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Regulation, Assimilation, and Life: Kant, Canguilhem and Beyond

Introduction

The modern classic on the *pre-history* of the concept of regulation is Georges Canguilhem's essay on the "Development of the Concept of Biological Regulation,"[1] which pursues this concept from Leibniz to Lotze – touching on clock technology, physico-theology, animal economy and the balance of nature – before arriving at the place all roads lead to: Claude Bernard.

Canguilhem's story is teleological and dialectical. It is teleological in the sense that, after locating the emergence of the concept of regulation towards the end of the 19th century, he asks how the prerequisites for the concept were acquired and how the impediments to the concept were removed. His story is dialectical in the sense that some of the prerequisites – or perhaps prerequisites of the prerequisites – turn out to be impediments, so that they have to be overcome (that is, preserved but removed) in order for science to move forward.

Canguilhem views the question of regulation from the point of view of the conceptualization of the *governor* of the world in physico-theology – he calls it the "physico-theology of regulation." The two poles of his dialectic are introduced by the opposition between Leibniz and Newton (Newton being assisted and represented by Samuel Clarke). Basically, Leibniz sees all questions of regulation and regularity in mechanics, physiology, animal economy, and politics in terms of equilibrium systems and conservation laws: God made and regulated his world so well that it runs smoothly without his intervention. Newton and Clarke emphasized the need for God (or the English king) to intervene actively in the affairs of his kingdom. The world system and English society need "inspection and government" from outside the system. God's world, they insisted, runs so well because he acts in it regularly to regulate and overcome the minor or major disturbances that occur when matter acts on its own. The regulator in this conception was an immaterial being (or at least a

[1] "La formation du concept de régulation biologique aux XVIIIe et XIXe siècles" In Canguilhem, *Idéologie et rationalité dans l'histoire des sciences de la vie,* Paris, Vrin, 1977, pp. 81-99.

being that is not part of the system), who intervenes to correct deviations from the goal or norm. But it was the Leibnizian view that, according to Canguilhem, determined the intellectual horizon of scientists thinking about what we now would call regulation questions. Leibniz conceptualized the kind of system studied by natural science as a physical perpetuum mobile, made so that as long as it merely acts according to its nature, it functions smoothly. He appealed to a deterministic pre-established harmony. Leibniz saw no place for adaptation or adjustment to unforeseen or unpredictable circumstances – what could God not foresee? So great was the prestige of conservative systems, says Canguilhem, that "it took a good half century [after Clausius] for biologists to begin to conceive of organic regulation in terms of adaptation and not just in terms of the function of conservation or restitution in closed systems."[2] Thus the basic dialectic is that the specific form of scientific, naturalistic approach represented by Leibniz blocked out any possibility of regulation in the modern sense.

Canguilhem's example to illustrate this dialectic is taken from Leibniz' debates with Pierre Bayle. For Leibniz any adaptation of a system to conditions in the environment had to be due to a pre-established harmony. Bayle had argued that even God could not make a ship that seeks its harbor by itself – unless he gave it something like a non-material mind that could represent the goal state or situation. But when Leibniz in his response argued that God could indeed make a ship that seeks its harbor all by itself, he did not describe it as a goal-directed system that uses whatever it has to achieve a goal represented within it under the circumstances given by the environment. Rather, the ship is a deterministic system for which all the vicissitudes of possible environmental influence have been precisely calculated in advance. The course of the ship is not adjusted underway by something like a natural pilot; rather the ship pursues a trajectory laid down from the beginning – so to speak in one complicated set of equations that determines every point of the trajectory, because all the details are determined in advance. Leibniz uses the analogy of a fireworks rocket following a complicated trajectory – *along a string*. For God, this pre-established harmony is no problem. But this conceptualization excludes any possibility of adaptation to the new or unforeseen. There is nothing unforeseen.[3]

To recapitulate the dialectic: A scientific or deterministic description of the phenomena has to side with Leibniz against Newton on the closed character of the material

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[2] Canguilhem 1977, 86.

