé coincides on this point: 'Ces machines optiques sont doublement paradigmatiques; de la vérité et de l'efficacité techniques de la science et tout á la fois du caractère fallacieux du monde visible' Cavaillé J.-P., *Descartes: La Fable du Monde*, Éditions de l'école des Hautes Études en Sciences Sociales, Librairie Philosophique J. Vrin (Paris : 1991), 47.

position. Certain kinds of representations provide an apter fit with reality than others. This is the foundation of what we may call Descartes' *other* method: not the deductive method advocated in his most famous work, but a philosophy that oversees the generation and application of analogies, pictures, rhetorical trickery, and the multifarious *technai* of scientific elucidation, explanation, promotion, and exposition.

Schouls argues that although 'throughout Descartes's works, from the most metaphysical to the most applied, there is the emphasis on utility', the philosopher always keeps his 'commitment to the ancient view that we live in a rational world as rational beings created by a rational God. It is the rationality of all three of these which guarantees in an a priori manner a potential fit between "fiction" and "fact".'[61] Our explanations may retain a certain fictitiousness, but 'to such 'fictions' there pertains nothing either nonrational or nonapplicable to our world.'[62] The rationality of this process rests on the notion of a *proportionality*[63] between the properties of matter, the figures in the brain, and the ideas in the soul. This law of representation rules over the tortuous path leading from matter to the judgments of the mind, all the way across the baroque perceptual system of the body-automaton. It ensures the rationality of this process, the congruence between perceptual (natural) representations and world, and the value of scientific (artificial) representations (both as technical intervention and bearers of a certain truth).

Proportionality can be described as a metaphysical doctrine whereby each link in the chain nature-perception-cognition represents without resemblance.[64] This proportionality grounds the process of perception (particularly, visual perception), and also

[61] Schouls P.A., *Descartes and the Possibility of Science* 142.
[62] Schouls P.A., *Descartes and the Possibility of Science* 141-2.
[63] The term is Sepper's, while Galison uses the term *congruence.* See respectively: Sepper D.L., *Descartes's Imagination*; Galison P., "Descartes's Comparisons" 320.
[64] One of Descartes' culprits here is the theory of *imagos*, a popular thesis of medieval optics (derived from ancient sources) which maintained that objects emit a series of phantom images or resemblances. In the *Optics*, after introducing the analogy of the blind man, Descartes says: 'And by this means your mind will be delivered from all those small images flitting through the air, called intentional species, which worry the imagination of Philosophers so much' (Descartes, *Optics* 68).

establishes the legitimacy (the 'apter fit') of the machine and its associated universe of representation. This ensures that, despite their largely illusory status, our perceptions are not merely arbitrary hallucinations but bear a consistent, logical relation to the world 'out there'. It also establishes a normative framework for scientific representations, which must act as 'natural' extensions of the cognitive apparatus.

5 – Machine Semiosis, or Proportionality at Work

How is this proportionality obtained? One of the central Cartesian paradoxes, or ironies, is that the procurement of clear and distinct knowledge rests largely on a stupendously intricate illusionist apparatus. Descartes' system of perception can be pictured as a flow of patterned emissions: from object, to plenum, to common sense, to imagination. These patterns do not 'resemble' each other, but are nevertheless proportional or congruent. There are four main 'nodes' in the system, four figures that correspond point-to-point. T. S. Hall enumerates them: 'the pattern of the object, the pattern of the retinal image, the pattern of the projection of that image on the lining of the brain cavity, and the pattern of effluence of spirits through the surface of the pineal gland.'[65] The notion of a 'corresponding figure' does not necessarily mean that, say, the same image appears in the inside wall of the brain, like some kind of screen projection. The reach of the term 'figure' is quite vast, and Descartes takes it to mean 'anything which … can give the soul occasion to sense movement, size, distance, colours, sounds, smells, and other such qualities; and even things that can make it sense pleasure, pain, hunger, thirst, joy, sadness, and other such passions.'[66] It is clear that in all other cases of perception (touch, smell, hearing, etc.) the patterns of figures and pressures do not resemble their causes in the least. Vision follows the same principle also, but the process of translation here follows determinable technical

[65] Descartes R., *Treatise on Man,* n. 132, 85.
[66] AT XI 176, G 149.

rules. The figures that occasion perception need not resemble visual pictures. In the words of Wilbur Mackenzie, the relation is 'phenomenal' rather than representational.[67]

In *Man*, Descartes gathers all the explanatory resources of the engineering of his time and puts them at the service of a strange and original task: to build a brain according to purely mechanical, pneumatic, and hydraulic principles. Jean-Pierre Séris writes that the principle of this machine is 'the instantaneous communication of differences at a distance, by encodings and automatic translations which save or preserve diversity …' and 'the decoding of the world of physical phenomena according to a grid or alphabet or a sieve which restores its effects …'[68]

Apologising for the anachronism, Séris likens the inside of the Cartesian brain to an information machine, comparing the mechanism of brain figures to the workings of a punched card computer. Yet, the Cartesian brain is an analogue machine—inasmuch as it does not work on the basis of 'on/off' circuits, zeros and ones. The patterns on the inner walls of the brain are shifting diagrams of pressures and flows, openings and closings, pushing and pulling motions. The figures of the brain show a duality: their status as figures

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[67] MacKenzie, A.W. "Descartes on Life and Sense", *Canadian Journal of Philosophy* 19 (1989), 163-192.

[68] Séris, J.-P., "Language and Machine in the Philosophy of Descartes", in Voss S. (ed.), *Essays on the Philosophy and Science of René Descartes*, Oxford University Press (Oxford: 1993), 183. Descartes holds two different views of ideas. The first is corporeal, equated 'with patterned flows of animal spirits' (Grosholz E., *Cartesian Method and the Problem of Reduction*, Clarendon Press, [Oxford: 1991], 128). In this view, animals can also have ideas. The second notion of idea is more mental, and requires the soul. The ideas in later Descartes are severed from their dependence on corporeal objects, and the intellectual world is granted a high degree of freedom from the physical. Schouls argues that this position forces Descartes to put up purely intellectual correlatives of the mind's faculties (such as an intellectual imagination, and an intellectual memory). It appears that Descartes had to modify the 'corporeal' view after the sustained onslaught that followed his *Meditations*. Thus, in the Second Replies, the ideas are features of *conscientia*: 'I understand this term [i.e., idea] to mean the form of any given thought, immediate perception of which makes me aware of the thought. Hence, whenever I express something in words, and understand what I am saying, this very fact makes it certain that there is within me an idea of what is signified by the words in question. Thus it is not only the images depicted in the imagination which I call "ideas". Indeed, in so far as these images are in the corporeal imagination, that is, are depicted in some part of the brain, I do not call them "ideas" at all; I call them "ideas" only in so far as they give form to the mind itself, when it is directed towards that part of the brain' (AT VII 160-1; CSMX 152-3). Descartes' more considered view has ideas as features of the mental acts themselves, and not separable from the act of thinking, remembering, etc. So, there are two sources of ideas, one is an innate capacity of the mind, the other are the figures abstracted from experience during the process of perception. Charles Larmore attempts to reconcile these two views. For him the notion of 'idea' is quite broad in meaning, applying to 'any sort of representation, but chiefly the content of a thought or a perceptual content' (Larmore C., "Descartes' Empirical Epistemology", in Gaukroger S. (ed.), *Descartes: Mathematics, Physics, and Philosophy*, Harvester [London: 1980], 16).

