

# UC Berkeley

## UC Berkeley Previously Published Works

### Title

"Unity, Plasticity, Catastrophe: Order and Pathology in the Cybernetic Era"

### Permalink

<https://escholarship.org/uc/item/6c6907cd>

### ISBN

978-3-11-031249-2

### Author

Bates, David W

### Publication Date

2014-12-31

### DOI

10.1515/9783110312584.32

### Copyright Information

This work is made available under the terms of a Creative Commons Attribution-NonCommercial-NoDerivatives License, available at <https://creativecommons.org/licenses/by-nc-nd/4.0/>

Peer reviewed

David W. Bates

## “Unity, Plasticity, Catastrophe: Order and Pathology in the Cybernetic Era”

**Abstract:** Catastrophe is usually seen as something that befalls the organized, adaptive system from the outside, threatening its future existence. While some cyberneticians explicitly pathologized catastrophe, the French mathematician René Thom in the 1970s redefined catastrophe as a sudden unexpected turn that is generated from within the complex system. While “catastrophe theory” had a limited impact, unlike the broader notions of chaos theory and complexity theory that are now more familiar, I use this idea to turn back to the earlier twentieth century, to locate the ways in which catastrophic events were understood to be essential to the functioning of a complex unity. I trace in Kurt Goldstein’s *The Organism* (1934) the idea of “weak catastrophe” and its relation to Georges Canguilhem’s ideas of pathology and norm in order to demonstrate that in fact, cybernetic-era theorists of the automatic machine were interested in developing what we might call a “pathology of the machine” that was influenced by organismic ideas of internal catastrophe.

Cybernetics was centered on a fundamental analogy between organism and machine. As W. Ross Ashby asserted: “I shall consider the organism ... as a mechanism which faces a hostile and difficult world and has as its fundamental task keeping itself alive.”<sup>1</sup> Because cybernetics intentionally blurred the boundaries between humans, animals, and sophisticated technological objects, it has often been accused of reducing living beings to the mere interplay of mechanisms. However, cybernetics always wanted to infuse machinic beings with the essence of life—purpose, adaptive responsiveness, learning, and so on—while opening up new insights by comparing organisms to some of the most innovative technologies of the era, namely servo-mechanisms, scanning instruments, electronic communication systems, analog computers, and, perhaps most notably, the new high-speed digital calculators that were emerging from secrecy in the postwar era. Cybernetics drew together advanced automatic machines and organisms on the basis of their shared capacity to respond flexibly to a changing environment—

---

<sup>1</sup> W. Ross Ashby, “Homeostasis,” in Heinz von Foerster, ed., *Cybernetics: Circular Causal and Feedback Mechanisms in Biological and Social Systems* (New York: Josiah Macy, Jr. Foundation, 1952), 73.

whether the external world or that inner domain the physiologist Claude Bernard called the “internal milieu.”

Incisive critics would question the analogy between machine and organism not so much because it was inherently reductionist, but instead because the infusion of vital “purpose” into technological objects distorted the essential nature of organismic life. As Georges Canguilhem argued in his 1947 lecture “Machine and Organism,” machines of course have ends that govern their design, however unlike an organism, the teleological orientation of a machine is always given to it from the outside. This purpose is not *intrinsic* to the machine’s own organization. A machine governed by externally given ends is always a slave to its given order: the machine must affirm “the rational norms of identity, consistency, and predictability.”<sup>2</sup> In contrast, the organism is organized by the goal of its own survival, and it was therefore capable, Canguilhem observed, of genuine improvisation in the event of crisis or even internal failures. Without a completely fixed structure restricting its potentiality, the organism was able to find new paths to success. The essential unity of the organism was maintained even in the event of catastrophic error because its organs were fundamentally “polyvalent,” and not limited to previously defined, specific deterministic functions, as the parts of a machine were. The organism could be saved by what are called here *pathological* responses. There was, Canguilhem declared, no such machine pathology, no machine “monsters,” because the machine could never *create* for itself new norms, new forms of existence. If life, as Canguilhem said, is “an attempt from all directions,” the machine is defined by a rigid singularity of purpose.

And yet, cyberneticists were intensely interested in pathological breakdowns. In his 1948 classic *Cybernetics: Or, Communication and Control in the Animal and Machine*, Norbert Wiener claimed that certain psychological instabilities had rather precise technical analogues: “Pathological processes of a somewhat similar nature are not unknown in the case of mechanical or electrical computing machines.”<sup>3</sup> In a sense, cybernetics as a transdisciplinary science had its very origin in the insight that pathological physiological performances could be mapped, structurally, onto technological failures with mathematically identical characteristics. While investigating the behavior of feedback systems in steering mechanisms, Wiener and his colleague Julian Bigelow discovered that excessive compensation could lead to increasing oscillations that eventually became uncontrollable, leading to great disorder and a failure to find equilib-

---

<sup>2</sup> George Canguilhem, “Machine and Organism,” in *Knowledge of Life*, tr. Stefanos Geroulanos and Daniela Ginsburg (New York: Fordham University Press, 2008), 90.

<sup>3</sup> Norbert Wiener, *Cybernetics: Or, Communication and Control in the Animal and Machine* (Cambridge, Mass.: MIT Press, 1948), 172.

rium. When they asked the medical researcher Arturo Rosenblueth if there were any similar pathologies known in human physiology, he immediately answered that there was indeed an *exact* neurological parallel—voluntary motion could degenerate into the same state of oscillation when the cerebellum was injured in specific ways.<sup>4</sup> Mathematical analysis of other forms of physiological disorder (for example, cardiac arrhythmias) would soon reveal a number of these pathological parallels.

This early interest in pathology at the very foundation of cybernetics is hardly surprising, given the fact that so many of its original practitioners were medical professionals with interests in both physical and mental illnesses. Warren McCulloch was a neurologist who worked in psychiatric clinics, Ashby was trained as a psychiatrist and practiced while developing his research projects in homeostatic stability, and Rosenblueth was a cardiologist. In an important sense cybernetics (especially its later incarnations) was a highly medicalized discipline, aimed at identifying the origins of instability in large, complex systems, diagnosing the sources of breakdown so as to eliminate them and recover unity and stability.

Cybernetics offers the hope of providing effective methods for the study, and control, of systems that are intrinsically very complex.... In this way it offers the hope of providing the essential methods by which to attack the ills—psychological, social, economic—which at present are defeating us by their intrinsic complexity.<sup>5</sup>

Instability appears in this framework as a “self-generating catastrophe” that leads to the collapse and death of the system if it is untreated.<sup>6</sup>

And yet, despite this extensive interest in failure, pathology, and catastrophic breakdowns, cybernetics might still be accused of greatly simplifying the problem of disorder and crisis, pathology and health. It was one thing to explain some forms of adaptive response in terms of automatic technologies, but it was quite another to explain the radical originality and inventiveness that one repeatedly encountered in the living world. This capacity was not reducible to any specific mechanism or logic: as the noted polymath Michael Polanyi observed, it flowed from an “active center operating unspecifiably in all animals.”<sup>7</sup> What thinkers such as Polanyi (and Canguilhem) were trying to suggest was that organisms

---

<sup>4</sup> *Ibid.*, 15.