[3] Canguilhem 1977, 83; Leibniz *Theodicee*, p. 41.

world and thus has no means to grasp adaptation to unpredictable changes in the boundary conditions of the system.

Canguilhem's physico-theology of regulation

I will now go through some of the steps of Canguilhem's story about clocks and regulation in my own terms and with my own examples, in order to explicate the subtlety of Canguilhem's insight. I am going to talk about two kinds of clocks, two kinds of material system, two kinds of physico-theological argument and two different eighteenth century views of the organism.

Let's begin with the clock, the basic model of material systems in early modern science. There were always two kinds of clocks that served as metaphors: the precision clocks made by skilled craftsmen and the not so precise ones made by the town smith. We are used to viewing clocks as metaphors for precision and perfection, but this was not always the case. In *Love's Labours Lost,* for instance, Shakespeare writes:[4]

> What, I love, I sue, I seek a wife —
> A woman, that is like a German clock
> Still a-repairing, ever out of frame,
> And never going aright, being a watch,
> But being watch'd that it may still go right!

The clock could be a model not only of precision but also of waywardness and the need for supervision; and philosophers in the early modern period reflected on the differences between the two kinds of clocks. The early propagator of Christianized atomism Walter Charleton characterized the difference as follows:[5]

> Consider we, first that an exquisite Artist will make the movement of a Watch, indicating the minute of the hour, the hour of the day, the day of the week, month, year, together with the age of the Moon, and the time of the Seas reciprocation; and all this in so small a compass as to be decently worn in the pall of a ring; while a bungling Smith can hardly bring down the model of his grosser wheels and balance so low as freely to perform their motions in the hollow of a Tower. If so; well may we allow the finer fingers of that grand Exemplar to all Artificers, Nature …

Charleton is interested here in the difference in skill between the blacksmith who makes the tower clock, and the skilled watchmaker, who makes a tabletop device, because he wants to continue the series on up to the divine clockmaker – God. He does not give a name to the

[4] Act iii, Biron's final monologue

[5] Charleton 1654, p. 114

particular product of the "bungling smith," but later authors sometimes made a terminological distinction between accurate *watches* and inaccurate *clocks*: For instance in the public exchange of letters between G.W. Leibniz and Isaac Newton's spokesman, Samuel Clarke, Leibniz always compares the world system, the subject matter of science, to a watch (*montre*) and Clarke consistently compares it to a clock (*horloge*).[6] This distinction may be fairly *ad hoc* and restricted to the confines of the correspondence, but it is nonetheless quite revealing and has a basis in the historical development of clock technology.

In a late medieval town, when the mayor bought a clock for the town hall, he often hired the clockmaker to service and tend the clock. The clocks were not very dependable as timekeepers. Only in the later 16th century did they regularly acquire a minute hand; and only in the later 17th century did the time lost or gained each day sink under 7 minutes. Such clocks had to be reset almost every day using a sundial. A town clock needed not only someone to build it but also to tend it: the officer tending the clock was called the *governor*.

> The office of the governor of the clock was not a sinecure. Often the governor had to wind up the clock twice a day and he therefore had to climb twice a day to the top of the clock tower; he had to grease the machine very frequently, because the gears were not so smoothly and precisely constructed; finally he had to reset the hand (or the hands) of the clock almost every time it was wound up, because the clock lost or gained much time in the course of half a day.[7]

For our purposes the relevant point is that the clock in the clock tower not only had an escapement mechanism, a balance or beam that moved back and forth – later replaced by the more accurate pendulum – which regulated the motion of the wheels, but it also had a *governor*. The motions of the hands of the clock and of the automatic figures had two causes: first the mechanism of the clock guided by what came to be called the regulator and second the external governor. When Leibniz and Clarke quarrel about God's inspection and government of the world system which he created, the term *government* had a very clear meaning.

Newton and Clarke viewed the world as a real town clock, that does not run true and therefore occasionally needs the assistance of God in order to continue to track the mathematical laws of nature. The actual motion of the hands of a tower clock is for the most

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[6] Correspondence. Clarke preserves the distinction in his translation of Leibniz for the English edition. See Freudenthal 1984.