suggests the possibility of geometrical representation; yet the 'points' that make up these figures are openings of tubes, a mechanical process that stymies any efforts at precise description or visualization. The points have dimensions, and Descartes even confers explanatory power to the *degree* of their openness. The holes and pressures allow for indefinite degrees of variation; like a hand-operated dial, if you wish.

The imagination is a crucial locus of this whole process. Sepper succinctly explains how proportionality obtains between objects, imagination and ideas (using *phantasia* as the corporeal correlative of *imaginatio*, the imaginative faculty):

> Light, instantaneously transmitted, as an instantaneous pressure, preserves the geometrical pattern of the object it illuminates. This pattern is impressed in the sense organ … [and then to] the phantasia, where the geometrical pattern is reproduced. The mind, attending to this pattern in the phantasia, sees the object not as a geometrical pattern but as a yellow peach, by virtue of a 'language' of ideas corresponding to signals, a language instituted by nature.[69]

The imagination is central to figuration and representation. It is in the imagination (and its corporeal locus in the cerebral ventricles and the pineal gland) that Descartes places the figurative capacities of the intellect, the locus where we hold and construct (among other things) analogical relations. The possibility of truth-bearing analogies and models is ontologically grounded on extension, which is shared by phantasia (the organ of the imagination) and the world. Sepper argues that

> … one can develop extended, narrative hypotheses that will in essence imitate the real world because the ontological nature and mobility of the fable's material substrate (phantasia) is the same as that of space. In another sense, however, this is not imitation or modelling at all: the likeness comes about as a result of the essential sameness of phantasia and external extension.[70]

In this space, I can imagine any motion that I want. Yet Cartesian science requires that the work of the imagination be limited by the understanding, rigorously guided by step by step deductions from incontrovertible principles (and here, architectural metaphors come to Descartes' aid). In the words of Sepper, 'my imagining, in order to be truthful, must be

[69] Sepper D.L., *Descartes's Imagination* 223-4.
[70] Sepper D.L., *Descartes's Imagination* 229.

guided by a few fundamental laws of motion that are not simply proper to the imagination.'[71] Descartes demands discipline in the imagination, the guidance of the intellect, especially at the stage 'where we look for power-bestowing knowledge in the development of science useful to us.'[72] The imagination must be reined in by the will, and kept under the vigil of the sovereign intelligence. To imagine something, we must apply our volition, and thus the imagination must obey not only reason but also the will. Involuntary imaginings (such as dreams and daydreams) are occasioned *in* the body, by the perturbation of the spirits (and they are, strictly speaking, *passions*).

From the corporeal imagination, figures are traced on the pineal gland, and interpreted by the incorporeal mind according to the algorithms of reason. Descartes locates the point of union between body and soul in this little gland, sitting at the centre of the brain ventricles and constantly emitting spirits. Different patterns on the walls of the brain prompt the spirits to flow in certain directions. It is the patterns on this gland, formed by the enlarging of its pores, which occasion sensations on the soul.

> Now among these figures, it is not those imprinted on the organs of external sense, or on the inside surface of the brain, that should be taken as ideas, but only those traced in the spirits on the surface of gland H [the pineal], where the seat of the imagination and the common sense is. That is to say, only these should be taken as the forms or images which, when united to this machine, the rational soul will consider directly when it imagines some object or senses it.[73]

This natural language of ideas, by which the mind decodes the patterns on the pineal gland, is beyond knowledge, representation and science. Maull suggests that the language of the mind can be conceived as 'algorithmic' in nature.[74] The process of representation, then, must follow the meta-mathematical parameters of incorporeal reason—and this is the point at which reason must stamp reality with its own character, guiding the process of material figuration.

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[71] Sepper D.L., *Descartes's Imagination* 220.
[72] Schouls P.A., *Descartes and the Possibility of Science* 136.
[73] AT XI 176-7, G 149.
[74] Maull N.L., "Cartesian Optics" 30.

The mind is like the abstract mathematical point at which representation becomes judgment, the fulcrum that brings figuration under the reign of the *cogito*. In the *Meditations*, Descartes offers the famous example of a piece of wax to illustrate the limits of the imagination. He begins by describing a piece of wax in all its distinct sensory richness. Just taken from the honeycomb, it retains the taste of honey and the scent of the flowers. It is 'hard, cold and can be handled without difficulty; if you rap it with your knuckle it makes a sound.' But as soon as we put the wax close to the fire, all these qualities disappear. Colour, shape, size, smell—they all change. The wax goes from solid to liquid. Yet, the same wax remains.[75] The nature of the wax, Descartes concludes, is something 'extended, flexible and changeable.' The nature of this extension and changeability cannot be grasped by the imagination. The wax is capable of countless changes, and 'I am unable to run through this immeasurable number of changes in my imagination, from which it follows that it is not the faculty of imagination that gives me my grasp of the wax as flexible and changeable.' The perception of the wax is not a matter of the senses or the imagination, but of 'purely mental scrutiny'.[76]

Reason is necessary to grasp the complexities that transcend the figurable and lie beyond what can be represented in extension (and not only the complexities, but the most general and elementary *simplicities*: the very notion of figure, for example). I can *understand* the properties of a chiliagon (a figure of a thousand sides), but its figuration is beyond the capabilities of the imagination.[77] I can understand the notion of *figure itself*, regardless of this or that figure. Therefore, in the *Meditations*, Descartes says that the nature of the wax is perceived by the mind alone. 'I am speaking of this particular piece of wax; the point is even clearer with regard to wax in general.'[78]

[75] AT VII 30, CSMII 20.
[76] AT VII 31, CSM II 21.
[77] AT VII 72, CSM II 50-1.
[78] AT VII 31, CSM II 21.