<sup>5</sup> W. Ross Ashby, *An Introduction to Cybernetics* (London: Chapman and Hall, 1961), 5–6.

<sup>6</sup> W. Ross Ashby and Mark R. Gardner, “Connectance of large dynamic (cybernetic) systems: critical values for stability,” *Nature* 228 (1970): 784. On catastrophe, see Wiener, *Cybernetics*, 113 and Norbert Wiener, *The Human Use of Human Beings* (Boston: Houghton Mifflin, 1950), 49.

<sup>7</sup> Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1958), 336.

were not just able to *respond* to changing conditions; they were also able to enter wholly new states of being, with new forms of order, and new potentials, when they were confronted with extreme challenges, drastic injury, or internal failures of communication. A pathological state was not simply the negative inverse of a normal function, as cybernetics at times seemed to imply, but rather an opportunity for the invention of radically new behavior.

The historical question is whether cybernetics did in fact understand and model this potentially productive relationship between genuinely pathological conditions and the radical novelty that was the reorganization of the organism. At stake is the legacy of cybernetics, which has reemerged as a question in the twenty-first century with the rise of the global information society, the beginning of new forms of human-computer symbiosis, and the acute conflicts over remote killing technologies. The cybernetic moment, it has been said, initiated a revolutionary transformation in the world after the Second World War, one that accomplished a rationalization and systematization of the economic and the political spheres, leaving the individual subjected to the teleological drive of these autonomous systems.<sup>8</sup> But what did cybernetics really stand for?

Peter Galison, for one, has forcefully argued that cybernetics, born in the midst of war and developed during the height of the Cold War, was at its heart a “Manichean” science, obsessed that is with maintaining order against the constant active threat of *disorder*. Cybernetics could hardly embrace a link between abnormality and creativity when it pathologized disorder as the ultimate enemy.<sup>9</sup> Andrew Pickering’s recent sophisticated analysis of cybernetic science affirms Galison’s claim. For Pickering, the pathological state was, for the cyberneticists, just another way of looking at the normal, ordered state—“in medicine the normal and the pathological are two sides of the same coin.” Cybernetic machines and organisms were defined by their inherent structures and both were kept “alive” by the processes that maintained homeostatic equilibrium. Breakdown might reveal something of the normative order, however pathology was never conceptualized independently.<sup>10</sup>

In practice, however, it is somewhat difficult to maintain a clear boundary between order and disorder in cybernetic discourse. The cybernetic analogy between machine and organism was being forged at a moment when biological thought had largely transcended the old opposition between mechanists and

---

<sup>8</sup> “L’hypothèse cybernétique,” *Tiqqun* 2 (2001): 40–83.

<sup>9</sup> Peter Galison, “Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision,” *Critical Inquiry* 21 (1994): 228–266.

<sup>10</sup> Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2010), 132.

vitalists. The key challenge in this period was to explicate organismic unity—first, to ascertain how an organism developed into a coherent formal structure from embryonic cells; and second, to identify how organisms could maintain those forms despite ever-changing conditions and a dynamic metabolic process. Unity of living beings was important because it linked transformation and destruction with continuity and stability. Unity was predicated on the inherent *plasticity* of organismic organizations, their capacity to take on new forms at key turning points, even catastrophic ones. To understand the cybernetic effort to create a science that bridged organismic and machine beings we must pay close attention to the way unity and flexibility were conceptualized in cybernetics. As we will see, illness, pathology, breakdown, all were vitally important questions for biological thinkers in this period. These states were not simply ascribed to “disorderly” Manichean forces attacking order, but instead were understood to be potentially productive crisis conditions that revealed the essential transformative potential that made the ongoing life of an organism possible in the first place. This complex relationship between systematic, technologized order and the risky opportunities of crisis seems particularly relevant to our own age. Tracing out this occluded intellectual trajectory in cybernetics will offer a critical perspective on the legacy of post-war technology and its conceptual underpinning.

## From Cybernetics to Catastrophe Theory

One of the central claims of cybernetics was that a process of “negative feedback” drove the homeostatic life of adaptive beings. The cybernetic entity (whether living or machinic) first sensed its environment, alongside its own “state” of being in that environment, then compared that information with its own “goal” states embedded somewhere within this being, before effecting certain actions that would bring the entity’s state in line with this ideal goal.<sup>11</sup> To be sure, from one perspective, this cybernetic concept of negative feedback could be read as privileging a predetermined, precisely defined “order” that is imposed on these active beings. Yet from another angle one might emphasize the importance of *deviation* in the functioning of any cybernetic being—this being has an existential relationship with error. It is not disorder or even error itself that threatens the cybernetics being, but instead an inability to *respond* appropriately to an ongoing state of disorder. Any dynamic adaptive being is in a condition of ceaselessly devi-

---

<sup>11</sup> See the iconic essay: Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow, “Behavior, Purpose, and Teleology,” *Philosophy of Science* 10 (1943): 18–24.

ating from its own formal ends. From this perspective, radical failure (even death) is not so opposed to normal homeostatic operation because the catastrophic turn is in fact continuous with normal efforts to maintain the health of the being in its essential errancy. That is, the boundary between normality (health) and catastrophic failure (illness, death) is defined by the limits of the being’s own errancy, and not at all by the mere presence of deviation. The great achievement of cybernetics was the demonstration that these limits to error were not at all *arbitrary*. As Wiener remarked, “the conditions under which life, especially healthy life, can continue in the higher animals, are quite narrow.”<sup>12</sup> As Ashby explained, in an essay on homeostasis, “if the organism is to stay alive, a comparatively small number of essential variables must be kept within physiologic limits,” and this applied to the “life” of technological entities as well. Their survival as unified systems depended on keeping error within proper limits.<sup>13</sup>

The crucial arbiter of the limit of error was therefore the survival of the being as a whole. As Ashby would make clear, the relationship between catastrophe and normal error or deviation is governed by the threat to the fundamental *unity* of the being in question. He gives the example of a mouse trying to evade a cat. The mouse can be in various “states” or postures, and certain values may even change drastically (it may lose an ear, for example), yet still, the mouse will survive. “On the other hand, if the mouse changes to the state in which it is in four separated pieces, or has lost its head, or has become a solution of amino-acids circulating in the cat’s blood then we do not consider its arrival at one of these states as corresponding to ‘survival.’”<sup>14</sup> The unity of the being is the ultimate mark of survival. Unity amounts to the capacity to maintain some stable form even while experiencing drastic—perhaps even violent—transitional states.

There is no fundamental distinction between order and disorder here. The definition of a formal unity determined the parameters of survival within the unified system. Both in biology and cybernetics, the unity of the being is what identifies the structural relations and variables that had to be maintained against the threat of extinction. To rethink cybernetics from the perspective of the organism, we must zero in on the nature of this unity and its status. How could a breakdown, even a catastrophic failure, become the opportunity for an unprecedented reorganization? How could a functionally determinate machine ever acquire this organismic capacity?

