The Information Turn in Modelling People and Society: early German Work

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The concept of 'information' is now so all-pervasive that few turn their attention to the origin and (initially slow) evolution of the concept as a basic element in science, technology, computing and even, these days, the social sciences and humanities. Indeed, anyone who considers the development of the notion of information is likely to be restricted to a few great names such as Claude Shannon and Norbert Wiener, or the famous series of Macy Conferences on cybernetics, systems thinking, and related topics. Yet there is a fascinating, and rarely told, pre-history. This paper considers early attempts by German scholars at viewing individuals and societies from what, in retrospect, can be considered an information point of view. Specific areas examined by such scholars are the dilation of the pupil of the eye, a general 'proto-cybernetic' approach to the human body, and feedback in organisms and the state. Such early work was not widely known by later German cyberneticists of the 1940s onwards, but it gradually came to inform their ideas: see in particular Henn [1]

Early work by biologists and others taking a much broader view of their subject did not form a coherent whole. In addition to those German scholars discussed below who drew attention to the specific links between feedback, biology and society, a number of other contributors are worth briefly mentioning. In 1917, for example, the Scottish mathematical biologist D'Arcy Wentworth Thompson wrote *On Growth and Form*, while Jan Smuts, who had academic interests as well as a military and political career, produced *Holism and Evolution* in 1927. As far as German thinkers are concerned, Franz Kröner wrote *The Anarchy of philosophical Systems* in 1929, while the even earlier Johann Heinrich Lambert (1728 – 1777) and Johann Gottfried von Herder (1744 – 1803) are also considered by many in the German-speaking areas to have contributed to early notions of systems thinking.

Physiology

The notion that living organisms can be considered in some respects as machines has a long history, dating at least as far back as Descarte's *De Homine* of 1643. Nearly two centuries later Charles Bell drew analogies between the biology of bones and internal organs on the one hand, and engineered structures and systems such as buildings, pumps and pipes on the other. Herbert Spencer in the 1860s considered the way organisms maintain dynamic equilibrium, drawing direct comparison with the steam engine, and also extended such ideas to the equilibrium of non-living systems in the natural world. At this point, although not made explicit, notions about information emerged. In Germany, Eduard Pflüger (1877) addressed the importance of feedback, using the example of the control of the dilation of the pupil, in a publication whose very title, 'Teleological mechanics of living nature' anticipated the classic 'Behaviour, purpose and teleology' of the classic 1943 paper by Rosenblueth, Wiener and Bigelow.

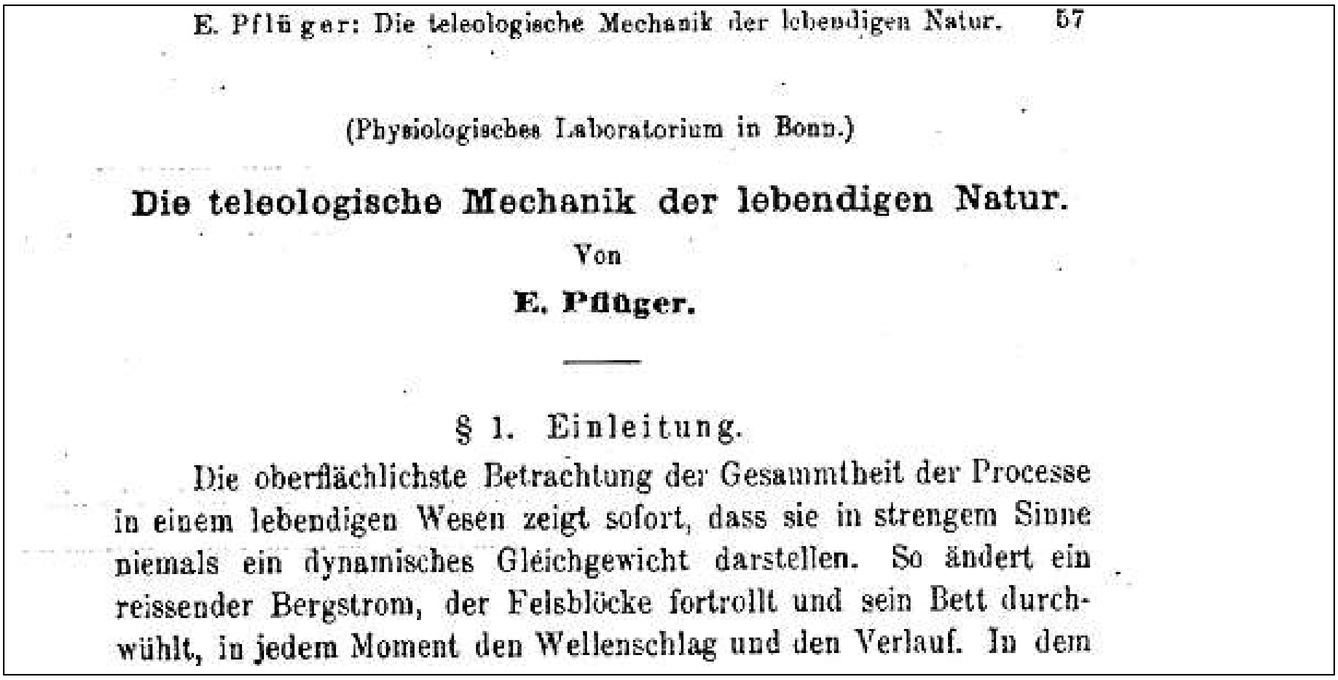
In a lecture published in 1879 Felix Lincke analysed mechanical regulation in general terms, and then applied his ideas to the human body. Lincke distinguished between the *indicator* (specifying the value of the parameter to be controlled), the *modifier* (valve, etc), the *transmission* system (between indicator and modifier), and the *motor* (to supply power for the actuation). In the human body these functions were carried out by the eye, muscles and nervous system, for example. Information flow was thus a key factor, as was feedback.