Reason and the imagination must constantly alternate in 'surrendering' to each other; and at certain stages in the work of science, reason itself will need guidance or discipline from empirical 'sensation and experimentation'.[79] So, 'proper' scientific method involves the close and reasoned coordination of the intellect, the imagination, and sensation (observation and experimentation).

However, the imagination has a large degree of independence, and as Véronique Fóti argues, its powers are fascinating and disturbing for Descartes. The imagination suggests a dimension of the mind that is obscure to consciousness, a power 'which threatens to disrupt the unity of the mind and to undermine the sovereignty of the intellect.'[80] As such, it carries an implicit danger as 'the fabricator of dreams which threatens to subvert the certainty of knowledge.'[81]

6 – Making a World

Le Monde, ou Traité de la lumière (*The World, or Treatise of Light*), which Descartes began in 1629, was intended as a new summation of the universe intended to replace Aristotle's. From an account of the principles of light, Descartes set out to build a complete system of physics embracing all aspects of nature, including the heavens, the earth, winds, tides, rainbows, and living organisms. Light is the central thread of the treatise, weaving together diverse topics such as stars, fire, and human vision. Four years later, Descartes abandoned this work after learning of Galileo's conviction at the hands of the inquisition. It was published posthumously in two separate parts: *Traité du Monde* and *Traité de L'homme* (*Treatise on the World*, and *Treatise on Man*).

Both *World* and *Man* are part of the same cosmological thought experiment about

[79] Schouls P.A., *Descartes and the Possibility of Science* 139.
[80] Fóti V., "The Cartesian Imagination", in *Philosophy and Phenomenological Research*, Vol. XLVI, no 4 (1986), 641.
[81] Fóti V., "The Cartesian Imagination" 637.

the creation of a hypothetical world. The continuous narrative is an expression of the unity of Cartesian knowledge, namely cosmology, physics and biology. The passage from the inanimate physics of *World* to the physics of living things (in *Man*) also entails a shift of technological frames of reference. The main source for Descartes' mathematical physics was the engineering tradition of the day, particularly the Dutch tradition, to which Isaac Beeckham had introduced him. As Gaukroger shows, Descartes' physics 'would remain very dependant upon a hydrostatic / hydrodynamic model.'[82] In *Man*'s physiology a different technological universe enters the picture, a language concerned with pneumatics and mechanical components (to which we will return in a moment).

Man is an event of celebrated significance in the history of physiology, and it occupies a pivotal place in the cultural histories of technology and of the human body. In the life sciences, it marks the moment technology became central to the conceptualization of organic life as a complex mechanism subject to physical laws. Although the map of knowledge would shift and rearrange itself dramatically in the centuries to come, the early modern period cemented close and dense connections between the life sciences and the knowledge of the technologist.

The fable of *World/Man* can be considered a 'truthful imagining', building an imaginary universe from 'what is absolutely necessary to presuppose as existing in corporeal phenomena, the motion of parts.'[83] It is the freedom of the imagination that

[82] Gaukroger S., *Descartes: An Intellectual Biography*, Clarendon Press (Oxford: 1995) 225. Elsewhere (see Gaukroger S., "The Foundational Role of Hydrostatics" 60-80), Gaukroger argues that Descartes' model for physics was hydrostatics in cosmology, and statics in optics. Despite the founding principle of rectilinear momentum, Cartesian physics is concerned with *constrained* motion, since every single particle in the universe is constantly colliding and changing course. Whereas kinematics offered a geometrical model of bodies in motion but could not account for force, statics did the opposite: it traditionally dealt with bodies which forces were in a state of equilibrium, but could not account for motion or model it. Gaukroger shows that Descartes based his physics on statics, since each body in the Cartesian universe exists in a state of balance, the product of the various forces impinging on it. This leads him into some problems (indeed, absurdities), particularly in what regards his principle of rectilinear inertia.

[83] Sepper D.L., *Descartes's Imagination* 225. According to Sepper, for Descartes the imagination not only 'represents' but 'also shares the nature of the extension and mobility observed in the external world; thus it can produce a proportional copy of the original rather than a mere representation, and anything that transpires in phantasia can possibly exist in external extension as well' (228). The epistemological role of analogies, then, depends on the fact that 'any imaginative analogy is really a copy to scale of what does or might occur

allows the introduction of fictitiousness, the elaborate theatre of *World/Man*'s fable—the most striking instance of the use of the imagination for scientific purposes.

The subject of his work is light, Descartes announces at the beginning of *World*. And the first thing we must understand about light is that its real nature has nothing to do with how it appears to us. Descartes uses the metaphor of language and touch, where the lack of resemblance between sign (words, sensations) and referent (nature, world, ideas) is most obvious.

> Suppose we pass a feather gently over the lips of a child who is falling asleep, and he feels himself being tickled. Do you think the idea of tickling which he conceives resembles anything present in this feather?[84]

This theory of representation is the cornerstone of Descartes' epistemology. It is a semiotics inasmuch as it is a theory of signs, about the relation between sign and referent. As we have seen, it concerns mechanical mediation, the transmission of patterns across chains of mechanisms.

Following this principle of non-resemblance, the realm of the perceptual, bodily and experiential is displaced in favour of a strange image of the world. (In this context, analogies from familiar situations participate, somewhat paradoxically, in the defamiliarization of the everyday). In the first five sections of *World*, Descartes outlines his physical theory, in which the qualities and forms of bodies 'can be explained without the need to suppose anything in their matter other than the motion, size, shape and arrangement of its parts …'[85] Once these principles are in place, and properties such as hardness and liquidity have been explained accordingly, Descartes proposes to tell us a story:

> … in order to make this long discourse less boring for you, I want to clothe part of it in the guise of a fable, in the course of which I hope the truth will not fail to become sufficiently clear, and will be no less pleasing to see than if I were to set it forth wholly naked. [*Chapter 6 begins*]. For a while, then, allow your thought to wander beyond this world to view another world—a wholly new one which I shall

in the world' (228).
[84] AT XI 6, CSM I 82.
[85] AT XI 26, CSM I 89.