In works such as *Design for a Brain* and *Introduction to Cybernetics*, Ashby introduced a formal way of thinking about the behavior of complex, adaptive

---

<sup>12</sup> Wiener, *Cybernetics*, 135.

<sup>13</sup> Ashby, “Homeostasis,” 73.

<sup>14</sup> Ashby, *Introduction*, 197.

systems. He noted that if we take the basic states of a system as variables—capable of change that is—then we could graphically plot them mathematically as vectors. In turn, variables could be integrated in a multi-dimensional “phase space” as a way of representing, with one single vector, what Ashby called a *line of behavior*.<sup>15</sup> Ashby’s innovation was to think of the cybernetic being as a set of potential states, states that could be visually represented in phase space as vectors whose functions were limited by boundary values. Ashby showed how the interpretation of these lines of behavior as mathematical functions opened up a new way of understanding complex systems. Mathematical analysis of physical systems was normally limited to continuous systems of a linear nature. A mathematical approach to biology, in contrast, would have to accommodate non-linear and discontinuous features of organismic behavior.<sup>16</sup> Ashby gave an example: any sudden transformation of activity might be governed by a so-called “step function,” where the value of the function changes abruptly when reaching a certain point. This mathematical representation of behavior would suggest that seemingly unpredictable events or even new, spontaneous behaviors in the life of a being might well be governed by some hidden, dynamical process modeled by a step function.<sup>17</sup> The main insight was the idea that transformations of the system’s behavior were strictly analogous to mathematical transformations of the operands.<sup>18</sup> For Ashby, this made it possible for cybernetics to study the innate “determinateness” of a system formally, in its own mathematical terms that is, and to ignore effectively the actual “material substance” of the system.<sup>19</sup>

Ashby’s graphical approach to cybernetic systems and self-governing stability had a precedent, in the work of one of the most prominent biologists of this period, C. H. Waddington. In his 1940 book on the role of genes in embryological development (morphogenesis), Waddington introduced the “epigenetic landscape,” a three dimensional virtual representation of the developmental pathways of an organism.<sup>20</sup> Imagining a plateau cut through with a series of valleys and ridges, Waddington explained that a ball rolled into this landscape would first bounce between different valley formations before settling into a specific one, where it would then roll up and down the sides, perhaps even exiting the valley altogether if it was shallow enough. But as the ball continued, it would become

---

<sup>15</sup> *Ibid.*, 25, 31.

<sup>16</sup> *Ibid.*, 27.

<sup>17</sup> W. Ross Ashby, *Design for a Brain*, 2nd. ed. (New York: John Wiley and Sons, 1960), 95.

<sup>18</sup> Ashby, *Introduction*, 37.

<sup>19</sup> *Ibid.*, 24.

<sup>20</sup> C. H. Waddington, *Organisers and Genes* (Cambridge: Cambridge University Press, 1940), 91. The frontispiece depicts the epigenetic landscape.



more and more confined in its path as the valley walls became steeper and the path narrowed. The point of this virtual exercise was to account for the way early embryonic cells, which lacked organizational order at the start, became increasingly specialized and distinct from one another as they divided. This representative landscape would also suggest why the path of the ball, despite perturbations from outside, would continue to its destination. This was an important issue, as Hans Driesch had famously shown in the last century that sea urchin embryos would continue to develop normally even when they were partially destroyed, split in half, or otherwise violently manipulated. The epigenetic landscape therefore was in part a description of what Waddington called the “canalization” of cell development, but also an attempt to represent (at least qualitatively) the *forces* that intervened to shape the paths of that development. The goal was to understand how the embryo itself was capable of developing this kind of internal organization, without invoking some mysterious vitalist force, as Driesch had done with his concept of entelechy. Modern biologists were interested in the ways that the “potential” of the organism, that is, its own teleological process of canalization, could be understood in strictly *biological* or physio-chemical terms.<sup>21</sup>

In his later, influential book *The Strategy of the Genes*, Waddington acknowledged Ashby’s innovative attempt to mathematically represent the behavior of a complex system in geometrical form. In a chapter entitled “The Cybernetics of Development,” Waddington approved Ashby’s effort to “map” the states of a system, but disagreed with his claim that increasing the number of variables in a system would lead to a greater probability of instability.<sup>22</sup> Waddington argues that this complexity in fact could have a positive function, in that it allowed for a greater number of possible states that the organism could use to find order. Like Ashby, Waddington emphasized the non-linear nature of biological systems, which could suddenly shift into new states, both as they grew and differentiated themselves in development and as they sought stability in their mature phases. Waddington rejected Ashby’s use of step functions as too simplistic, returning instead to his earlier notion of the epigenetic landscape, which was in essence a *qualitative* (rather than strictly quantitative) representation of the behavior of an organism as its cells found paths (his term for these paths was “chreods”) leading from relative disorder to increasing order and organization. The landscape was a neutral metaphor that eschewed both vitalist and mechanist assumptions. It was a description of a process with its own internal dynamic.

---

<sup>21</sup> See, for example, Alan Turing’s late work on the mathematics of chemical diffusions in morphogenesis.

<sup>22</sup> C. H. Waddington, *The Strategy of the Genes: A Discussion of Some Aspects of Theoretical Biology* (London: George Allen and Unwin, 1957), ch. 2.

Waddington's insight would become the foundation of a more precise science of the complex. Later in his career, Waddington became very interested in the work of the French mathematician René Thom, who in the 1960s was developing a theoretical and methodological technique that would become known as "catastrophe theory."<sup>23</sup> Thom introduced his notion of "structural stability" in the context of developmental biology and homeostatic constancy at an interdisciplinary gathering organized by Waddington to generate new theoretical models in biology.<sup>24</sup> Thom explicitly rejected cybernetic approaches to stability that drew on the concept of feedback. "Like all notions taken from human technology, the notion of feedback cannot properly be invoked to explain the stability of biological processes.... The only notion which is mathematically and mechanically acceptable is that of 'structural stability.'"<sup>25</sup> His point was that stability had to be inherent in the form itself, understood in terms of its formal organization that is, and not the substrate of the formal order (whether biological or inorganic). Central to Thom's thinking was the idea that the response of the living being to some "shock" should not be conceived as an actual feedback mechanism of some kind but instead as a function of the mathematical organization *inherent in the formal order of the being* itself.<sup>26</sup> He redefined the organism as a geometric object whose transformations could be mapped (as Ashby had argued earlier) in a multi-dimensional phase space.<sup>27</sup> Thom drew here on the groundbreaking work of D'Arcy Thompson, whose *On Growth and Form* (1917) not only probed the physical underpinnings of patterns in nature, but also suggested that the shapes of organic forms may be related to one another geometrically.<sup>28</sup> However, Thom's own topological approach was novel. He argued that changes of the organism (as it developed as an embryo, or as it maintained itself in changing environmental conditions) should be understood as *topological transformations* (that is, bending and twisting) of a multi-dimensional geometrical object. It was this object that

---

**23** For an overview of the theory, its genesis and reception see Alexander Woodcock and Monte Davis, *Catastrophe Theory* (New York: Dutton, 1978).