[7] E. Gélis, *L'Horlogerie ancienne,* Paris, 1949, p. 48.

part due to the inner mechanism but also partly determined by the intervention of the governor of the clock. Thus Leibniz and Clarke could agree that the world was something like a clock, but they disagreed on the nature of this watch/clock and on the duties of its governor. Newton, who thought to govern meant to intervene, is criticized as follows by Leibniz, who thought a king could also govern by wise educational measures:[8]

> 'Tis just as if one should say, that a king, who should originally have taken care to have his subjects so well educated, and should by his care, in providing for their subsistence, preserve them so well in their fitness for their several stations, and in their good affection towards him, as he should have no occasion ever to be amending any thing amongst them; would be only a nominal king.

In this debate – at least from Canguilhem's point of view – there is a clear favorite: Leibniz views the material universe as a conservative system, a physical *perpetuum mobile* in which no force is lost and none acquired. God governs the universe only in the sense that he made it so perfect that it runs without intervention or assistance. But there are different ways to view the Newtonian clockwork model: For instance, the actual motion of the world system, conceived as a blacksmith's clock, has two causes – one natural and the other supernatural (this is how Leibniz saw it). But there is another way to view the two causes of the clock's motion: one is normal and the other is corrective, one prearranged and the other adjusting (this is, as we saw above, how Pierre Bayle saw the problem). It is true that Bayle goes on to assume that the adjusting or correcting cause had to be mental, that is, somehow non-material or supernatural; but this is historically contingent. In Bayle's terms one can sensibly ask whether the adjusting cause with its representation of the goal state is necessarily supernatural or whether it is possibly natural: but one cannot, in Leibniz' terms, sensibly ask whether the supernatural cause with its representation of the goal state might not be a supernatural cause.

It was Leibniz's view of the governor of the clock that according to Canguilhem became a model for science in the 18th century. This far I think we can go with Canguilhem; but he goes a step farther and extends his conclusions from the conceptualization of the world system to the explanation of the organism – appealing to Leibniz's preformation theory of the organism. While it is plausible that a scientific view of the world demands that the frequent and arbitrary intervention by immaterial beings, who may add to or subtract from the mechanical energy of the system, has no place in physics, it is not so clear that subsystems

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[8] Leibniz-Clarke Correspondence, Leibniz' second letter.

like organisms must also be closed systems unable to adapt or to be adapted to their surroundings. And Leibniz' preformation theory of the organism had no difficulty distinguishing between a preformed species form or structure and environmentally induced fine tuning or adjustment. In the following I want to argue that the relation of questions of the *order* of the world system to those of the *organization* of organic subsystems was not so clear cut and determined as Canguilhem seems to believe – neither on the level of physico-theology nor on the level of biological argumentation about the nature of the organism.

Two kinds of material system: animal economy and the economy of nature

Canguilhem takes the Leibnizian closed system of the world as the model of all material systems, in particular for the economy of nature and for the animal economy; he can therefore treat it both as a prerequisite for and an impediment to the development of a concept of regulation. But the order of the world system and the organization of an individual organism are two quite different levels of explanation, and it is somewhat questionable whether, for instance, the economy of nature and the animal economy are so closely connected as Canguilhem assumes, such that the order of nature is automatically the model for the organization of an organism. I shall make some differentiations between the two levels – at first remaining within the framework of Canguilhem's account: what he calls the "physico-theology of regulation". David Hume, for instance, distinguishes between the organization of parts and the order of whole systems criticizing "the narrow views of a peasant, who makes his domestic economy the rule for the government of kingdoms."[9] One of Hume's basic problems in the *Dialogues on Natural Religion* is the disanalogy that he saw between the level of order of the system and that of the organization of the component parts. The order of the economic system of Britain is produced by market forces and needs no guidance or planning. But Hume cannot use this spontaneous order of the greater system as a model for the explanation of the organism because the elements of the larger spontaneous system are themselves planned: Although the order of the economy of great kingdoms occurs without design, the basic components (farms and firms) are teleologically structured – and this might be relevant for explaining the possibility of order. It is possible that the invisible hand of the marketplace guides only intentional actions.

