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Chapter 8

The chain of motions and the chain of thoughts. The diachronic mechanism of Spinoza's friends.

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Abstract: This chapter introduces the notion of “diachronic mechanism” to account for experimental approaches to living phenomena that were developed in Spinoza's circle in the late seventeenth-century. This notion of “diachronic mechanism” allows me to distinguish two compatible types of mechanistic explanations: the well-known synchronic mechanistic explanations, which explain organic functions through the reduction of organisms into smaller components, and what I propose to call “diachronic mechanism,” which focuses on the temporal aspect of organic modifications. This diachronic mechanism describes organic modifications as a continuous series of physical events without specifying the inner structure of the parts which initiate the process. As a consequence, a new kind of analogy between automata and human beings is developed. It shifts the emphasis towards an experimental approach to the interactions between bodies and their environment.

Keywords: mechanism, Spinoza, Leibniz, Swammerdam, Steno, irritation, spiritual automaton, mental faculties, memory

Introduction

When we speak of “mechanism” today, we immediately think of the different attempts to automatize the human behavior that were developed in the twentieth century – for instance, the assembly line factory work or the partial replacement of humans by computers. All these attempts, which are based on the analogy between human beings and artificial machines, aimed at increasing the efficiency of human beings. In the 17th century, “mechanism” –or, more exactly, “mechanical [p. 120] philosophy” – corresponded to a rather different project: the analogy between living beings and artificial machines had above all an epistemological purpose. Indeed, in order to better understand the structures and functions of animal and human bodies, a great number of seventeenth-century thinkers considered that that living bodies obeyed the laws of mechanics articulated notably by Galileo and Huygens. According to Descartes, for example, all bodies are governed by the same universal and natural laws, whether these bodies are macroscopic or microscopic, artificial or natural, highly composite or mere elements, in movement or rest, fluid or solid (Garber 1993). Mechanics, which studies the laws of movement, thus offers a first entry into the understanding of the behavior

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of living bodies. This does not mean that animals, for example, simply are some kinds of clocks or catapults, or that they should be instrumentalized without limit. The core doctrine of “mechanism,” which assumes the difference between a rock and an animal body to be essentially a matter of degree of complexity, first concerns the intelligibility of bodies.

As scholars working on medical sciences have emphasized, the general postulate of the mechanism that was promoted in the seventeenth-century came in a great variety of forms (Des Chene 2005; Roux 2009; Wolfe in this volume¹). Regarding the relationship between mind and body, there are almost as many mechanical philosophies as there are philosophers. But, generally speaking, if specialists of the early modern period have indeed examined various kinds of mechanical explanations, they have principally discussed what I propose to call “synchronic mechanism.” What do I mean by this notion? “Synchronic mechanism” includes the different approaches that seek to explain complex phenomena, such as motricity, sense-perception, or digestion, through the behavior of the small and hidden components of living bodies. In other words, synchronic mechanism is interested in the composition of animal bodies. It imputes macrophenomena to microphenomena; it explains the behavior of bodies by their internal structures, exactly as the clockmaker explains the functioning of the clock through the relationship between its different cogwheels and springs. In contrast to this kind of “compositional analysis” (Craver 2007), I wish to highlight a “diachronic mechanism,” which functions in a radically different manner: it remains at the same level of analysis and focuses on the continuous chain of motions that are transmitted from one organic part to another.

Diachronic versions of mechanism seek to explain an event by describing its antecedent causes. This is a mechanism which does not include explicit corpuscular hypotheses on the hidden components of the organic parts. It is a mechanism without hidden springs and wheels, so to speak. Diachronic mechanism is interested in the transmission of motions inside and outside living bodies; it leaves outside of the picture the question of the nature and specific interactions of the components that [p. 121] are involved in these motions. Are synchronic and diachronic mechanisms incompatible? They are not. They only correspond to two perspectives, to two different ways of looking at the same phenomena; and, as a matter of fact, these two perspectives may well be combined in the work of a single author.

I propose this distinction only as a heuristic tool in order to draw attention to an approach to animal motions that was proposed in an inchoative form by Jan Swammerdam or Nicolaus Steno in the 1660’s. Their neuro-physiological studies, which have been undeservedly neglected, do not focus on the vertical relations between the mind and the animal body, but on the horizontal interactions between the animal body and its environment. In both cases, this starting point leads them to propose a kind of proto-behaviorist approach to the human body. Although they developed it only in allusive and fragmentary texts, it is interesting for at least two reasons. First, it brings to our attention a conception of human actions that is partly opposed to the Cartesian explanation of the mind-body relationship. Second, the diachronic mechanism, which was developed in Spinoza’s circle, may allow one to better grasp the specificity of Spinoza’s own representation of the human body, by contrast with the synchronic mechanism developed by the Cartesians.

¹ Charles Wolfe emphasizes the fluidity of the boundaries between mechanism and vitalism (which may have a “mechanism-friendly” form). In addition, historiographically speaking, those labels have been often used polemically to discredit an adversary’s doctrine (see also Andrault 2018). When I use the term ‘mechanism’ here, I mean methods of investigation developed by late seventeenth-century anatomists who endorsed notions of matter and motion consistent with the new mechanical science proposed by Galileo and Descartes.