**24** The papers were published in C. H. Waddington, ed., *Towards a Theoretical Biology* (Edinburgh: Edinburgh University Press, 1968).

**25** René Thom, comments on C. H. Waddington, "The Basic Ideas of Biology," in *ibid.*, 33.

**26** René Thom, "Théorie dynamique de la morphogenèse," *ibid.*, 162–3.

**27** René Thom, *Structural Stability and Morphogenesis: An Outline of a General Theory of Models*, tr. D.H. Fowler (Reading, Mass.: W. A. Benjamin, 1975), 151–2.

**28** D'Arcy Thompson, *On Growth of Form* (Cambridge: Cambridge University Press, 1917). Thom explains the moment of insight that initiated catastrophe theory occurring while he was observing, in a natural history museum, a representation of the embryonic development of the frog and saw it as a kind of continuous transformation of a single entity. See René Thom, *Paraboles et catastrophes: Entretiens sur les mathématiques, la science, et la philosophie* (Paris: Flammarion, 1983), 45.

would be represented graphically, not the numerical values of independent variables. What the technique may have lost in precise predictive power it gained by enabling an understanding of the trajectory of a complex system (such as an organism) as a *unified* set of values.

Thom’s major mathematical contribution was the insight that complex systems with several controlling variables would inevitably undergo radical and sudden transformations. These were called “catastrophes,” mathematical singularities. And Thom further demonstrated that if the number of control values were limited, these systems would only exhibit seven kinds of catastrophe, which he called the “elementary catastrophes”—they ranged from the simplest folds and cusps to complex three-dimensional “slices” of higher dimensional objects. The central claim was that the *discontinuity* marked by the catastrophe was nonetheless still a topological transformation of the original form, continuous with it mathematically even as the system exhibited dramatic non-linear change when perceived from within a particular phase space. Thom therefore believed he had solved the vexing problem of morphogenesis, the origin of biological form. Discontinuities (for example, differentiations of the embryonic cells into specific organs) were *mathematical* catastrophes and not radically new *material* phases. Thus they did not have to be explained as the product of some specific mechanism or ethereal vitalistic force.<sup>29</sup> The mathematical form was itself *intrinsically stable* through the catastrophes, and moreover, this form could withstand a certain amount of deformation imposed from the outside.<sup>30</sup>

Like Canguilhem, Thom resisted anthropomorphic concepts of biological order derived from the realm of technology. However, Thom would admit:

This is not to say that comparisons of the life dynamic with some other manifestations of human technology (automata, electronic computers, etc.) are pointless, but rather that these comparisons have validity only for partial mechanisms, fully developed with their complete functional activity, and they can never be applied to the global living structure or to its epigenesis and physiological maturation.<sup>31</sup>

Thom rarely cited other thinkers in his work, but here he referred explicitly to Jacob von Uexküll’s influential work in theoretical biology. Von Uexküll (who died in 1944) emphasized the idea that living organisms were not systems made up of various functional parts, but instead subjects capable of unified experience.

---

<sup>29</sup> Thom, *Structural Stability*, 157–8.

<sup>30</sup> *Ibid.*, 209. Here we can see a connection between theoretical biology and the investigation of self-organizing systems in the inorganic world, systems that Ilya Prigogine would later describe as “dissipative structures.”

<sup>31</sup> Thom, *Structural Stability*, 200–201.

While he echoed later cybernetic concepts of homeostasis and informational processing, von Uexküll insisted that the organs of biological beings come into existence to serve that unified subject as it navigates its environment, the *Umwelt*.<sup>32</sup> Thom picked up on this idea when he claimed that machines must receive their order all at once—the parts must be created contemporaneously then fitted together in a broader organization that comes, as Canguilhem noted, from outside its own organization. Organisms, in contrast, *develop* their internal organs; functions emerge as a product of the original unity of the being differentiating itself. Life is therefore a process of *individuation*. For Thom, the specific configurations of the organismic order make sense only within the encompassing unity of being. The machine's unity is artificially imposed on the parts, and for this reason there is no active force of unity, as there is in the organism.

The importance of this contrast between machinic order and organismic unity for Thom is evident when he came to address pathology and the breakdown of order. Unlike a mechanical system, whose parts can only play a predetermined role in the organization, the organism is capable of actively *reorganizing* its components in response to perturbations. However, there is a limit. As Thom explained, if the “shock” to the life field is too great, it will not be compensated for and the organism will “enter a zone of qualitative indeterminacy.” In this zone, greater activity will take place and “larger variations in the global physiological state” will be allowed. The organs that are not affected by the perturbation will become extra-excited. Healing will occur if this extra activity stabilizes the affected (sick) organ. Interestingly, Thom notes that the healed state will *not* be continuous with the normal state prior to the injury or illness, since the system has moved into a wholly new organization of activity due to the shock. The pathological state here is understood to be a transitional phase, leading to a new form of the being (a new topology) with its own stabilized order. The definition of life is tied, as it was with Ashby, to this continuous articulation of a unified being, a stable formal structure whose dissolution marks the end of that life. What is important about Thom's catastrophe theory is that it conceptualizes this life as a set of parameters with an internal organizational relationship. It is entirely agnostic as to the metaphysical ground of this biological unity—even as it describes organismic development and dynamic homeostatic processes as a *function* of that formal unity. As with cybernetics, then, a perturbation of the system is overcome in normal operation by a “correction” of the local deviation, a deviation defined by the formal

---

<sup>32</sup> *Ibid.*, 200. The epigraph to this chapter is a passage from von Uexküll's *Bedeutungslehre*, where he contrasts the centripetal (*zentripetal*) development of mechanisms with the centrifugal formations in the organic world. Thom also cited Kurt Goldstein as another important influence on his theory. The emphasis on holistic unity may be traced to his work as well, as we shall see.

organization. However, as Thom revealed, a *pathological* state is one in which a mere local correction gives way to a *global* reorganization of the system.<sup>33</sup>

This relationship between normal “catastrophes” and more profound transformations in crisis that potentially undermined the structural analogy between organismic life and the engineered behavior of advanced machines because there was no obvious technological counterpart to reorganization. Yet cybernetics was in fact already closely tied to this catastrophic discourse of the organism.