> bring into being before your mind in imaginary spaces. The philosophers tell us that such spaces are infinite, and they should certainly be believed, since it is they themselves who invented them. But in order to keep this infinity from hampering and confusing us, let us not try to go right to the end: let us enter it only far enough to lose sight of all the creatures that God made five or six thousand years ago; and after stopping in some definite place, let us suppose that God creates anew so much matter all around us that in whatever direction our imagination may extend, it no longer perceives any place which is empty.
>
> Even though the sea is not infinite, people on some vessel in the middle of it may stretch their view seemingly to infinity; and yet there is more water beyond what they see.[86]

Secure foundations for knowledge must be sought somewhere else, away from the illusory evidence of the senses. But (another paradox) in *World* this search for solid foundations involves a journey into a highly imaginative mind-space, a faraway land; while in *Man* we descend from these cosmological heights into a mechanical microcosmos, a virtual double of the human-animal body.

Thus, to understand how the world really is, independent of our subjective impressions, it is necessary to undergo a reasoned experiment: to imagine ourselves in another world that is also our world. In a way, this invented space is more real than our world, for it is a world bereft of appearance. Yet at the same time it is *pure appearance*: a fable, a mechanical theatre. All the secrets of nature, the invisible mechanisms of her marvellous machines, are open to our vision, to total knowledge. We can witness how the planets are formed, how vortices arrange themselves to compose the solar system. We can travel down to the microscopic realm of bodily phenomena and watch, for example, how food is tasted and digested.

Descartes employs the conventions of myth and fable with an ironic distance, as a pedagogical metaphor. His use of myth is reminiscent of the way Parmenides employed religious poetry more than two thousand years before, turning the language of *mythos* against *mythos*. Ortega y Gasset's remarks on Parmenides can easily also apply to Descartes, since both philosophers drew on canonical religious myth of their time while 'no

[86] AT XI 31-33, CSM I 90.

longer believing in it, as mere instrument of expression, that is, as vocabulary. Defunct beliefs endure a long time transformed into mere words. Once dead, mythology shows a terrible tenacity.'[87]

But the context has changed. Descartes' production resonates with the spirit of the baroque, a period enamoured with the notion that the world is a stage and life an illusion. Descartes' tale is also informed by other, real theatres: theatres of anatomy, the machinery of stage production, and mechanical spectacles, as Jean-Pierre Cavaillé has comprehensively shown.[88]

This fable is a mechanical production allowing us a peek at the elaborate machine that sustains the spectacle behind the stage. Descartes deflects potential clashes with doctrine (in particular, the account of creation in Genesis) by emphasizing the speculative nature of his tale. If things have followed a different process in this imaginary world, this is just for the sake of exposition, to help us understand the world better by following how it came about.[89] However, there is a clear impression that Descartes intended *World* to be an account of how things really happened. If God created a world anew by infusing motion within a block of inert substance, this world would be the same, for 'God is immutable and … acting always in the same way, he always produces the same effect.'[90] As Bitbol-Hespériès shows, Descartes alternates regularly between the expressions 'real world' and

[87] Ortega y Gasset J., *Origen y Epílogo de la Filosofía,* Ediciones de la Revista de Occidente (Madrid: 1967) 134. Translation mine.
[88] Cavaillé J.-P., *Descartes: La Fable du Monde*.
[89] In Part Five of the *Discourse*, Descartes explains his choice of mode of exposition: 'Yet I did not wish to infer from all this that our world was created in the way I proposed, for it is much more likely that from the beginning God made it just as it had to be. But it is certain, and it is an opinion commonly accepted among theologians that the act by which God now preserves it is just the same as that by which he created it. So, even if in the beginning God had given the world only the form of a chaos, provided that he established the laws of nature and then lent his concurrence to enable nature to operate as it normally does, we may believe without impugning the miracle of creation that by this means alone all purely material things could in the course of time have come to be just as we now see them. And their nature is much easier to conceive if we see them develop gradually in this way than if we consider them only in their completed form' (AT VI 61-3, CSM I 142-3).
[90] AT XI 43, CSM I 96.

'new world', using these exactly the same number of times throughout the text.[91] Similarly, in *Man,* the assertion that living bodies are *nothing but* machines must be taken in the most literal way—despite the outrageousness of his imagined automaton. The oscillation between imaginary and real, metaphor and literality, is pivotal to Descartes' line of attack. Moreover, Descartes puts this rhetorical strategy, this enigmatic textual play of mirrors, to great use. *World/Man* is a fertile scientific fiction that sidesteps confrontations with religious and intellectual authorities and the need to provide observational and experimental corroborations, while making the exposition 'less boring', promoting Cartesian philosophy in a didactic and engaging manner.

At the beginning of *Man*, when the time comes to speak of the creation of humans, Descartes writes that the hypothetical men of his tale are composed of a body and a soul, and that each is to be treated separately. He continues:

> I suppose the body to be just a statue or a machine made of earth, which God forms with the explicit intention of making it as much as possible like us. Thus He not only gives its exterior the colours and shapes of all the parts of our body, but also places inside it all the parts needed to make it walk, eat, breathe, and imitate all those functions we have which can be imagined to proceed from matter and to depend solely on the disposition of our organs.
>
> We see clocks, artificial fountains, mills, and other similar machines which, even though they are only made by men, have the power to move of their own accord in various ways. And, as I am supposing that this machine is made by God, I think you will agree that it is capable of a greater variety of movements than I could possibly imagine in it, and that it exhibits a greater ingenuity than I could possibly ascribe to it.[92]

Descartes offers an account of digestion, the formation and circulation of the blood, the actions of the heart, breathing, and other bodily processes; then proceeds to describe the brain and the mechanisms behind animal-human perception. The reach of the mechanistic paradigm is ambitious and vast. At the end of the treatise, Descartes invites the reader to

[91] 'L'alternance, du reste parfaitement équilibrée dans la suite du texte entre les expressions «nouveau monde» et «vrai monde», est significative: huit occurrences pour «nouveau monde», huit également pour «vrai monde», qualifié en outre, à deux reprises, d'«ancien monde».' Bitbol-Hespériès A. – Verdet J.-P. (eds.), *Le Monde, L'homme*, Éditions du Seuil (Paris :1986), xxxi.
[92] AT XI 120, G 99.

consider all the functions he has ascribed to this machine:

> the digestion of food, the beating of the heart and the arteries, the nourishment and growth of the bodily parts, respiration, waking and sleeping; the reception of light, sounds, odours, smells, heat, and other such qualities by the external sense organs; the impression of the ideas of them in the organ of common sense and the imagination, the retention or imprint of these ideas in the memory; the internal movements of the appetites and the passions; and finally the external movement of all the bodily parts … and in this they imitate as perfectly as is possible the movements of real men.[93]

The passage from the physics of matter into the theory of life is seamless. The same principles apply to cosmic fluids and animal spirits; the same metaphysics embraces the animate and inanimate. The continuous narrative expresses the unity of Cartesian knowledge, traversing astronomy, physics, biology, and technology.