A new kind of automaton

During the 1660's, Swammerdam wrote a small text on muscular that Boerhaave published posthumously in the *Biblia Naturae* (Leiden, 1737-1738, with the original Dutch and a Latin translation; 1758 for the English translation). This text is entitled *Experiments on the particular motion of the muscles in the Frog, which may also, in general, applied to all the motions of the muscles in Men and Brutes*.² If, as the title indicates, the dissertation primarily concerns the apparently very specific anatomical topic of the muscular motions of frogs, Swammerdam includes therein general considerations on animal and human motion that also have a philosophical interest. It is thus not surprising that this text was also translated in a 1758 volume of the *Collection académique* which was meant to disseminate in France the most famous and important texts of natural history published in "foreign countries". In order to present Swammerdam's "diachronic mechanism", which is characterized by an analogy between memory and muscular motions, I have first to explain the main point of his anatomical demonstration.

Swammerdam sought to refute the most usual explanation of animal motions of that time, to wit, the thesis that animal motions are caused by the inflation, or fermentation, of a kind of nervous juice inside muscles. According to this idea that Swammerdam invalidates, muscular contraction corresponds to a real swelling of the muscle due to an afflux of the so-called "animal spirits," that is to say, of the small active particles forming the fluid whose circulation in nerves and muscles was supposed [p. 122 to be responsible for sensory-motor functions. This thesis, the "balloonist theory," was, for example, adopted with important variations in the 1630's by Descartes, as well as in the 1660's by the English anatomist Thomas Willis, who compares the action of animal spirits to the propagation of light (Sutton 1998, 46). Swammerdam relates in his dissertation some very sophisticated experiments on excised muscles of frogs or dogs that he invented in order to compare the mass of a contracted muscle with the mass of a non-contracted muscle (Cobb 2002, 398). As Swammerdam indicates, he performed certain of these experiments in the presence of his friend Nicolaus Steno, and showed some of them to the Great Duke of Tuscany during his visit in Amsterdam.

Swammerdam's experiments demonstrate that the mass of a contracted muscle is not greater than the mass of a non-contracted muscle³ —a fact which invalidates the usual explanations of muscular motions through the hypothesis of animal spirits. He opposes to this consensual balloonist theory the notion that muscles are in constant state of contraction. As a matter of fact, the smallest solicitation, or "determination" of the nerves, as he puts it, can produce a muscular motion. It suffices that the anatomist slightly "irritates" —or touches— the nerve which is connected to the muscle with a needle, a chemical solution, or a finger, to immediately put into action the whole muscle on several occasions.⁴ And the fact that "the motion of each muscle is restored by only stimulating, provoking or irritating the nerve" contradicts the idea that a specific afflux of a nervous fluid is necessary to produce each muscular motion (Swammerdam 1758, 124b). From this experimental fact, Swammerdam

² For the Dutch original, see *Biblia Naturae*, t. 2, 1738, 833-860.

³ He even considers that the contracted muscle has a mass which is inferior to a dilated muscle, a claim that Steno does not take over.

⁴ For example: If we "lightly pinch or prick the nerves of the diaphragm in a living dog, opened for the experiment, with the point of a very fine needle; or if we stimulate them by putting them near the fire, or by pouring acrid liquors into them; we immediately see the diaphragm performs its natural function: [...] the same experiment may be often repeated in the same subject, if the nerves of the diaphragm be first irritated" (Swammerdam 1758, 122b; in Dutch, *id.* 1738, 837b: "irritatie").

concludes: “a simple and natural motion or irritation of the nerves alone is necessary to produce muscular motion, whether it has its origin in the brain, or in the marrow, or elsewhere” (*ibid.*, 124b).

This demonstration may seem anecdotal; and yet, it changes completely the representation of the source of motion in animals and humans. Their muscles and nerves are not depicted as passive and hollow receptacles which need to be animated, or put into action by an unobserved fluid or by a violent chemical interaction between unobservable particles, like a hydraulic machine (Starobinski 1966, 176-7; see also Giglioni, 256). On the contrary, according to the decentralized pattern depicted by Swammerdam, muscles and nerves, and, thus, the animal body as a whole, are continually and constantly ready to move, and even inclined to move. One of the causes explaining animal movement is indeed “*the perpetual and natural irritations* which the nerves are *continually* engaged in urging them [p. 123] to contraction” (*ibid.*, 130b; emphasis is mine). What causes animal motion is not what occasionally provides an large quantity of force; it is a minimal impulse associated with the natural and constant tonus of the animal body.⁵