## Shock and the Plasticity of the Organism

We must remember that the theory of homeostasis, one of the central concepts of cybernetics, was intimately linked to these notions of crisis and catastrophic shock. The concept was first developed in the 1920s by the American physiologist Walter Cannon, who, as a collaborator of Rosenblueth later in his career, directly introduced the idea to cybernetics. Cannon was intensely interested in the dynamic quality of all forms of organismic stability. Although we can trace the idea of bodily self-regulation to Claude Bernard’s influential study of the “interior milieu,” Bernard’s theory explicitly asserted the relative independence of the internal regulatory mechanisms from the external environment and its effects on the organism.<sup>34</sup> In contrast, Cannon’s notion of homeostatic regulation was a product of both his clinical experience of shock in the Great War and his interest in what might be called “emergency states” of the body. In an early work from 1915, Cannon explored the endocrine system, which was capable in crisis situations of putting the body automatically into a heightened state of action, capable of either “flight or fight,” as Cannon famously phrased it.<sup>35</sup> Cannon would go on to study the problem of physiological “shock” through examinations of numerous soldier-patients suffering extreme injuries, and also through animal experiments that induced shock artificially through massive bloodletting and the like.<sup>36</sup> Can-

---

**33** Of course, it is also possible that the pathological condition will lead to instability and eventual death, or what Thom calls a “generalized catastrophe,” distinct from the many specific catastrophic turns that the system will always undergo. As Thom puts it: “our everyday life, on the physiological plane, may be a tissue of ordinary catastrophes, but our death is a generalized catastrophe.” Thom, *Structural Stability*, 250–1.

**34** See Steven J. Cooper, “From Claude Bernard to Walter Cannon: Emergence of the Concept of Homeostasis,” *Appetite* 51 (2008): 419–27.

**35** Walter B. Cannon, *Bodily Changes in Pain, Hunger, Fear, and Rage: An Account of Recent Researches into the Function of Emotional Excitement* (New York: Appleton, 1915).

**36** Walter B. Cannon et al., *The Nature and Treatment of Wound Shock and Allied Conditions* (Chicago: American Medical Association, 1918).

non's interest in these organismic reactions to extreme emergency conditions led him to the idea that shock, like the "fight or flight" mechanism, was not just a particular local "correction" of a physiological parameter, but instead a new state of being that the body entered under stress: "every complex organization must have more or less effective self-righting adjustments in order to prevent a check on its functions or a rapid disintegration of its parts when it is subjected to stress."<sup>37</sup> Cannon's theory of homeostasis, further developed in the 1920s and 1930s, was intimately linked to these extreme shocks and the threat of peril.

Cannon's approach to the dialectic of order and stress in physiology was consistent with other efforts in this period to understand how bodies reorganized themselves in times of unexpected shock and injury. Of particular interest in this context was the nervous system, whose plasticity (ability to change structure) had been a topic of speculation and research since the discovery of the synapse by Charles Sherrington early in the 20th century. And as Sherrington himself had famously emphasized, the brain and nervous system functioned as an essential unity—every action and reaction had to be understood as a *total* response involving the entire system.<sup>38</sup> This theorization would revolutionize the approach to brain-damaged patients (whose numbers dramatically increased in the Great War). In contrast to an earlier interest in specifying the localization of various functions in the brain by inferring what was lost when a part of the brain was damaged (Broca's area, responsible for language, was an early discovery), new clinical research recognized how complex functional responses of the brain involved the brain as a complex whole. In the Soviet Union, Alexander Luria, studying the impact of brain injury on cognitive abilities, observed that the brain had the startling ability to reorganize itself in order to compensate for the loss of functions after stroke or accident. As he noted, numerous studies showed "the high degree of plasticity shown by damaged functional systems, due to dynamic reorganization and adaptation to new circumstances and not to regeneration and restoration of their morphological integrity."<sup>39</sup> Karl Lashley's research in the 1920s, while initially aimed at finding the precise neural location of memory traces, in fact ended up revealing the plasticity of the brain's performance grounded in a structural complexity that defied localization. After teaching animal subjects certain tasks (maze running, for example), Lashley proceeded to surgically destroy certain parts of the brain. Following injury, animals were

---

<sup>37</sup> Walter B. Cannon, *The Wisdom of the Body* (New York: W. W. Norton, 1932), 25.

<sup>38</sup> Charles Sherrington, *The Integrative Action of the Nervous System* (New York: C. Scribner Sons, 1906).

<sup>39</sup> A.R. Luria, *Restoration of Function after Brain Injury*, tr. Basil Aigh (New York: MacMillan, 1963), 33.

still able to recover their earlier performances, revealing a significant reorganization of the brain’s activity. The unity of the brain’s systematic complexity was the structural frame for these reorganizations, which were, according to Lashley, themselves just one more example of the brain’s *normal* capacity to integrate its activity across the areas of the brain. “The whole implication of the data is that the ‘higher level’ integrations are not dependent upon localized structural differentiations but are a function of some general, dynamic organization of the entire cerebral system.”<sup>40</sup> Lashley called this capacity “equipotentiality,” alluding to how the brain sought multiple paths for its activity, thereby giving it the capacity to circumvent damage by relocating activity to some other part of the brain.

Extensive clinical experience with brain-damaged patients (many of them soldiers with bullet wounds and other war injuries) furnished the data for Kurt Goldstein’s innovative work on the nature of unity and plasticity in biological systems. In his classic 1934 book, influenced by Gestalt theory, the theory of brain “shock” championed by Constantin von Monakow, as well as broader holistic forms of thought in the interwar period, Goldstein defined the organism as a unity, arguing that in its continual struggle with the world, within the essential “milieu” of its activity, the organism maintained its stability by constantly reorganizing itself to accommodate new conditions.<sup>41</sup> Goldstein’s focus on “pathological” data was, to be sure, aimed at illuminating the normal functions of a dynamic organismic life. (50) This approach did not, however, involve an analysis of the “mere defects”(48) of the organism as a way of capturing, in an inverse image, the “normal” state. Instead, Goldstein saw that the pathological state had its own particular characteristics, its own symptomology, its own way of being. The difference between healthy and pathological states, for Goldstein, was the difference between “ordered” and “disordered” behavior. In the first case, the performances of the total organism were, he said, “constant, correct, adequate.” The disordered state is defined by shock—Goldstein refers to the activity of the organism in this state as a *catastrophic reaction*. This *Katastrophenreaktion* was “disordered, inconstant, inconsistent” and had a “disturbing aftereffect.”(48–9) In normal conditions, the organism is challenged by its milieu, and meets this

---

<sup>40</sup> Karl Lashley, *Brain Mechanisms and Intelligence: A Quantitative Study of Injuries to the Brain* (Chicago: University of Chicago Press, 1929), 176.

<sup>41</sup> Kurt Goldstein, *Der Aufbau des Organismus: Einführung in die Biologie unter besonderer Berücksichtigung der Erfahrungen am kranken Menschen* (Hague: Martinus Nijhoff, 1934); in English as *The Organism: A Holistic Approach to Biology derived from Pathological Data in Man* (New York: Zone, 1995). Further references (to the translation) will be in the text. An excellent account of Goldstein’s work and the German contexts of theoretical biology can be found in Anne Harrington, *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler* (Princeton: Princeton University Press, 1996).

challenge with a reaction that will bring the organism into equilibrium with its environment. In the pathological state, the organism has no proper response at hand. And yet, as Goldstein stressed, the organism is constantly *seeking* an ordered condition—and injured, shocked, creatures do often return to some form of health. His interest, then, was to show how the organism rediscovered stability and normality after a catastrophic reaction.