The mechanical spectacle comes to act as a framing metaphor, taking on a similar function to that of the fable of *World.* The text, images and diagrams of *Man* are like a surrogate of the theatrical machinery, assembling together an aggregation of mechanical processes and components into a strange but coherent picture of a fictitious machine.

The mechanical theatres that had become fashionable with the nobles of renaissance Europe during the fifteenth and sixteenth centuries were a direct source of inspiration for Descartes. The art reached its peak first in Italy. The garden theatres consisted of an arrangement of terraces and grottoes where the spectator could wander at leisure. The spectacle included singing mechanical birds, moving statuary, automated organs, trumpets, ornate water fountains, and mythological scenes enacted by large numbers of self-moving figures.

One of the most lavish and accomplished creations in this vein was the Royal Château of Saint-German-en-Laye, which Descartes most likely visited between the summer of 1614 and the autumn of 1615. The description in *Man* is consistent with the grotto of Orpheus:

[93] AT XI 202, G 169.

> Now as these spirits enter the cavities of the brain, they also pass in the same proportions from there into the pores of its substance, and from these pores into the nerves. And depending on which of these nerves they enter, or even merely tend to enter, in varying amounts, they have the power to change the shapes of the muscles into which these nerves are embedded, and in this way to move all the limbs. Similarly, you may have observed in the grottoes and fountains in the royal gardens that the force that drives the water from its source is all that is needed to move various machines, and even to make them play certain instruments or pronounce certain words, depending on the particular arrangements of the pipes through which the water is conducted.
>
> And the nerves of the machine that I am describing can indeed be compared to the pipes in the mechanical parts of these fountains, its muscles and tendons to various other engines and springs which serve to work these mechanical parts, its animal spirits to the water that drives them, the heart with the source of the water, and the brain's cavities with the apertures. Moreover, respiration and similar actions which are normal and natural to this machine, and which depend on the flow of spirits, are like the movements of a clock or mill, which the normal flow of water can make continuous. External objects, which by their mere presence act on the organs of sense and thereby cause them to move in many different ways … are like strangers who on entering the grottoes of these fountains unwittingly cause the movements that take place before their eyes.[94]

In the late sixteenth century, King Henry IV enlarged the Château with the aim of turning it into the main royal residence. For this purpose, he enlisted the talents of Tommaso and Alessandro Francini, who set to work in 1598 to install a series of grottoes and fountains in the layered terraces separating the Seine River from the residence. Francini later installed waterworks for King Louis XIV at the palace of Versailles. A contemporary visitor to St.-German (André Du Chesne) recorded the scenes in these grottoes:

> There is a nymph standing in half-relief with a laughing face, beautiful and gracious, who allowing her fingers to be moved by the movement of the water, plays on an organ. Near the window is a statue of Mercury with one foot in the air and the other placed on a support, noisily sounding and intoning a trumpet. The cuckoo is heard and recognised by his song. On the way out … a fierce dragon is encountered who beats his wings with great vehemence, and violently belches forth huge mouthfuls of water. The dragon is accompanied by various little birds, which truly seem not painted or imitated by alive, fluttering their wings, making the air echo with a thousand warblings, and above all, the nightingales singing very beautifully in several choirs.[95]

[94] AT XI 130-1, G 106-7. The passage goes on to describe an automaton of a bathing Diana who hides in the reeds as soon as the visitor approaches; if the visitor gets closer, a Neptune steps forth threateningly with his trident.

[95] Chapuis A. – Droz E., *Automata: A Historical and Technological Study,* Neuchatel, Editions du Griffon, B.T. Batsford Ltd (London: 1958), 44.

Another contemporary, after praising the skill of the mechanician, expressed his contempt at the bad taste of 'this gim-crack ironmongery'.[96] In these displays, the observer wandered through a series of tableaus, mechanical spectacles, ornate water features, etc. The spatial layout structured the experience. Knoespel points out: 'As the observer moved through the new renaissance gardens, he simultaneously undertook an allegorical journey based on established mythographic stories and encountered an array of new technological devices that challenged him to a new awareness of technology.'[97] The fountains in these gardens, Simon Schama writes in *Landscape and Memory,*

> were conceived as stations en route to illumination often connected by lines of water that mapped the progress of the visitor along a strictly predetermined and allegorically saturated path. That path was thus transformed into a river-road itself, navigated with the help of mythological and poetic references.[98]

These places, Schama adds, were not designed for 'casual strolls', and the visitors were expected to be literate in a variety of classical texts (Ovid, Virgil, and compilations of pagan myths). Besides this ambulation, the gardens require no physical involvement, save standing and watching, and walking to the next exhibit.

In technical terms: 'Little change and no improvement had taken place in these mechanisms since the time of Hero.'[99] The main motive forces of these automata were weights, water and simple pneumatic principles, conveyed in pulleys, ropes, gears, water wheels, reservoirs and pipelines. Yet their ingenious combination achieved spectacular results. And incrementally these designs became more ambitious. As Knoespel suggests above, these machines drew attention to their own artificiality, directing wonder at the power of human art.

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[96] Chapuis A. – Droz E., *Automata* 47.
[97] Knoespel K.J., "Gazing on Technology: *Theatrum Mechanorum* and the Assimilation of Renaissance Machinery", in Greenberg M. – Schachterle L. (eds.), *Literature and Technology*, Associated University Presses (London and Toronto: 1992), 112.
[98] Schama S., *Landscape and Memory*, HarperCollins Publishers (London: 1995), 275.
[99] Chapuis A. – Droz E., *Automata* 41.

Like these automated displays, the body-machine of *Man* is an instructive spectacle. The treatise imagines a supplementary moment to the wonder experienced in these gardens; Descartes unveils the mechanisms, takes the reader on a behind-the-scenes tour of what makes the automata move. The ambulant spectator walking through the paths and grottoes is transformed into a non-located, omniscient observer. The assemblage of text and images becomes a technologically enhanced eye, born of the science-fiction marriage of microscopy and mechanical simulacra. As Jean-Claude Beaune says, 'the automaton is a spectral model, a sort of *theoretical microscope* enabling a 'sighting of depth': the anatomy and the internal movements are seen across the corporeal envelope, supposedly negligible, as one would see the wheels of a machine.'[100] Both microscope and automaton materialize the spectacular play of visibility and invisibility, surface appearance and inside mechanisms: the logic of illusion that animates Descartes' theory of life and knowledge.