Before examining Swammerdam’s proto-behaviorism, it is important to specify four features of his analysis of animal motion. First, Swammerdam puts natural and artificial stimulations on the same level: he considers that the stimulations, or “irritations,” that are triggered by an experimenter on excised organs, give relevant and reliable pieces of information on the *natural* functioning of the animal body. Second, Swammerdam emphasizes that voluntary motions occur in the exact same manner as spontaneous or “natural” motions: “I admit no essential difference between the natural and spontaneous contraction of the muscles and that performed by the will;” “those very muscles, by whose assistance we perform our voluntary motions, are notwithstanding always themselves moved in a natural manner” (Swammerdam 1758, 125a and 131b).⁶ Third, Swammerdam apparently understands the triggering of muscular motions on the model of mechanical impulsion: according to his terms, when nerves are “touched,” “moved,” or even “tickled,” they immediately “determine” muscles to contract; and the “action” of muscles consists in their tendency to restore their first and natural state of contraction as soon as they are moved, exactly like a spring.⁷ Fourth, he uses analogies between species in order to better describe muscles’ natural tendency to immediately react to mechanical stimulations. According to him, the comparison with the behavior of the contractile plant *herba impatiens*, which, “in consequence of any momentary irritation, most suddenly contract,” could shed some light on the contractility of muscular fibers (Swammerdam 1758, 129a). Thus, there could be interesting similarities between different kinds of fibrils, whether they are vegetal, nervous, or muscular. Moreover, beyond these explicit comparisons, Swammerdam’s approach supposes that the experimental study of *animal* motions allows one to better understand *human* motions. In other words, from the point of view of neuro-muscular connections, there is no reason to consider that human motions do not suppose the same kind of physio-anatomical determinations as animal’s ones.

These four features of Swammerdam’s explanations contribute to the naturalization of animal and human motions, which are conceived of on the model of mechanical stimulations. Accordingly, they can reasonably be regarded as “mechanical.” But, first,

⁵ Tonus is not a term that Swammerdam uses; Pubols mentions it to emphasize Swammerdam’s contribution to the understanding of “reflex” (Pubols 1959).

⁶ Such a view also modifies the usual understanding of Galen’s anatomical taxonomy, which defines muscles as “organs of voluntary motion” (Galen 1856, VIII, I, 1, 324; see Andraut 2016, 80-82).

⁷ In an early dissertation on respiration, Swammerdam defends the view that respiration only requires pressing or pushing motions (*versus* attractive motions or attractive forces; see Swammerdam 1667).

Swammerdam does not develop analogies between artificial machines and animal bodies. At the very end of his dissertation, he only mentions the “wonderful machine of our body,” but he does not develop this very common metaphor [p. 124] (Swammerdam 1758, 131b). Second, he does not specify the various physical or mechanical actions which are at stake in the physiological processes he is interested in. Indeed, Swammerdam remains very cautious about the true causes of animal motion: if he insists on certain “determinations” that suffice to trigger muscular contractions, he indicates that a great number of elements remain to be known in order to exhaustively explain animal actions, whether in the environment of the animal (the atmosphere, the nature of our food) or inside the organism (the blood, the brain, the marrow and the nerves; Swammerdam 1758, 131b). At the very beginning of his study, he even acknowledges that he does not completely know the intimate structure of the muscle, and particularly the intimate structure of the smallest fibrils that compose muscles. To account for the continual contraction of muscles, Swammerdam ventures several hypotheses which he presents as such.⁸ However, he does not speculate on the ultimate causes of animal motions –nor on their sufficient causes: his main scientific purpose is to experimentally elucidate, as far as possible, the anatomical conditions of animal motion. Nevertheless, as we will see, the small anatomical claims that Swammerdam defends in this text drastically change the meaning of the analogy between artificial machines and human beings.

The man with the hat

In order to show that all our own actions, whether voluntary or involuntary, require the natural nervous and muscular motions that he describes in his dissertation, Swammerdam dwells on several examples of involuntary actions:

If, for example, a man’s skin be very gently rubbed and irritated with a hair double several times, I often observed, that the motions of the antagonist muscles of the arm and hand was immediately determined; so that the person instantaneously, as it were, unknown to him, has put his hand to the place where he felt the titillation and then scratched the skin until he made it red, imagining that it was probably occasioned by a Flea, or some other insect. But when I stopped, his hand and arm rested likewise, because the natural contraction was then equal in all the muscles. (Swammerdam 1758, 125b-126a)

This example shows how a very slight stimulation (a tickling with a hair) can provoke a whole series of human actions. These actions suppose only that the equilibrium of size and strength between antagonist contracted muscles is slightly perturbed by a new “determination, which, causing one muscle, to be contracted somewhat more strongly than another, at length moves our limbs” (*id.*). First, Swammerdam particularly insists on the fact that the person that actually performs all these actions either does not know, or is misled about the cause of his own movements. Second, his description emphasizes the disparity between the mechanical cause of the action (a gentle rubbing) and its automatic consequences (the scratched skin becomes red) [p. 125] : the mechanical cause is “slight” and can go unnoticed; the consequences it triggers, on the other hand, cannot escape our attention and may even seem excessive –that is to say, may seem require an explanation that mentions greater causes, like the intervention of the will or an afflux of animal spirits in muscles. Third, hand and arm gestures immediately cease when the experimenter stops rubbing the skin. For these three reasons, the experimenter looks like a puppet master, and the man like an automaton who is deprived of all kind of autonomy, though his body is not