As Goldstein argued, with numerous examples, organisms have the capacity to modify themselves and their performances to reduce or minimize any defect that had led to a catastrophe reaction. (52) New paths to successful performances are found, or, alternatively, new milieus are sought out that do not require the same kind of adaptation previously required. (105) This reorganization is explained, by Goldstein, as the tendency of the unity of the organism to seek closure—what the Gestalt theorists called the law of *Prägnanz*. (293) The catastrophic reaction, then, is not a mere interlude between states of health, but instead an interruption that demands a new foundation of order for the organism as a whole, because it must overcome the persistence of a defect in its being. In this way the pathological state can best reveal the essence of the organismic unity because it demonstrates in sharp relief how a living being seeks out novel forms of order to overcome a disordered state, whereas in the healthy being there is an occlusion of this capacity, due to the relative automaticity and predictability of the ordered responses.

The successful response to a catastrophic reaction is clearly not a return to the previous state, a regaining of past performances—the organism seeks *ordered behavior* in both normal and pathological states. Crucially, Goldstein observes that *every* action of the organism is a response to a challenge, not just those of a catastrophic interruption. “The normal person, in his conquest of the world, undergoes, over and again, such states of shock. If in spite of this, he does not always experience anxiety, this is because his nature enables him to bring forth creatively situations which insure his existence.”(237) The catastrophic reaction gives us insight into the creative action that is the organism’s essential nature, according to Goldstein. The unity that marks the boundary is not a predetermined formal structure that is subsequently defended or repaired. The unity is a tendency of the organism in its temporal existence to find order, although this order is, at every moment, always put in question by the changing conditions of the milieu. “Therefore reactions scarcely ever occur that correspond to a perfectly adequate configuration of the organism and the surroundings.”(227) As Goldstein argued, the organism is never entirely “normal” because at each moment it is being challenged by the environment and must continually seek the proper adjustment: “normal as well as abnormal reactions (‘symptoms’) are only expressions of the organism’s attempt to deal with certain demands of the environment.”(35)



And so Goldstein writes that the life of the organism can be considered a series of what he calls “slight catastrophes” (*leichter Katastrophenreaktionen*), where inadequacies are first confronted and then “new adjustments” or “new adequate milieu” are sought to respond to this lack. (227) The serious catastrophe is in effect continuous with this normal, constantly repeated weaker form of catastrophe; what is different is only the scale and intensity of the reaction. The whole organism in its unity is always falling into states of shock and must, over and over again, create new order to overcome these shocks. The key point is that catastrophic shocks of some form are *essential* to the organismic being. And not just in the physiological sense. Goldstein notes that the foundation of learning, for example, is an unpleasant confrontation with one’s inherent inadequacy analogous to the experience of the brain-injured patient in recovery. (249) As he later wrote: “we assume that ‘coming to terms’ with the world must proceed by way of constantly recurring catastrophic situations, with concomitant emotions of the character of anxiety.”<sup>42</sup>

In the end, Goldstein will admit that perhaps we should not even oppose “Being-in-order” and “Being-in-disorder” because the catastrophic states of disordered behavior are foundational opportunities for achieving some degree of order—and that order is always in question. “If the organism is ‘to be,’ it always has to pass again from moments of catastrophe to states of ordered behavior.” (388) The catastrophic reaction manifests the essence of life itself:

All the minor catastrophic reactions to which the organism is continually exposed thus appear as inevitable way stations in the process of its actualization, so to speak, as the expression of its inescapable participation in the general imperfections of the living world. (392)

Thus for Goldstein, normative behavior is never really the norm. Normal ordered existence is a product of the essential pathological disequilibrium of the organism and its surrounding condition, its milieu: “these shocks are essential to human nature and ... life must, of necessity, take its course via uncertainty and shock.”<sup>43</sup> The organism’s creative plasticity allows it to find a new form of being that preserves unity and not any one particular privileged order.<sup>44</sup>

---

<sup>42</sup> Kurt Goldstein, *Human Nature in the Light of Psychopathology* (Cambridge, Mass.: Harvard University Press, 1940), 109.

<sup>43</sup> *Ibid.*, 112.

<sup>44</sup> Goldstein makes the link between organismic plasticity and the catastrophic reactions of the nervous system explicit in “Über die Plastizität des Organismus auf Grund von Erfahrungen am nervenkranken Menschen,” in A. Bethe, ed., *Handbuch der normalen und pathologischen Physiologie* (Berlin: Springer, 1931), vol. 15: 1133–1174.

Canguilhem's theory of the normal and the pathological was greatly influenced by Goldstein's work.<sup>45</sup> The idea that catastrophic reactions are *normal* informed Canguilhem's approach to pathology, and lies behind his critique of the analogy between machine and organism. While machines can be endowed with a purpose, it was impossible to imagine a machine that would be capable of suffering something like a catastrophic reaction, let alone rising to this challenge by reorganizing itself into an altogether new form of unity. Pointing to the great plasticity of the nervous system, Canguilhem noted that if a child suffers a stroke that destroys an entire half of the brain, that child would not suffer aphasia (as is the case with many brain injuries later in life) because the brain reroutes language performance to other regions in order to compensate for the damage.<sup>46</sup> Organisms are stable as *unities* precisely because their organization is *not* fixed into any one rigid structure—they are open, and thus equipped to surmount even a traumatic loss of functions in some cases.

One major challenge for cybernetics, then, was to explain how this close relationship between unity, plasticity and catastrophe, so characteristic of organismic life, could be engineered into the cybernetic machine. According to the influential biologist and systems theorist Ludwig von Bertalanffy, cybernetics could never account "for an essential characteristic of living systems," namely their ability to maintain stability despite the constant metabolic creation and destruction of its own material essence.<sup>47</sup> Like other critics of cybernetics such as Polanyi, Bertalanffy believed that "a mechanized organism would be incapable of regulation following disturbances," since a machine could not radically transform itself—as the organism could—to accommodate shock and injury.<sup>48</sup> Open systems were plastic, and never fully determined; they possessed what Bertalanffy called "equifinality," the capacity to follow multiple paths for the maintenance of life—an echo of Lashley's depiction of the brain's "equipotentiality."<sup>49</sup> While these sophisticated critiques cannot be easily dismissed, it is also the case that cybernetics was entangled with these same questions. Tracking the problem

---

<sup>45</sup> See George Canguilhem, *The Normal and the Pathological*, tr. Carolyn R. Fawcett and Robert S. Cohen (New York: Zone, 1991), ch. 4, "Disease, Cure, Health," where Goldstein's work is discussed extensively, including his concept of the catastrophic reaction.

<sup>46</sup> Canguilhem, "Machine and Organism," 79.

<sup>47</sup> Ludwig von Bertalanffy, *Robots, Men, and Minds: Psychology in the Modern World* (New York: George Braziller, 1967), 68.

<sup>48</sup> Ludwig von Bertalanffy, *General System Theory: Foundation, Development, Applications* (New York: George Braziller, 1968), 213.