[9] *Dialogues*, part 2, (Hume 1976).

Physico-theology or the "argument from design" is an empirical argument for the existence and properties of God, which became very popular in Britain in the second half of the 17th century. From the phenomenon of order or purposiveness (also called "design") in Creation we infer a divine plan or intention as its cause, thus arriving at a divine Designer or Creator who possesses the plan or intention. This kind of argument produced its own literary genre and was pursued by some of the best British scientists of the later 17th century: Walter Charleton, Robert Boyle, Isaac Newton, John Ray. The genre grew in popularity in the course of the 18th century especially in Germany, though after the first two generations its proponents were more likely to be practicing theologians than working scientists.

There were two different forms of design argument.[10] These are most easily characterized by the kind of example chosen: the *order* of the world system or the *organization* of a particular organism. However, the difference is not primarily one of the size of the objects discussed; rather the logic of the arguments is different: a two-step argument from order and a one-step argument from purpose. The different forms of the argument have different consequences and appeal to different kinds of supernatural intentional causality. The divine artisan always has two things in mind when he roles up his sleeves, and both of these were called *design*: (1) a *plan* or representation of what he is making (the *causa formalis*) and (2) a *purpose* that the thing made is to serve (the *causa finalis*). Robert Boyle, for instance, speaks not only about the "design" or plan of the world system, but also about "what God designed in setting matter a-moving."[11] Thus "design" can denote either the representation of the object to be produced or the representation of what the object is supposed to do.

The first form of the argument from design (the two-step argument from order) views the purposive structure of the world system (or any other appropriate material system) as underdetermined by the intrinsic properties and causal interactions of the parts and particles. It can only be considered to be fully determined if we first assume a plan and then infer a planner. However, the technical model for the *machina mundi*, was neither a steam engine nor a cotton gin but a clockwork: The world machine generates no power, performs no useful work, and produces no commodities. Thus the solar system, for instance, may be said to be designed, but it has no apparent purpose (other than perhaps the secondary purpose of conveying information about God's grandeur). Most authors of the time were content to

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[10] Hurlbutt 1965, 8–10; McLaughlin 2005.

[11] Boyle 1772, p. 396

exclude or just ignore the question of God's *intentions* here: in any case you can't read these intentions off the artifact. God's design of the world system will not necessarily tell you what his designs were in designing it.

The second form of the argument from design (the one-step argument from purpose) generally took the organization of organisms as its point of departure. Organisms, too, seem underdetermined by the intrinsic properties and causal interactions of their parts, but it would seem that at least some of these parts (organs or traits) are not just designed but also *designed to fulfill particular purposes*. Not only are eyes and muscles regular, ordered, and purposive like the solar system, but the purpose *for which* they were designed is obvious. Robert Boyle, for instance, although he was reticent about ascribing a final cause to the world system, insisted that the final causes of some things are clearly visible:[12]

> For there are some things in nature so curiously contrived, and so exquisitely fitted for certain operations and uses, that it seems little less than blindness in him, that acknowledges, with the Cartesians, a most wise Author of things, not to conclude, that … they were designed for this use.

Whereas the world system may have no specifiable final cause, but merely a formal cause in the design of the creator, many of the organs of organisms not only have formal causes but also seem to have an obvious final cause. Legs and eyes are not just designed, they are designed *for* walking and *for* seeing. They not only presuppose a *plan* (design), but also display the *purpose* (design) that that plan is to serve. It is thus understandable that proponents of the design argument might consider organic examples to be more convincing than celestial ones. Robert Boyle, for instance, after chiding the Cartesians for admitting a Creator but ignoring his intentions, which become obvious in anatomical dissections, emphasized the physico-theological importance of the level of *organization*:[13]

> … I cannot but think, that the situations of the coelestial bodies do not afford by far so clear and cogent arguments of the wisdom and design of the Author of the world, as do the bodies of animals and plants. And, for my part, I am apt to think, there is more of admirable contrivance in a man's muscles, than in (what we yet know of) the coelestial orbs; and that the eye of a fly is (at least as far as appears to us) a more curious piece of workmanship than the body of the sun.