⁸ He mentions, for example, the continual impulse of blood (Swammerdam 1758, 125b)

deprived of spontaneous motion and tonus. Regarding this kind of involuntary motion, there is no difference between the functioning and behavior of animals and those of human beings:

Of the same experiment be made on sleeping dogs or cat, it is likewise observed that a determinate motion is produced in the muscles which move their skin; and therefore it is pleasant to see them suddenly draw it up their hairs, and sometimes shaking them in their sleep. By this familiar instance, it is evident how our muscles are in like manner voluntarily moved without any great attention of the will, by something of this kind (*ibid.*, 126a).

Swammerdam's insistence on human involuntary motions leads him to develop comparisons between the behavior of animals and the behaviors of humans. But he does not indicate the limits of this comparison. He seems to keep the notion of "voluntary" motion, and of will, for human beings; but the rest of his analysis insists more on the similarity between animals and humans than on their differences, as we are going to see.

Indeed, the cognitive faculties of man that are usually regarded as actions –and, sometimes, as typically *human* actions–, such as attention or will, are actually relegated to the sidelines of Swammerdam's text: their intervention is minimized. On the contrary, mental faculties which are supposed to be passive or illusory, such as the imagination and the memory, are brought to the forefront. Swammerdam's aim is indeed to show, first, that the will alone, without a "determining principle," cannot produce any movement, and, second, that this "determining principle" which escapes the will can trigger the kind of movements that we wrongly believe to be exclusively produced by the will. Two other comparisons particularly insist on the surprising actions that a man can perform in the absence of any conscious will and self-control. Classically enough, the first one is the dream:

Cannot a simple dream, or some absolute phantom, presenting itself before us in the night to affect us? Even in this case, we immediately start, tremble, and perhaps get out of bed, shriek, and call for assistance. And all this we do merely because we then just determine another way our muscles, already prepared for action (*ibid.* 131b).

Swammerdam does not question the fact that the will may have some causal power in the production of these movements, nor does he deny that "a mere casual thought" can be in itself a "determining principle" triggering these movements. His lack of strong philosophical commitment about the true "causes" of motion concerns also the will or the causal power of thoughts. However, Swammerdam still minimizes the role of conscious and voluntary thoughts, and, correlatively, still emphasizes what renders us comparable to the animals on which he performs his experiments. [p. 126]

When he considers the influence of representations on the flow of blood and on muscular contractions, he insists on the power of "imagination", that is, on the power of something that is usually regarded as illustrating the passivity of the human mind. As he explains, the simple fact of imagining objects that are amusing or sad makes the heart to contract or to dilate:

[The] imagination alone is often powerful enough to have the same effect, as our muscles are at that time variously influenced according to the lively or gloomy nature of the thoughts which then possess us, and proportionably contract and shut, or expand our hearts. (Swammerdam 1738, 853b; 1758, 128b)

Swammerdam thus systematically insists on what conditions our thoughts, actions, and psychophysical feelings, whether these conditions are to be found in the environment (any

“external principle” or “object”) or in the human body (all the anatomical motions that his dissertation seeks to identify).

The second comparison which illustrates the importance of automatic gestures in our life is a key passage:

We often observe, that a natural contraction takes place in those muscles, which are said to move as the will directs; as is manifest in our walking, standing, and making use of our hands: for we certainly move our limbs almost every moment, without reflecting in the least upon what we do. Thus, with regard to external objects, we often salute a person we meet, merely because another in our company takes off his hat, or because we are affected by such external object, though we do not know who the person is we have saluted, nor so much as think of our saluting him. For this reason therefore it is plain that, as our memory is local, and is assisted by the image of one thing in passing to that of another, and so on without end, the contractions of our muscles are in like manner natural; and the muscles themselves are urged by one cause of motion to another, and from this to a third, and so on without any interruption (1758, 131a-131b).

Here also, Swammerdam insists on our lack of knowledge in performing our so-called “voluntary motions.” Indeed, according to this excerpt, we do not even know that we are saluting someone—we may know that only afterwards, when we explicitly realize what we have just done. But there is something quite noticeable in Swammerdam’s comparison. When one wants to emphasize that a motion is performed automatically, that is, performed involuntarily without self-conscious purpose, one usually mentions examples from the physical and inanimate world, for instance the regular motions of the wheels of a clock or the movements performed by an inert puppet. Here, Swammerdam does exactly the opposite of this strategy: he reverses the usual *comparans* (examples from the physical world) and the usual *comparatum* (the so-called “mental” actions). He uses the process of memory as the most obvious example of automatic functioning. Memory, by which one image endlessly flows into another, illustrates for him the natural and interrupted chain of determinations by which any animal motion is produced. Memory is depicted as the natural course of a series of images which cannot be interrupted, deviated, nor partially shot-circuited by any kind of interruption. In the exact same manner, animal motion is naturally produced by a succession of physically sited “determinations,” or “commotions”, without any vertical interruption or intervention from another kind of agency.