In an important sense, *Man* is a technological treatise, doing as much for engineering as for anatomy or physiology. Although the body-machine follows the same principles as the rest of Descartes' physics, it allows a considerable expansion of the explanatory resources of mechanism. It is not until we enter the body that we can experience the full poetic potential of the machine, as Descartes deploys an astonishing array of mechanical-analytical elements (rods, bellows, valves, pulleys, tubes, levers, sieves, counter-weights and wheels), machines (organs, self-moving statues, fountains, clocks, mills), principles of work and sources of power (water, air, weights, levers and balances, pressures and collisions), and technical processes (distillation, sieving, impressions on cloths) to assemble a see-through model of a lost flesh-and-blood original.[101]

[100] Quoted in Judovitz D., *The Culture of the Body: Genealogies of Modernity*, The University of Michigan Press (Ann Arbor: 2001), 77.

[101] Catherine Waldby's notion that biomedical images are produced "through a sacrifice of their referent" is suggestive in this context. See Waldby C., *The Visible Human Project: Informatic Bodies and Posthuman Medicine,* Routledge (London and New York: 2000), 36.

Occasionally, one-to-one analogical connections (A:B::C:D) are established between specific, known mechanisms and organic processes. However, what matters to Descartes is not this or that machine, but the laws of all machines, the very ontology of machines. The *logos* of technics comes to gather the most disparate devices and technical practices. Descartes anticipates modern notions of technology as a rational discourse that organizes and systematizes scattered knowledges and things. The Cartesian body-automaton is an attempt to integrate heterogeneous technological experiences into a single corpus of knowledge: a 'universal mechanics'. Disparate knowledges such as metallurgy, the building of pipes and conduits, the craft of making scientific instruments, can now share a common foundation. Descartes' gesture is more programmatic than practical, and is influenced by the vibrant tradition of machine treatises of his day. In many ways, *Man* announces the engineering branch of the Cartesian dream of a universal mathematical physics.

As Carl Mitcham argues, one of the main differences between ancient conceptions of *techne* and modern technology is their respective ontologies of matter.[102] Although Plato and Aristotle, for example, conceived of craftsmanship in different terms, for both of them the raw matter and procedures of *techne* entailed dimensions that escaped rationalization. Both Plato's divine craftsman and Aristotle's nature had to work with the pre-existing qualities and potentialities of substances. What's more, for them technical activity was goal-oriented, and could not be considered separately from its ends. Mitcham argues that this is one of the reasons there are no treatises on *techne* in the Greek tradition, with the notable exception of Aristotle's *Rhetoric*.

The ready-made virtual automaton of *Man* confronts us not merely with collisions of particles, but with a highly ordered arrangement of mechanisms and materials; a universe

[102] Mitcham C., *Thinking Through Technology: The Path Between Engineering and* Philosophy, The University of Chicago Press (Chicago: 1994), 131-2.

of meshes, threads, conduits, cavities, sieves and patterns of little holes. Descartes' innovation is to show us not just inert arrangements, but structures in motion—a kind of virtual cinematic tour of a living body that pushes to the limit the visual and conceptual tools of anatomy and the technological treatise. In the centuries that followed, the conceptual procedure of breaking things down into elements and chains of mechanical action developed its social counterpart in the organization of labour and industry, a crucial area of endeavour as European empires gained economic and cultural ascendance.

Descartes' conception of technology is also modern because it removes the theological injunction that separated art and nature, and human skill from the supreme artistry of God. Descartes prescribes no theoretical limits to the technical activity of humans. As such, this wondrous mechanical fable about our bodily interior can be seen as a poem to the possibilities of human ingenuity, told by way of a journey through an imaginary machine.

7 – Making Pictures: Setting the imagination into action

Man is extraordinary in terms of the techniques of representation it deploys and the demands it makes on the imaginative capacities of the reader. The operations of text, image, imagination and reason are closely coordinated, creating an unparalleled experience.

The illustrations ('figures') of *Man* seek abstraction and simplicity, and occupy a halfway point between sensory qualities and the language of the ideas. The structure of the body must be made visible and comprehensible in terms of schematic elements and relations between motions and figures. In *Man*, anatomy aspires to the condition of mechanics. In her study of this treatise, Rebecca Wilkin argues that, as products of the imagination, figures are 'the form of thought that manipulates sensual data …'[103] Figures

[103] Wilkin R.M., "Figuring the Dead Descartes: Claude Clerselier's *Homme de René Descartes* (1664)", in *Representations* 83 (2003), 44.

are 'expository schema that give shape (and credence) to truths deduced through reason.'[104] As Clerselier, editor and publisher of the French edition, pointed out: 'it is up to reason alone to make known those [things] that are too subtle to submit to the senses …'[105]

But rather than an inert series, the text-image assemblage of *Man* animates these figures and presents them to the imagination as a contraption in motion. The body-automaton is alive, and we can follow it in action, its insides open to our gaze.[106]

A distinct product of the sixteenth century is what Knoespel calls a 'cultural fascination with the visual staging of knowledge …'[107] This period witnesses the application of novel pictorial styles and techniques across diverse areas of endeavour. Says Catherine Wilson: 'Reading documents of the period, one is repeatedly struck by references to seeing, and seeing for oneself—to widening the horizon of visual experiences by direct acquaintance with objects or with the help of pictures and models.'[108] As Michel Foucault notes, the visual paradigm was closely joined to the order of discourse, establishing the transparent transcription from vision into language, and allowing 'the visibility of the animal or plant [*and we might add here* 'or machine'] to pass over in its entirety into the discourse that receives it.'[109] It is in this context that we should understand the dense web of cross-references images and text in *Man*.