Thus the two kinds of design argument differ not only in the *kinds* of phenomena used to argue for the existence or properties of God but also in their structure. The order of the

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[12] Boyle 1772, p. 397.

[13] Boyle 1772, .p. 403.

universe can be adduced as empirical *evidence* for design (planning). The eyes and legs of an animal, however, are adduced as *instances* of design (purpose).[14] Every argument from design contains a deductive part that infers a designer from design, but each of these two particular arguments establishes the existence of design itself by different means: (1) inductive or analogical evidence that supports the first premise of the inference in the one case and (2) direct intuition or perception of design in the second case. The first argument takes as its point of departure the empirical phenomenon of order, harmony, or purposiveness; the second argument starts from the 'empirical' phenomenon of design, intentionality, or purpose.

Thus even in the physico-theological realm preferred by Leibniz the organization of organisms had a status independent of that derived from the system of the world.

Organism theories

My second qualm about Canguilhem's thesis is that it was not 50 years after Clausius but 20 years before the Leibniz-Clarke debates that the organism was first conceived as something other than a well-made closed system. The thesis itself is not wrong here, but its substantiation must be a little more circumspect. There were alternatives to the form of mechanism (preformation) attached by Leibniz to his pre-established harmony. In fact a quite different conceptualization of the organism, which became important in the course of the 18th century, was actually already partially known to Leibniz (though unfortunately some of its key elements did not survive the translation into French). In 1694, only sixty years after the invention of the Cartesian animal machine, John Locke did more than just put a few epicycles on the clockwork organism. Locke developed a conceptualization of the organism as a self-reproducing system, that made regeneration or metabolism the key property of organic or organized systems. Self-reproducing systems play an important role in the political economy of the 19th century, but they were already central to some aspects of biology of the latter 18th century. The identity of the organism according to Locke consists in constantly replacing parts by assimilating new matter and conferring life upon the new material.

[14] The distinction between instance of and evidence for design is made by Hume in the *Dialogues*. See McLaughlin 2005.

The identity of an organism over time consists not in the identity of a substance but rather in the identity of a life process, the process of the continual renewal and regeneration of the parts of the system by the system itself:

> We must therefore consider wherein an Oak differs from a Mass of Matter, and that seems to me to be in this; that the one is only the Cohesion of Particles of Matter any how united, the other such a disposition of them as constitutes the parts of an Oak; and such an Organization of those parts, as is fit to receive, and distribute nourishment, so as to continue, and frame the Wood, Bark, and Leaves, etc. of an Oak, in which consists the vegetable Life. That being then one Plant, which has such an Organization of Parts in one coherent Body, partaking of one Common Life, it continues to be the same Plant, as long as it partakes of the same Life, though that Life be communicated to new Particles of Matter vitally united to the living Plant, in a like continued Organization, conformable to that sort of Plants.

Locke distinguishes here between two levels of organization, labeled "parts" and "particles". The parts are the result of the arrangement or "disposition" of particles); these parts (organs, tissue) in turn are arranged into an organism or an "organization". The life of this organization is characterized by the ability of the system to assimilate new particles and thus to renew ("continue and frame") its parts or to reproduce its point of departure. And this life of the system can be communicated to new particles when they are "vitally united" to its parts. An organism is conceptualized by Locke as something that remains identical to itself by continually reproducing itself and its parts. It would seem that the organism as a whole has a causal influence on the existence and properties of its own parts. Self-reproduction in the sense of self-repair is what characterizes an organism, whether animal or vegetable.

The process Locke describes here acquired the name "reproduction" in natural history and physiology in the course of the eighteenth century, where it came to be seen as the characteristic activity of an organism. Regulation of organic form and assimilation of external material become the basic characteristics of life in such a conception. Locke himself was interested merely in the question of identity and of how there can be individual entities that seem to be less like substances than like processes, but he has nothing at all to say about the micromechanics of regeneration and how the same organism and species of organism is reproduced. What we can take from Locke is the demand for an explanation of these phenomena but no hint as to how to provide it.