Even more strikingly, Swammerdam refers to memory as “local,” as if it was a mere physical process that would be as easily observable as a city on a map [p. 127]. What does he mean by this term “local” –*plaatselyk* in the original Dutch—?⁹ It may simply refer to the fact that memory always works through particular and limited images that are related to physical places and that are necessarily linked one by one: the process of remembering is neither synthetic nor global. In any case, the person who is remembering something is more like a witness than like an actor of his own memory: a succession of images passes through his mind, which seems like a completely passive receptor. To depict what he called “flying thoughts,” i.e. the thoughts that escape our own power and attention, Leibniz proposes an eloquent metaphor that allows us to better understand Swammerdam’s point here: “It is like a magic lantern, with which one can make figures appear on the wall by turning something on the inside [...], the mind embarks as it sees fit on certain trains of thought which lead it to others” (*New Essays on Human Understanding*, II, XXI, 12; Leibniz, 1996, 177).

⁹ Swammerdam’s notion here seems to be a reference to the ‘local memory’ of ancient medicine, that is to say, to the *ars memorativa* which teaches us how to retain ideas by spatializing them in various places. In any case, insofar as Swammerdam insists on the fact that memory corresponds to a process, his use of the adjective ‘local’ does not seem to correspond to what Sutton call the ‘local model of memory’ (memory as ‘unchanging items in storage spaces’, see Sutton 1998, 5).

We usually regard memory as an inner process that is mainly mental. We speak also of a psychophysiological process which inextricably involves body and mind. In the second half of the 17th century, there were, of course, different conceptions of what memory is, how it works, and what the anatomical conditions of the process of remembering are. When referring to human beings, memory was assimilated to a passive faculty of the mind entirely dependent upon the motions occurring in the body, and, more particularly, in the brain (Sutton 1998, 57 and 67). This widespread representation does not prevent Descartes from sometimes referring to the human memory as something that may be merely intellectual, and thus incorporeal (Descartes 1965, III-85). As for Swammerdam, he does not mention memory as a brain function that may depend on the inner power of a rational being endowed with an efficient will. Rather, he considers as well-known –or “plain”– the notion that memory is a natural, constant, and regular process that consists in an endless series of images, which are entirely determined. In addition, he never says if animals are endowed or not with memory, or imagination, and, consequently, to what extent the comparisons he develops between animals and men are valid.

The diachronic mechanism and the role of mind

Let us summarize. Swammerdam considers the invisible process of remembering as a model for involuntary motions, to wit, for motions that are systematically triggered by some external occasion, according to an endless chain of determining causes. Complex human actions, like saluting or remembering, often escape psychological control, exactly as is the case in the long and complex chain of [p. 128] determinations which govern muscular contractions inside our bodies. A pre-understanding of the automatic functioning of mental faculties thus offers Swammerdam a model to understand the natural functioning of muscles in animal motions –not the other way around. Such a conception of the causal chain of images and motions modifies the comparison between a statue and a man with which Descartes opens his *Treatise of Man* (published in the original French in 1664; in his Latin translation in 1662). According to Descartes, the body works exactly like an automaton: the physical interactions between the various anatomical elements that compose the human body suffice to produce organic functions, such as nutrition or motility. Here is a relevant image of this automaton:

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. (Descartes, 107).

It is important to note that the hydraulic system of fountains is not the only analogy that Descartes develops. This analogy simply helps to imagine the possible connection between the human body and the human mind, or soul, that may interact with its body without changing the general manner in which it performs its merely physical functions:

when a rational soul is present in this machine it will have its principal seat in the brain and will reside there like the fountaineer, who must be stationed at the tanks to which the fountain's pipes return if he wants to initiate, impede, or in some way alter their movements (*ibid.*).

To be sure, mind-body relationships are not limited to the action of control that the human mind exerts on its body. As Descartes emphasizes in the Sixth Metaphysical Meditation, the