In its zeal for encyclopaedic knowledge, technological treatises gathered together various technical dimensions (military, urban, industrial, entertainment, etc.) into works that applied uniform regimes of visual and textual representation.[110] Similar representational

[104] Wilkin R.M., "Figuring the Dead Descartes" 49
[105] Quoted in Wilkin R.M., "Figuring the Dead Descartes" 53.
[106] The perspective is that of a disembodied 'total optical system' (Kember, cited in Waldby C., *The Visible Human Project* 5). Both modern imaging technologies, and early modern anatomical atlases are based on procedures 'for transforming the volumetric bulk of the singular, locatable corpse [or living body] into a readable, and hence writable, object' Waldby 58.
[107] Knoespel K.J., "Gazing on Technology" 100.
[108] Wilson C., *The Invisible World: Early Modern Philosophy and the Invention of the Microscope,* Princeton University Press (New Jersey: 1995), 24.
[109] Foucault M., *The Order of Things: An Archaeology of the Human Sciences*, Routledge (London: 1970), 135.
[110] The most important works were: *De re metallica* (Agricola, 1557); *Le diverse et artificiose macchine* (Agostino Ramelli, 1588); *Theatrum instrumentorum et machinarum*. (Jacques Besson, 1569); *Nuovo teatro*

styles and formalisms traversed various domains, applied to geographical spaces, buildings, machines and bodies. According to Sawday, 'the visual rhetoric with which the illustrators of both the machine books and anatomy texts worked was a shared system.'[111] In the words of Sawday, machine books 'opened up a world of *interior* mechanical invention which was analogous to the interior world which the magnificent Vesalian and post-Vesalian books of anatomy laid before their wealthy readers.'[112] But whereas in anatomy this peeling away had a concrete referent in the practice of dissection, the representation of technology posed some different challenges, such as picturing force or direction. Anatomy is '*par excellence* a descriptive science' where 'the visual representation acts as a surrogate for the eye-witness experience or as a visual summation of many eye-witness experiences.'[113] In technological treatises, on the other hand, the reader must learn a range of specific visualization techniques. It is necessary to imagine how the machine works, how it moves, and how the parts slot together. As a result, renaissance and early modern illustrations of machines are often equal parts drawing and diagram. Technological treatises also depicted actual objects both in their appearance and inner workings; also, they portrayed many *invented*, possible (and impossible) machines.

di machine et edifici (Vittorio Zonca, 1607); and *Les raisons des forces mouvantes avec diverses machines tant utiles que plaisantes ausquelles son adjoints plusioeurs desseigns de grotes et fontaines* (Salomon de Caus, 1615).

[111] Sawday J., "Forms Such as Never Were in Nature': the Renaissance Cyborg", in Fudge E.—Gilbert R.—Wiseman S. (eds.), *At the Borders of the Human: Beasts, Bodies and Natural Philosophy in the Early Modern Period*, MacMillan Press (London: 1999), 178.

[112] Sawday J., "Forms Such as Never Were in Nature" 178. Among these we can cite: techniques to produce the illusion of three-dimensional space and volume (such as shading); the cut-away view, the exploded and transparent views; the convention of letters indicating elements of the drawings to allow cross-referencing with the text (pioneered by Leonardo, and appearing first in anatomical contexts before migrating to the machine context); and the theatrical stage as framing metaphor. Pictures in both contexts perform a kind of analysis we may term 'elementary decomposition', considering the body or machine as an aggregate of interlinked components that can be disassembled and subjected to taxonomical classification. This is the historical beginning of one of the most decisive analytic and representational tools of machine design, which would later develop into attempts at a universal grammar of machine components (such as the 'mechanical alphabet' of Christopher Polhem at the end of the seventeenth century, later systematized by Carl Johan Cronstedt).

[113] Kemp M., "Vision and Visualisation" 19.

Rather than a collection of plates of different machines (or a succession of individual bodies and parts, as in Vesalius' treatise), *Man* studies the same machine from a number of perspectives, as a complex amalgamation of systems and mechanisms. Descartes' innovation is to show us not just inert arrangements, but moving structures, a kind of cinematic tour that pushes to the limits the available technologies of representation.

In its complex imaginary deployment, the machine image invokes two complementary but relatively autonomous modes of representation, which we may call the *geometrical* and the *micromechanical*. Descartes' theory of vision combines these two approaches most clearly. Rays of light are rectilinear tendencies to motion transmitted through the plenum. As they reach the eye, they are refracted and refocused into points of pressure, tracing patterns at the back of the eye. The lines and figures of geometry are applied to the modelling of physical effects. Light rays are (geometrically speaking) straight lines that (physically speaking) do not exist as such, but arise from tendencies to motion traversing the plenum.

At the moment the pressures at the back of the eye are communicated to the brain through the tubes, we leave the language of images (an optic-geometric paradigm) to enter the machine proper (pneumatics and mechanics). From the neat figures of light rays, we enter the cavernous industry of the brain, a frantic and bustling world of collisions, motions, vortices, fluids and particles in constant agitated interaction. The break is clearly visible in the figures of *Man* and *Optics*. There are a vast number of filaments in the optic nerves corresponding to each point of the image; different patterns of pressure pull different fibres, enlarging the openings in the brain and thus forming different figures inside it.

On one hand, we have figures, patterns, and the pictorial representations of geometry. On the other, we have motions, collisions and the affairs of matter. The physical motions of light obey laws that are geometrically expressible, since tendencies to motion

follow rectilinear paths between points. But as soon as we enter the optic nerves, the geometrical diagram gives way to the anatomical/technological illustration, concerned with the visualizable structures of organisms and machines. The illustrators of *Man* juxtapose these two modes of representation in the same picture, a hybrid that instantiates and enacts the machine metaphor to a hitherto unseen degree.

These two modes of representation correspond not only to two traditions of illustration, but also to two phenomenological registers. At the biomechanical level, the machine metaphor has a strong *tactile* component, involving images of pulling, pushing, sieving, pressing, tensions, agitations, flows, and other physical actions that may not be readily visualized, but have an affective basis on bodily experience. Moreover, the visual is ontologically subordinate to touch, of which it is a special case. Images in Cartesian epistemology, as we have seen, do not have any cognitive value, and '[w]hat is transmitted by the physical processes leading up to the sense organ … is motion or pressure, not an image.'[114] In both the *Dioptrics* and *Man*, the paradigm of vision is blindness.[115] The value of this analogy is that, for the blind man, there is clearly no resemblance between experience and its physical referents. There is a yawning abyss between the real properties of the world and the world as is present to our perceptual awareness. This makes possible the displacement of the phenomenological immediacy of visual perception in favour of geometrical thought and a heuristic regime where analogy and the imagination must come under the aegis of reason.