The prime candidate for an exception to Canguilhem's rule, if one is looking for organic regulators in the 18th century, is Georges-Louis Leclerc de Buffon, in the middle of the 18th century. In the second volume of his *Histoire naturelle* (1749) he articulated a concept of reproduction (i.e. regeneration) that was widely adhered to in the 18th century. It is primarily through Buffon that the Lockean conceptualization of the organism acquires a wide following. Whereas Locke on one occasion almost as an afterthought characterizes the organism as having the ability to assimilate anorganic particles to its living process, Buffon in many of his chapters talks about assimilation on every page. As Buffon explains in the first chapter of the natural history of animals, the paradigmatic phenomenon of life is regeneration – a phenomenon widely studied in the 1740s. This is what he sees as the basic characteristic of life forms; and he calls it "reproduction." Buffon characterizes regeneration as the most general form of reproduction and then goes on to distinguish various more specific forms of reproduction: nutrition, growth, and generation. With this he has not only characterized the subject matter of what came to be called 'biology' as a system that reproduces itself, he has also *extended* the meaning of the term 'reproduction' to include not just regeneration but also the phenomena of nutrition, growth, and propagation. All these processes involving the assimilation of external matter to the organic system were explained in terms of the same somewhat occult mechanism, the "moule intérieur." This internal mould or model enables the organism to reproduce itself in regeneration, nutrition, growth and generation. In a way it seems to be a power or faculty of the organism that enables it to regulate organic form – that is to do all the things that Locke took to belong to the identity conditions of an organism. In Buffon's early works that first introduce the notion of the *moule* it seems very much like a materialistic version of a Newtonian governor of the organic clock.[15] Nonetheless, however the *moule intérieur* may originally have been intended by Buffon, in the later development of his thought it did not become an internal material representation of the species or individual form, which might govern or regulate reproduction – regeneration, growth and propagation. Rather it was conceived as the necessary *result* of universal attractive and repulsive forces operating under contingent climatic and geological conditions. The *moule intérieur* is in the

[15] The moule is first introduced as a specific organic force and compared with the force of gravity. Buffon *Histoire naturelle,* vol. 2, 34–36 and Vol. 4, 215–216.

end less a regulator than simply a slot in a periodic table of organic forms. Even though the organism was not necessarily always conceived as a closed system, as Canguilhem suggested, nonetheless the ability of the organic system to influence the properties of its parts was in effect treated as a holistic causal process and not as the effect of a special trait or function that could in some way represent a goal state and regulate the actions of the system.

Kant and Lotze

The notion of regulation arises not in connection with the production or reproduction of organic form but in connection with the stabilization of physiological function. And the regulator arrives not in the role of the governor of the organic clock, but so to speak as his nemesis. Regulation is introduced not to correct influences from outside an otherwise closed system but rather to correct spontaneous perturbances from within the system.

Immanuel Kant took Buffon's notion of the organism as the point of departure for his concept of *Naturzweck* or "natural purpose". According to Kant a natural purpose is characterized by the three forms of reproduction articulated by Buffon: An organism (1) "produces itself with regard to its species" by generating another individual of the same species; (2) an organism "produces itself as an individual" by growth; and (3) each part of an organism "produces itself in as much as there is a mutual dependence between the preservation of one part and that of the others."[16] However, Kant's thoughts on the mechanisms of the self-reproduction of organic systems remain within the framework of invisible hand explanations and the assimilation of new parts to an existing form. Simple reproduction (regeneration), expanded reproduction (growth) and generic reproduction (propagation) determine those aspects of biology that move us to make use of teleological vocabulary. The problem that they create for us is, however, not simply the underdetermination of the origin of the organic system out of its component parts, but rather the apparent holism of the causal relations in the workings of the system. Although in explaining the organism Kant replaces the apparent causal influence of the whole organism on the properties of its own parts with the (merely regulative) assumption of the causal influence of a representation of the whole on the production of those parts, he nonetheless insists on phenomenal holism in describing the organism. In fact he characterizes the science of biology