mind is not only in its body like a pilot in his ship (Descartes 1965, IX 64). Nevertheless, the various analogies between human body and artificial machines that Descartes develops in *The Treatise of Man* offer an image of the body that is very different from Swammerdam's comparison between memory and muscular motion. To clarify the mind-body relationships, Descartes has to give a clear and synthetic view of the inner composition of the body machine. Most notably, once we have a synthetic view of the manner in which the merely organic functions are performed, we may visualize how mental functions like memory, imagination, attention, or will mobilize the physical components of the body. Accordingly, the Cartesian body is depicted as a quasi-autonomous system of solid and fluid organs, which is clearly delimited, and to which the mind is connected *via* a unique central point, the brain, which is also at the top of the physical structure.¹⁰ Quite the contrary, Swammerdam does not put forward a synthetic view of the human body as a machine; his text does not even give a general survey of the muscular system. [p. 129] First, his experimental study only focuses on a few controversial elements that are necessarily involved in muscular contraction. Second, and more importantly, his comparisons and examples emphasize the local complexity of an organic process that no one is able to grasp and schematically represent in full. This process is by definition endless, and indirectly governed by exterior causes and environmental influences which the anatomist does not claim to know. Both Descartes and Swammerdam deal with automatic and involuntary organic motions. But, while automatism refers in Descartes to the physical autonomy of an artificial machine which is built on the model of a real animals or humans, it refers in Swammerdam to an implacable sequence of events which is dependent upon a great number of uncontrolled circumstances. This is an automatism without autonomy, so to speak. This new way of looking at animal motions induces a kind of myopic approach to their physio-anatomical conditions; but this myopic approach is presented as such, i.e. as due to the provisory and limited nature of our knowledge: it is only our partial ignorance of the whole chain of causality that leads us to isolate some temporal sequences of causally connected events. Moreover, memories, images, representations, and thoughts of the mind are not conceived of as the proper products of different faculties. Swammerdam only depicts them as phenomena –both animal and specifically human– which work on the same model as merely mechanical motions. Consequently, it is more the powerlessness of the mind that is put forward than its ability to control, interfere with, or benefit from the machine of its body.

This does not imply that Swammerdam is explicitly opposed to Descartes. First, when Swammerdam refers to Descartes in other works, it is to praise Descartes' philosophy. He cites for instance the "Great Descartes" who, according to him, spent all his life seeking to transform philosophical speculations into practice (Swammerdam 1669, 9). More generally, in this entomological work, Swammerdam regularly insists on the fact that the works of God depend upon a small number of rules which have no exception (Jorink 2010, 316). This implies that all animals are formed according to the same universal laws, and that no animal has been formed or transformed by chance through a process of "metamorphosis," as Harvey's theory of generation had wrongly supposed. According to this claim, Swammerdam seeks to experimentally prove the continuous and very progressive character of all the natural changes that various insects undergo. For instance, his observations allow him to grasp the physical continuity that underlies the change from the state of caterpillar to the state of butterfly. Such a view developed by Swammerdam in his natural history could well be considered as faithful to Descartes' philosophy. It is even possible to see

¹⁰ I specify "quasi-autonomous" because of course, in Descartes' physiology, the human body, as well as its artificial analogona, is not a completely closed system: it has exchanges with the outside, most notably through the processes of feeding, respiration, perspiration, or occasional sensory stimuli.

Swammerdam's naturalization of muscular motions more as a systematization of Descartes' mechanism than as its partial refutation (on Descartes, see Antoine 2009, 58-75). Nevertheless, this systematization, and Swammerdam's insistence on the temporal continuity of all organic processes, completely change the manner in which he analogically represents muscular motions. There is a shift from a mechanism which presents a synchronic view of the human body as a machine endowed with psycho-physical faculties, toward a diachronic mechanism which focuses on various temporal sequences of homogeneous inter-determined phenomena. [p. 130]

The automaton organist

Although his *History of Insects* confirms the importance of the notion of continuity in his epistemology, Swammerdam does not develop elsewhere his diachronic approach to animal motions. His work on muscles could thus appear too sketchy and isolated to justify the new category of "diachronic mechanism." Nevertheless, I have found elsewhere some echoes of this approach.

Steno and Swammerdam were friends in the early 1660's in the Netherlands, and, then, in the mid-1660's, worked together near Paris in the house of their common patron Melchisédech Thévenot. As Swammerdam and Steno acknowledged, they performed experiments on muscles together. In one of his works on muscles (1667), Steno emphasizes his ignorance of some factors that are certainly involved in muscular contractions. Like Swammerdam, he focuses on what he believes he knows: how the muscular fibrils are moved during the process of contraction and the fact that nothing supports the common balloonist theory which mentions the so-called "animal spirits" (Kardel 1994, 41; Andraut 2010). But it is only in sketchy manuscript notes, probably written in 1684, during a stay in Hamburg, that Steno develops a diachronic approach, which is comparable to Swammerdam's.¹¹

In the 1684 manuscript, Steno examines the complex connection between sensory impulses and motor responses. He observes that various sensory impulses can lead to the same motor response, and, conversely, that a single sensory impulse may prompt different motor responses. Among other examples, he uses the example of a musician –probably a singer who accompanies himself on the organ. The simple sight of a note on a sheet of music may trigger various motor responses: various motions of the eyes, of the tongue, of the hands, and also of the feet to use the pedal. According to the octave which is chosen, the motions performed by the muscles of all these parts are not exactly the same.¹² Steno illustrates with four small diagrams the difficulty of accounting for such a various and variable connection between sensations (s) and motions (m) (see figure 1). He considers various solutions: Could the connection between nervous sensory filaments and nervous motor filaments be solid? Could it be rather a fluid? Steno concludes that it is impossible to account for this sensorimotor connection by only mentioning a physical intermediary –that is to say, in Steno's epistemology, a mechanical intermediary, an intermediary which would be merely "extended". Paradoxically enough, a strict experimental point of departure allows Steno to conclude that there is an immaterial 'I' between sensations and motions, "otherwise an impulse of the same nerves would always result in the motion of the same corresponding

¹¹ On Steno's machine-body analogy, see Andraut 2016, 50-61.