Since matter is indefinitely divisible and the machines of nature unimaginably complex, the explanations of *World* and *Man* are always pushing the limits of what can be meaningfully visualized. Descartes is constantly reminding us of the indefinite complexity

[114] Sepper D.L. *Descartes's Imagination* 218.
[115] The analogy of blind man is an old one, and not Descartes' original invention. Meli points out that it occurs in 'Simplicius's commentary on Aristotle's *De anima* and in *Liber de oculis*, attributed to Galen and included in different Latin editions of his work.' Gassendi also referred to it in his *Syntagma Philosophicum* (Meli D.B. "The New Anatomy of Marcello Malpighi", in Meli D. B. (ed.), *Marcello Malpighi: Anatomist and Physician,* Leo S. Olschki (Firenze: 1997), 42).

of matter in motion, of which both geometric and mechanical elements are rather emblematic stand-ins. A considerable region of activity remains *beyond* visual, geometrical and textual representation ('…you may reasonably think it capable of a greater variety of movements than I could possibly imagine in it, and of exhibiting more artistry than I could possibly ascribe to it.'[116]) Simple lines and diagrams come to represent the unimaginable activity of corporeal patterns, bodily flows, and natural processes in general. The complexity of the body-machine can be grasped in the most abstract of manners; the way we understand a chiliagon, for example. The complexity is not only spatial (too small or large), but temporal: these figures flicker and combine at amazing speeds well beyond the reach of perception. What is remarkable about the Cartesian representational machine is how it lets us perceive or *feel* this bustling complexity, just outside the reach of the imagination.

8 – Conclusion:

I hope this paper is a contribution to a better historical understanding of the scientific revolution; in particular, in establishing how technology and science entered into dialogue, transforming each other, becoming productive and constitutive of each other. Descartes' use of technological metaphor can be modelled as the meeting of two transversal lines. On one hand, we have the *techne* of discursive reason: a number of analogies, models, metaphors, comparisons, images, etc. On the other, a plethora of machines, techniques, instruments, artefacts and technocultural forms. Machine imagery does not always have a simple analogical function, but enters Cartesian natural philosophy in complex and much more fundamental ways. Technology itself also spills in other directions as well, associated with myriad meanings, and embedded in various cultural contexts and forms (articulating, for example, themes such as wonder, the theatre, fable, illusion and

[116] AT XI 120, CSM I 99.

error). As we have seen, the meeting of these two threads can be taken as a single line of inquiry, as a consistent strategy that cuts across various aspects of Descartes' thought. Indeed, it could be argued that the machine metaphor ties together the whole of Descartes' natural-philosophical project—especially if we consider the machine not just as an isolated group of metaphors but as a kind of *meta-analogy*: an overarching image that sustains Cartesian metaphysics. Etymologically, the very notion of machine supports this understanding: *machina* also means 'framework', or scaffolding. Thus, it becomes impossible to construe Descartes' metaphysics without attention to the 'machine': the abstract conceptual structure that not only *results from* this multifarious activity, but also constitutes its point of origin, its condition of possibility.

There are a number of directions we can go from here, and what follows is a rough sketch of some possible conclusions.

One of the features of early modern science, as we have mentioned, is an explosion of metaphor, as new worlds were made visible and new explanatory frameworks tried out. What is peculiar to the machine metaphor (by far the most important class of metaphor in this period) is that it later disappears, becoming a tacit, implicit assumption. For modern science, the assumption that the world and living organisms are machines becomes commonplace, an invisible, high-order structure that frames more specific, local projects. As the technological apparatus of scientific experimentation grew in density and complexity, so did the metaphor of natural things as artefacts grow to become embedded in material set-ups, no longer needing to be explicitly articulated. A single plenum connects the natural and the technological. Of course, the metaphor has meant a number of things, not all of them compatible. For example, the machine could accommodate both a plenarist metaphysics and a metaphysics that admitted vacua. Leibniz's use of the image was totally

different to, say, Hobbes'. But even people who opposed the mechanistic conception had to engage with the machine image, if only to point out its shortcomings.

In fact, the machine image resurfaces precisely when its status as a high-order assumption is brought into question (e.g., the debate between vitalism and mechanicism). Descartes' use of the metaphor is illuminating inasmuch as it allows us to glimpse how this high-order assumption was set in place, how it had to be forcefully worked into the fabric of philosophy and science. This is what makes *Man* such an interesting piece of work: it suggests the machine hypothesis was outrageous and unworkable.

With Descartes, the machine image became starkly literal. It did not arise out of trying to find the best theory to suit the data, or as a hypothesis providing a common ground for disparate observations; it entered the theatre of metaphysics as a device of the imagination, an idea that had to be grasped more in terms of its potential than any concrete scientific attainment. The world-machine was not only an intermediary hypothesis but a categorical and literal statement of practical identity. It was both heuristic device and ontological thesis. In the centuries that followed, machine imagery became central in the conceptualization of organic life as a complex mechanism subject to physical laws. Descartes set the metaphysical conditions of possibility for the merging of organism and machine in a range of industrial, military, medical and scientific contexts. The first attempts to compare the cavities of the brain to a wind-powered musical instrument, or the human nervous system to a hydraulic puppet might strike the modern reader as surreal or downright comical. The machine image was, in many ways, a clumsy and unworkable metaphor, often counter-intuitive, and in some cases (such as with LaMettrie or d'Holbach) blatantly offensive. Furthermore, it straddled through massive difficulties in what we would now call biology and organic chemistry, in trying to explain chemical phenomena such as fermentation and combustion, and vital processes such as growth and generation. In

Gabbey's words, the mechanists 'tried to explain everything, which was too much by a long chalk.'[117]

But from these humble and unlikely beginnings, this odd notion (that all natural phenomena, including ourselves, can be understood in the light of technical objects and activities) has become pervasive, commonsensical even, and one of the fundamental myths of our age. It not only affected profoundly the outlook and practice of modern science, but also the social fabric of the modern world, and the way we perceive ourselves.

The preceding ruminations also highlight an intriguing tension between metaphors as provisory hypotheses and as constitutive images. Although certain models can be explicitly established as such (as throw-away conceptual structures useful exclusively in terms of their predictive and explanatory value) the history of science repeatedly shows us that there is another important type of metaphor: a *metaphoricity* that is constitutive of thought itself, essential to the very possibility of science. On one hand, science wants to conceive of its rhetorical and representational apparatus as the *techne* of reason, an instrumental means to a higher end: knowledge, correspondence, truth. Yet metaphor can be conceived as the very condition of possibility of thought—suggesting the prospect that all *logos*, in the end, amounts to nothing but *techne*.

[117] Gabbey A., "The Mechanical Philosophy and its Problems: Mechanical Explanations, Impenetrability, and Perpetual Motion", in Pitt J.C. (ed.), *Change and Progress in Modern Science*, D. Reidel Publishing Company (Dordrecht: 1985), 13.