By the 1920s a number of German zoologists and physiologists had taken up the study of biological control processes. Jacob von Uexküll (1864-1944) and Richard Wagner (1893-1970) both considered the rôle of feedback. Von Uexküll used what we would now term signal flow diagrams to represent both internal feedback loops and the relationship of the organism with its environment, while Wagner explicitly discussed biological feedback. Both authors also applied biological ideas to society. Wagner was the anonymous author of a short 1932 publication entitled *Unemployment and deflation in the body economic from the point of view of biological laws*, in which he proposed solutions to the economic crisis based on biological metaphors including feedback.

Let us turn now in a little more detail to the contributions of these early German thinkers in this area, contributions which mark the beginning of the application of information ideas to biological and social systems.

Eduard Pflüger (1877)

Pflüger studied medicine at the Marburg and Berlin, becoming professor of physiology at the University of Bonn, where he remained for the rest of his career. He made contributions to many branches of physiology, and also conducted research into neurology, metabolism, and the regulation of body temperature. Such researches made him think naturally in systems terms about a living organism and general biological regulatory functions. In particular, Pflüger considered the control of the dilation of the pupil in a publication entitled: 'Teleological mechanics of living nature'.


E. Pflüger: Die teleologische Mechanik der lebendigen Natur. 57

(Physiologisches Laboratorium in Bonn.)

Die teleologische Mechanik der lebendigen Natur.

Von

E. Pflüger.

§ 1. Einleitung.

Die oberflächlichste Betrachtung der Gesammtheit der Processe in einem lebendigen Wesen zeigt sofort, dass sie in strengem Sinne niemals ein dynamisches Gleichgewicht darstellen. So ändert ein reissender Bergstrom, der Felsblöcke fortrollt und sein Bett durchwühlt, in jedem Moment den Wellenschlag und den Verlauf. In dem

Figure 1. The opening of Pflüger's publication

With great foresight he noted: "the need here is for the correct degree of excitation of the optic nerve, in the way most suitable for acute perception. Thus the *excitation* of the optic nerve itself must control the width of the pupil" [2]. This is particularly important as it was one of the earliest papers to identify *information* flow in an implicit biological feedback loop.

Felix Linke (1879)

Linke was Professor of Mechanical Engineering at the Polytechnikum Darmstadt. Otherwise, little is known of him. In 1879 he gave a lecture, subsequently published [3], in which he explicitly compared the workings of the human body to elements of the control systems that were becoming so important in the mass production of the industrialised countries. In terminology remarkably similar to that of modern control engineering, he distinguished between the "indicator", "modifier", "transmitter" and "motor" – very much as we would now talk about sensors, controllers and actuators.

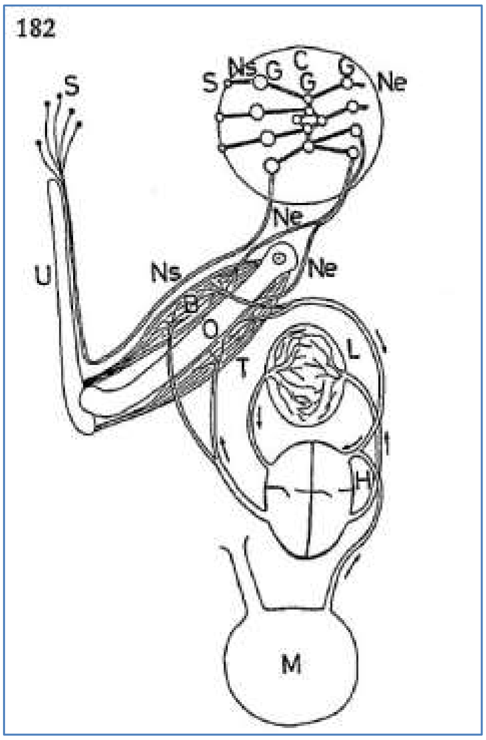


Figure 2. Lincke's 'proto-cybernetic' view of the human body

Figure 2 shows Linke's identification of the heart, lung, stomach, brain, sensory organs, nerves and muscles in a stylised, almost 'proto-cybernetic' form.