¹² "Eadem nota musica per nervos oculorum communicando fili impulsum introrsum infinitas determinationum ab intra mutations producit, per nervos ad linguam, quoties supra vel infra octavam ejus potest intonare, per nervos ad singulos digitos, quibus eandem per singulas octavas percutare potest, item et versus pedes" (Steno, 1952, 950; see also the manuscript: *Biblioteca Nazionale Centrale di Firenze*, Gal. 291, fol. 183).

muscle, and vice versa” (Steno 1952, 949). But here, I am not interested in Steno’s conclusion (on this point, see Andrault 2018, 106-109). I will rather focus on the three main presuppositions of his astonishing demonstration.

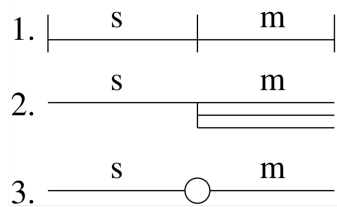


Figure 1. Steno, 1952, 948

[p. 131] Steno’s anatomical point of departure is the distinction between sensory nervous filaments and motor nervous filaments. The two kinds of filaments link the white and medullary substance of the brain to the various parts of the body which are in contact with the “outside” and, more specifically, with sensory objects (Steno 1952, 949). Swammerdam also firmly distinguishes the nerves that trigger muscular motions and the nerves that communicate sensations (Swammerdam 1758, 125a), and Fearing considers that this distinction is a “fundamental contribution to neuro-muscular physiology and physiological psychology” (1929, 443). In both cases, the experimental study of the relationships between the animal body and its environment requires describing the transmission of physical “impulsions” from peripheral organs through the nervous “filaments” and their corresponding muscles. The physio-anatomy of the sensorimotor system can be schematized through a network of parallel lines representing the propagation of an impulsion along muscular and nervous fibers. Similarly, in both cases also, the causal relationship between the different motions of these fibers is expressed by the notion of ‘determination.’ Indeed, under Swammerdam’s pen, each stimulation of the nerves, whether it is an “irritation” or a “commotion,” has a consequence which is specific and systematic: the same determination always leads to the same consequence. This determination may not suffice to *produce* the consequence; but at the very least, it *conditions* its occurrence. Steno speaks of the “determinations of motions.” In Cartesian physics, “the notion of determination is intimately linked with the directionality of a body in motion” (see Garber 1992, 189). In all cases, to “determine” the motion of a physical element means to provoke a change of its position.

These various presuppositions, which constitute in my opinion the core of Steno’s and Swammerdam’s diachronic mechanism, induce a kind of proto-behaviorist approach to the human body, whose movements are conceived of on the model of animal actions. Indeed, Swammerdam and Steno adopt an experimentalist perspective on human actions which is in accordance with their disciplinary training as anatomists and naturalists: when they examine phenomena such as sensations and motions, they restrict themselves to a third-person approach which, on the one hand, excludes introspection and the psycho-physiological heritage of sixteenth-century medicine, and, on the other hand, consists in empirically tracking down the continuity of certain anatomical modifications. They naturalize these anatomical modifications in so far as they translate them into continuous series of entirely determined phenomena. Conversely, phenomena that cannot be integrated into these continuous series are excluded from their empirical studies: they are either treated [p. 132] as illusory or as belonging to a range of phenomena which is beyond physio-anatomical examination.

The man with the hat, as well as the organist mentioned by Steno, seem to be automata. But neither Swammerdam nor Steno deal with the different functions, or faculties,

with which these automata are endowed. More generally, their studies put into brackets the question of a possible inner cause of human behavior. They only describe in a fragmentary way the determined motions that come through these automata. They only seek to observe how these automata integrate and reflect these motions through the observable modifications of their nerves and muscles. The starting point of their analyses is an external stimulus: the experimenter who pricks the nerve with a needle, the friend who raises his hat, the sight of a note on a sheet of music. Human actions are regarded as motor effects of sensory stimuli; not as proper productions of distinct inner faculties, whether mental or physical. The power of the mind is only depicted as something unclear and problematic. Indeed, how to think the insertion of free-will and thought into these sensorimotor sequences? It is perhaps because of this unsolved problem that neither Swammerdam nor Steno published their works on the sensorimotor connection.