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[16] Kant 2000, §§64–65. See McLaughlin 1990, Chap. 1.

by a fundamental contradiction between an holistic ideal of description and a reductionistic ideal of explanation.[17]

Although Kant places the question of the reproduction of the system in the center of consideration, he gives us no hint of what mechanisms or structures must be available to an organism if it is to maintain its status quo in the face of external changes. One reason for this is of course that Kant was not developing a biological theory of the organism but rather a philosophical analysis of the peculiarities of our attempts to explain organisms. But there is also a second reason: Kant still conceives of the organism as an equilibrium system. Even a dynamic equilibrium is still an equilibrium; and disturbances of equilibrium can be seen to be compensated locally and may thus basically provide their own solution. Local deviations are compensated locally. The environment acts, the organism reacts, and equilibrium is restored. A beam balance suspended from above its center of gravity is able to compensate an externally caused disequilibrium by internal redistribution of mass to the side that goes up.[18] As long as the organism is viewed as an equilibrium system, it needs no regulator: compensation is automatic.

Kant's approach to the organism has no need for a regulator, but – as Canguilhem suggests without going into any detail – the concept of regulation does indeed grow out of developments within Kant's school of thought. Canguilhem locates the germ of what he calls the "conceptual advance" of German physiology in Hermann Lotze's 1842 article on *Lebenskraft* (life force), where Lotze attributed the capacity of regulation to an animal's central nervous system, which can counter perturbations or disturbances (*Störungen*) of a particular kind that Kant had not dealt with in analyzing the organism on the model of metabolism or vegetation. Like Locke Kant viewed the organism primarily as a vegetative system. Lotze, on the other hand, is more interested in perception and voluntary motion. The animal's capacity for voluntary motion or action is seen to be the source of a kind of *internal* disturbance that cannot be compensated for locally. Because an animal is capable of spontaneous or arbitrary change of its internal states, it needs the ability to anticipate, react upon, and compensate for these irregular changes.

> The actual goal of animal life is without doubt sensation and autonomous motion … But all influences of the mind, all impulses of the will on the body occur without the

[17] Kant 2000, §§69–70. See McLaughlin 1990, Chap. 3.

[18] Known since Aristotle. See Aristotle 1930(*Mechanical Problems*) pp. 348–349 (850a2–15).

slightest periodic regularity … This is the most important point of all general physiology. The living body viewed as a mechanism is distinguished from all other mechanisms by the fact that is contains a principle of immanent disturbances [Störungen] that obey no mathematical law in their strength and recurrence. This lawlessness is not accidental to [animal life] but rather belongs to its essence.[19]

An organism is too complex for local solutions to disturbances, and the disturbances are not just contingent occasional events. An animal's physiology cannot just wait for a disturbance to occur and then initiate counteractions; it must have its own "regulating motions" into which the self-produced spontaneous disturbances can be integrated.

> An easy source of regulation on the other hand is offered by the continual spontaneous change of the acting masses, in whose motion the motions of the disturbances disappear.

Lotze then appeals to a central concept of medical vitalism of the French Enlightenment, the notion of crisis, viewing regulation as a "mechanism of crises".[20] Regulation does not compensate external disturbances but rather internal disturbances, and these occur only in animals: "Plants, as far as we know, have no immanent principle of irregular disturbances." The key to regulation is not to be found in the study of organic form, which occupied Kant, but in the concept of life which he relegated to psychology and morals.

Canguilhem's dialectical and teleological prehistory of regulation ends with Lotze. The Leibnizian deterministic closed system that needs no external mental regulator because it is perfectly predetermined becomes a self-repairing, metabolizing system with a regulating central nervous system that compensates not for external influence but for internal spontaneity.

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[19] Hermann Lotze, "Lebenskraft" in Wagner 1842.

[20] Lotze 1842, p. il, l. See Bordeu "Crise".

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