<sup>49</sup> See Ludwig von Bertalanffy, "The Theory of Open Systems in Physics and Biology," *Science* 13 (1950): 23–29.

of plasticity in this new discipline can reveal some unexpected dimensions of the cybernetic vision for the living machine.

## Cybernetic Forms of the Plastic Being

Cybernetics put a great deal of pressure on the theory of the central nervous system as an information processor that governed behavior. In his own speculations on the nature of the nervous system, Wiener enumerated the fundamental analogy between neural organization and the binary architecture of the computer, but he raised many questions about this comparison. As early as 1948, he wrote that the realization that the brain and the computing machine have much in common “may suggest new and valid approaches to psychopathology, and even to psychiatrics.”<sup>50</sup> He was equally interested in how the brain maintains its information states without ever localizing them in particular spaces, the very problem that prompted Lashley’s own neurological research. Memory, for Wiener, could not be something merely physical. Instead, it had to be a constantly flowing circulation, and therefore subject to deviation; this system, he said, could “hardly be stable for long periods of time.”<sup>51</sup>

However, it was the nature of neural plasticity in particular that constituted the main challenge to the cybernetic project of assimilating machine and organism into one comprehensive framework. From the very beginning plasticity was on Wiener’s mind. A central question was how to explain the nervous system’s agile flexibility; Wiener wondered “how the brain avoids gross blunders, gross miscarriages of activity, due to the malfunction of individual components.”<sup>52</sup> With instability and malfunctions in mind, Wiener would explore several different analogies between psychological pathologies and computer malfunctions. He observed, for instance, that the drastic effort to “clear” the brain of its pathological activity with the use of electrical or chemical “shock treatment” (in lieu of the more permanent surgical lobotomy) might well parallel the necessary purging of the computer of all data when a pathological “configuration of the system” disrupts its operations.<sup>53</sup> Wiener also remarked more than once on the essential plasticity of the brain. He gave the example of Louis Pasteur, who suffered a major stroke early in his scientific career. After his death, it was discovered that he had only “half a brain.” Yet Pasteur was, Wiener pointed out, only mildly affected by

---

<sup>50</sup> Wiener, *Cybernetics*, 168.

<sup>51</sup> *Ibid.*, 171.

<sup>52</sup> *Ibid.*, 168.

<sup>53</sup> *Ibid.*, 172.

some physical paralysis, and mentally he was not at all diminished, as his great scientific achievements following the stroke proved. Wiener also used the very same example Canguilhem had offered, noting that infants can suffer “an extensive injury” to one hemisphere of the brain, only to have the remaining half take on all the functions of the destroyed one. “This is quite in accordance with the general great flexibility shown by the nervous system in the early weeks of life,” Wiener wrote.<sup>54</sup>

In this early, often speculative phase of cybernetics, Wiener could not offer much in the way of a real explanation for this plastic quality. And yet he realized that if the brain is basically a processor of information, and not a purely physical system, we are likely to find that pathologies of the mind will not be traceable to specific lesions of the mechanism (i.e., the level of the neurons) but instead to a failure of the system *as a whole* to manage information flows between functional centers.<sup>55</sup> Wiener claimed that because complex human behavior no doubt involved a great deal of neuronal connectivity, it may well be the case that the human brain is often running “very close to the edge of an overload,” that could at any moment result in “a serious and catastrophic” failure. With increasing neural flows, “a point will come—quite suddenly—when the normal traffic will not have enough space allotted to it, and we shall have a form of mental breakdown, very possibly amounting to insanity.”<sup>56</sup> Here Wiener hinted at a cybernetic form of the “catastrophic reaction,” but again, he was limited here by his inability to say much about how the brain (or the computer network analogue) could recognize the failure and *reorganize* itself in these moments of extreme crisis and breakdown, as Goldstein and others had demonstrated. Still, Wiener hoped one day that a “new branch of medicine” would be developed—he called it “servo-medicine”—that would deal with these kinds of informational disorders of control, when the “strains and alarms of a new situation” put demands on an information system that was not equipped to deal with such situations.<sup>57</sup>

John von Neumann, Wiener’s cybernetic colleague and fellow mathematician, had more than a passing interest in the architecture of computing devices and the challenge of malfunctions. Appointed to oversee the development of an electronic computer at the Institute for Advanced Study at Princeton from 1945–1951, von Neumann looked to neurology for inspiration. That the brain and the nervous system exhibited an amazing robustness was, von Neumann observed, in stark contrast to the immense fragility of the new high-speed computers then

---

<sup>54</sup> *Ibid.*, 178–9.

<sup>55</sup> Wiener, “Problems of organization,” *Bulletin of the Menninger Clinic* 17 (1953): 132.

<sup>56</sup> Wiener, *Cybernetics*, 178.

<sup>57</sup> Wiener, “Problems,” 134.

being constructed out of mechanical relays, telephone switches, or vacuum tubes. Von Neumann was careful to draw attention to the critical *differences* between digital machines and the nervous system.<sup>58</sup> Yet he himself was drawn to the nervous system as a model for the computer. One of the most important marks of the natural communication and control system was its inherent flexibility.

It is never very simple to locate anything in the brain, because the brain has an enormous ability to re-organize. Even when you have localized a function in a particular part of it, if you remove that part, you may discover that the brain has reorganized itself, reassigned its responsibilities, and the function is again being performed.<sup>59</sup>

Von Neumann was interested in finding out what he might be able to learn from these natural, robust systems as he planned his own artificial thinking machine. Speaking at the celebrated Hixon symposium on the brain, held at Cal Tech in 1948, von Neumann, alert to the holistic perspective of thinkers such as Goldstein and Lashley (the latter was also a Hixon participant), stressed that the elements of a living system were always organized into a unity, making it important to understand how the “functioning of the whole is expressed in terms of those elements.”<sup>60</sup> This was a crucial point when it came to understanding how the fragility of the system’s components could be related to the system’s plasticity, for what was in question was precisely how the unitary order of the system could be “reconfigured” among remaining component parts in the event of a failure or defect within the system. For von Neumann, ideally one would design machines that could imitate the organism’s ability to react to unforeseen errors; as someone noted in the discussion of von Neumann’s paper, we must “not only be able to account for the normal operation of the nervous system but also for its relative stability under all kinds of abnormal situations.”<sup>61</sup> While von Neumann never succeeded at building a computer with such a flexible plasticity, he did insist in his technical work in computer design that “error be viewed ... not as an extraneous and misdirected or misdirecting accident, but as an essential part of the

---

<sup>58</sup> John von Neumann, *The Computer and the Brain* (New Haven, Ct.: Yale University Press, 1958).

<sup>59</sup> John von Neumann, *Theory of Self-Reproducing Automata*, ed. Arthur W. Burks (Urbana, Ill.: University of Illinois Press, 1966), 49.

<sup>60</sup> John von Neumann, “The General and Logical Theory of Automata,” in *Collected Works*, vol 5: *Design of Computers, Theory of Automata and Numerical Analysis* (Oxford: Pergamon, 1963), 289.