Philosophical echoes? The spiritual automata

Swammerdam and Steno have a dynamic conception of neuromuscular connections which is compatible with the core of mechanical philosophy, even if it does not correspond to its well-known Cartesian or atomistic versions. The notion of “diachronic mechanism,” with which I summarize their conception, has the merit of drawing attention to a neglected chapter of “the long history of mechanistic models of the mental.”¹³

Beyond the small circle of anatomists, Steno’s and Swammerdam’s works were praised by distinguished philosophers, such as Leibniz (on Swammerdam natural “series”, see Leibniz 1923, VII-353-354). We have no indication that Spinoza, who attended Steno’s dissections in Leiden during the early 1660’s, knew Swammerdam’s study on muscles. We know that the three of them were friends then (Jorink 2016). But this biographical connection cannot suffice to establish any influence of Swammerdam’s physiology on Spinoza, nor of Spinoza’s philosophy on Swammerdam’s inchoative reflections. Steno’s manuscript mentions critically Spinoza’s philosophy, but it is too allusive to understand the link between Steno’s physio-anatomical presuppositions and Spinoza’s philosophy.¹⁴ However, my [p. 133] hypothesis is that there is something common in the way they look at the human body and its insertion in nature. While they have a mechanical understanding of physical interactions, they do not adopt the Cartesian understanding of the human body as Malebranche did, for instance. They rather insist on the lacunas and errors of the Cartesian physiology, and emphasize more generally our common ignorance of both the exact relationships between our body and the other bodies, and the exact interactions between the different components of our own body (Spinoza 2016, 1306; Andrault 2019). But this insistence on the limits of our knowledge does not prevent them from claiming that bodies are submitted to intense and numerous (if not infinite) interactions with other natural bodies. According to Spinoza, there can be no interruption of the causal chain of events, whether of thoughts or of motions, for “there is nothing contingent, but all things have been determined from the necessity of the divine nature to exist and produced an effect in a certain way” (Spinoza, *Ethica*, I-29). Consequently, step by step, the causal endless chain which integrates the mechanical modifications of the human body includes the whole of nature.

¹³ Glennan and Illari (2018, 3) referencing Miłkowski 2018, who does not speak of this diachronic mechanical approach to the mind. Historical studies of neuro-muscular connection have also neglected Swammerdam, and his interesting and long-lasting notion of “irritation,” to the benefit of Glisson, Haller and Boerhaave, the editor of Swammerdam’s works (see Cobb 2002 on this diagnosis).

¹⁴ Steno 1952, 949: “Nullum studium virtutum in Spinoza, sed studium solarum veritatum.”

When Spinoza presents a plausible explanation of the physiological process that conditions imagination and memory, he only mentions how an external stimulation lastingly modifies the usual interactions between fluids and solids in the human body (Spinoza, *Ethica*, II-17, dem.). This representation of the body is connected to two well-known theses on the mind. First, Spinoza's philosophy considers only immanent causality: he rejects direct causal interactions between the soul and the body, and accordingly, the very notion of free will that leads us to "conceive man in nature as a dominion within a dominion," i. e., as an exception (*Ethica*, III, praef.). Second, Spinoza does not regard memory or imagination as different faculties. For him, they only correspond to various chains of thoughts that differ "from the connection of ideas which happens according to the order of the intellect, by which the Mind perceives things through their first causes, and which is the same in all men" (*Ethica*, II-18 schol.). For memory, this order corresponds to the strictly determined order of physical "images" which succeed one another in the body: memory is "nothing other than a certain connection of ideas involving the nature of things which are outside the human body—a connection that is in the Mind according to the order and connection of the affections of the human Body." The conclusion recalls us Swammerdam's notion of a "local" memory: "And from this we clearly understand why the Mind, from the thought of one thing, immediately passes to the thought of another" (*id.*).

When Spinoza speaks of "automaton," he refers to a connection of causes and effects which is strictly governed by natural laws. More precisely, he speaks of a *spiritual* automaton when he distinguishes himself from the "ancients", who "never conceived the soul (as we do here) as acting according to certain laws, like a spiritual automaton" (Spinoza 2016, 68). Leibniz also compares the soul to a "spiritual automaton" (Leibniz 1997, 17), whose thoughts follow an ordained sequence which strictly corresponds to the sequence of motions simultaneously occurring in the human body. To be sure, the two philosophers do not have the same conception of [p. 134] what the mind is;¹⁵ and I do not claim that the two of them were directly influenced by Swammerdam's small study on muscles. However, I do think that this philosophical use of the notion of "automaton" has a conceptual and historical affinity with what I call "diachronic mechanism." In both cases, the focal point of the philosophical analysis of the mind is the causal sequence of interconnected thoughts, exactly like the focal point of the analysis of human actions in Swammerdam and Steno is the temporal sequence of connected motions that causally links the actions performed by the human body with external stimuli. In these different authors, we can detect a shift from a Cartesian mechanism to a more naturalized mechanism which focuses on the causal connection between various phenomena occurring at the same level of decomposition, or of observation. According to this view, the analogy between the chain of thoughts, or the chain of images, and the chain of motions, contradicts the Cartesian psycho-physiological explanation of free will, and as a corollary, the Cartesian conception of the difference between animals and humans.

¹⁵ In addition, Leibniz combines the two kinds of mechanisms: the synchronic mechanism, with the notion of "divine machines" (Andraut 2016, 105-107) and the diachronic mechanism, with the notion of "spiritual automaton" corresponding to the "hypothesis of concomitance" between mind and body (Giglion 1995, 260-268). This is also the case of Wolff (see Matteo Favaretti in this volume).

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