<sup>61</sup> *Ibid.*, 323.

process under consideration.”<sup>62</sup> Unlike contemporary automatic computers, the nervous system, he observed, is

sufficiently flexible and well organized that as soon as an error shows up in any part of it, the system automatically senses whether this error matters or not. It doesn't matter, the system continues to operate without paying any attention to it. If the error seems to be important, the system blocks that region out, by-passes it, and proceeds along other channels.<sup>63</sup>

There is an echo here of Goldstein's claim that an organism in crisis will seek out new paths when a normal performance is frustrated by obstacle or injury, and it is perhaps an implicit allusion to Lashley's equipotentiality, or Bertalanffy's notion of equifinality. In any case, von Neumann was always fascinated by how natural organisms *reorganize* themselves in response to the challenge of what he called “emergency” conditions.<sup>64</sup>

It was exactly this problem of reorganization in crisis that Ashby faced head on in creating his cybernetic model of the adaptive organism, the Homeostat machine. Ashby knew that by definition a machine was fixed, and its operations wholly determined. A machine, in its ideal operating state, had only one form of behavior and therefore could not change its fundamental design. Although it is possible to have a machine that enters new states depending on changing environmental variables (a thermostat is a simple example), the design of the structure will still govern its operation at all times. In this respect Ashby would agree with Canguilhem's understanding of the machine. In a notebook fragment from 1943, Ashby cited the great psychologist William James, who compared the rigid machine to the nervous system, an entity that paradoxically exhibits *both* fixity of structure and open-ended adaptive plasticity.<sup>65</sup> The notebooks show that Ashby was also reading Sherrington's revolutionary work on neural integration at this time. Ashby wrote out several passages from Sherrington, where the neurologist described the organism as a “moving structure, a dynamic equilibrium,” something constantly adjusting itself to ever-changing conditions. The living system

---

<sup>62</sup> *Ibid.*, 329. On von Neumann and the role of error in his thought, see my “Creating Insight: Gestalt Theory and the Early Computer,” in Jessica Riskin, ed., *Genesis Redux: Essays in the History and Philosophy of Artificial Life* (Chicago: University of Chicago Press, 2006): 237–259, and Giora Hon, “Living Extremely Flat: the Life of an Automaton; John von Neuman's Conception of Error of (In)Animate Systems,” in Giora Hon, Jutta Schickore, and Friedrich Steinle, eds., *Going Amiss in Experimental Research*, Boston Studies in the Philosophy of Science (2009), no. 267: 55–71.

<sup>63</sup> Von Neumann, *Self-Reproducing Automata*, 71.

<sup>64</sup> *Ibid.*, 73.

<sup>65</sup> W. Ross Ashby, *Journal*, pp. 1523–4. Available at the W. Ross Ashby Digital Archive, rossashby.info/index.html, accessed July 24, 2013.

was “labile” and indeed, its greatest strength, for Sherrington, was its very fragility, because that fragility made it more sensitive to its surroundings.<sup>66</sup> If his own Homeostat was going to be an adequate representation of self-organization, Ashby had to figure out how to model the behavior of a genuinely *open* system, one that could assume a determinate structural organization, like any machine, but at the same time was not eternally *bound* to any one order. Remember that the influential systems theorist and biologist von Bertalanffy had criticized cybernetics precisely for their misguided use of closed systems to model the fundamentally open structures of natural organisms.

Ashby himself was hardly unaware of this issue, and he thought deeply about how to create mechanical systems that could not only respond to environmental changes, but in fact actually change its very *organization* as a way of finding new paths to stability and equilibrium. Ashby’s insight was that if a machine, defined by a specific form and purpose, was ever to reorganize, then logically it must in fact be capable of becoming a wholly different and new machine. In 1941, he had admitted that man-made machines that change their organizations were “rare” (and he failed to give any concrete example, though he did point out elsewhere that the inclusion of memory in a system would amount to such reorganization).<sup>67</sup>

Yet Ashby would push much further, seeking to conceptualize a machine that had, like the nervous system, what James had called an “incalculable element” that could interrupt, productively, the machine’s own fatalistic operation. Ashby made a conceptual breakthrough by thinking about the potential value of *failure*, something that was, after all, inevitable in any working machine. Ashby realized that when a machine broke, it became in essence a brand new machine with a new “design,” so to speak: “A break is a change in organization.”<sup>68</sup> Ashby’s goal was to engineer a machine that could take advantage of its own breaks as a way of entering into a new state. Genuine breaks of this kind were exceedingly rare in artificial machines. According to Ashby a break was: “1) a change of organization, 2) sudden, 3) due to some function of the variable passing a critical value.”<sup>69</sup> If a homeostatic machine were constructed in such a way as to “break” when pushed to the limit of its ability to maintain equilibrium, this machine could acquire a new organization, another possible path to equilibrium. “After a break, the organization is changed, and therefore so are the equilibria. This gives the machine

---

<sup>66</sup> *Ibid.*, 1906–09.

<sup>67</sup> *Ibid.*, 1054.

<sup>68</sup> W. Ross Ashby, “The Nervous System as Physical Machine: With Special Reference to the Origin of Adaptive Behaviour,” *Mind* 56 (1947): 50.

<sup>69</sup> Ashby, *Journal*, 1054.

fresh chances of moving to a new equilibrium, or, if not, of breaking again.”<sup>70</sup> The breakdown was in essence a temporary shock to a system that was not succeeding in its quest to find equilibrium. Ashby invented a form of *cybernetic plasticity* by taking advantage of the very weakness of all machines—their ultimate fragility.

As Ashby would point out, the brain was a special kind of machine in that its many highly differentiated component parts—the neurons—were constantly connecting and disconnecting with each other as the brain responded to perturbation and change. Built into its dynamic organization was an inherent tendency to break down and thereby give way to new organizations, for the neurons have a built-in latency period: after a certain amount of activity, neurons temporarily “disappear” from the system, only to reappear fully active again once they have recovered their potential. Ashby suggested that the cybernetic machine and the organism could be linked by this shared capacity to self-organize in moments of breakdown, a capacity that ultimately could be traced to the tendency to *fail*—at least temporarily—on a repeated basis.<sup>71</sup>

Reading cybernetic concepts with and against contemporary theorizations of open, living systems, it is possible to glimpse some important and provocative intersections between the technological discourse of cybernetics and continental forms of thought that emphasized holistic and vitalist concepts of organismic order. A crucial marker of the open living system was the important and productive role played by pathological and even catastrophic states in maintaining the persistence of organismic unity. Having recognized this themselves, the cyberneticists had faith that it would be possible to create artificial machines that possessed genuine plasticity, so necessary for survival in times of extreme crisis. In the cybernetic era, both organisms *and* advanced machines were sites of stability and instability, truth and error, order and disorder, health and pathology; all were intertwined, in sometimes strange ways, to produce fragile yet powerful beings, endowed with astonishing and unpredictable creative powers. This is worth remembering in our own age, where human thought and human identity is so easily assimilated by the hyper-technologized visions of the brain and the body.

---

<sup>70</sup> Ashby, “Nervous System,” 55.

<sup>71</sup> *Ibid.*, 57–8.