He went further:

> "The difference between our voluntary actions and the operation of a machine is only quantitative. The reliability and effect of [our biological] organs, or a combination thereof, simply contrasts with the absolute express and undisputed result of a machine."

And:

> "[…] we observe the movement we have induced. In other words, the stimuli to the sensitive nerve endings resulting from the changes in our relationship to the external environment are transmitted to the brain by the sensory nerves and brought to consciousness. As we see, hear, feel, etc the motion caused by our 'machine' and the accompanying phenomena, we are in a position to bring our actions into harmony with our overall intention, as well as to modify or halt them in response to changes. [...] the activity we use to direct our human 'machine' towards its goal always derives from the difference between the will and the perceived or imagined reality – that is, the difference between the desired and actual result of the action."

In particular, Lincke distinguished between the "nerves of will" (what we would now call motor nerves) and the "nerves of sensations" (sensory nerves), pointing out that "the brain is a communication bridge between the nerves of sensation and the nerves of will". He also emphasised the significance of what we would now call the 'error' in a closed-loop system: his "difference between the will and the perceived or imagined reality".

Jakob Von Uexküll (1920)

Von Uexküll was born in Estonia, of an aristocratic family. Although the family money was mostly lost in WW1, he retained a villa on Capri, visited by the likes of Walter Benjamin!

Uexküll was interested in how living beings perceive their environment, arguing that organisms perceived the experience of living in terms of species-specific, spatiotemporal subjective reference frames that he termed *Umwelt*, now used as the general German word for environment. He wrote the seminal book *Theoretical Biology* (1920) [4], founded the Hamburg Institute for Environmental Research, and established the discipline of biosemiotics. Figure 3 shows the cover of *Theoretical Biology*.

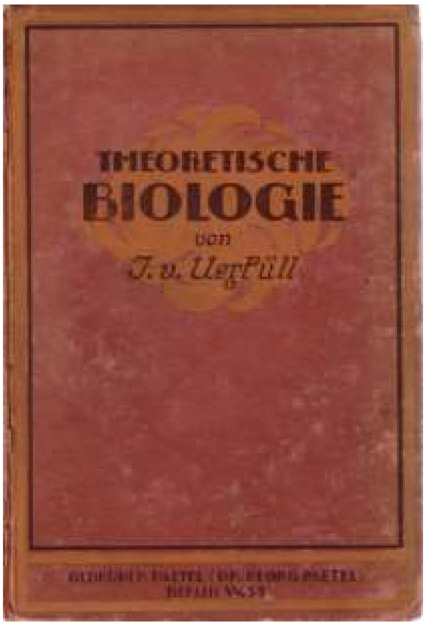
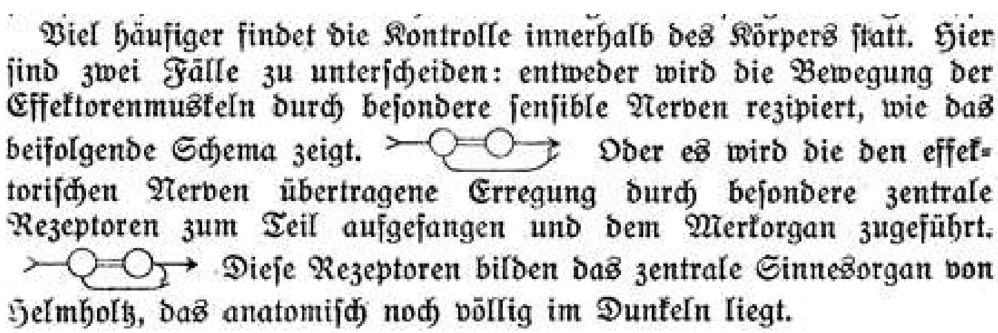


Figure 3 The cover of Theoretical Biology

The 1920 book included many explicit in-text diagrams of an informational nature – what we would now term, 'signal flow diagrams' (Figure 4).



Viel häufiger findet die Kontrolle innerhalb des Körpers statt. Hier sind zwei Fälle zu unterscheiden: entweder wird die Bewegung der Effektorenmuskeln durch besondere sensible Nerven rezipiert, wie das beifolgende Schema zeigt. Oder es wird die den effektorischen Nerven übertragene Erregung durch besondere zentrale Rezeptoren zum Teil aufgefangen und dem Merkorgan zugeführt. Diese Rezeptoren bilden das zentrale Sinnesorgan von Helmholtz, das anatomisch noch völlig im Dunkeln liegt.

Figure 4. Some of Von Uexküll's text, showing his in-text 'system' or 'signal-flow 'diagrams

In the second edition (1928) we find some even more surprising representations, very close to modern neural net approaches (Figure 5).

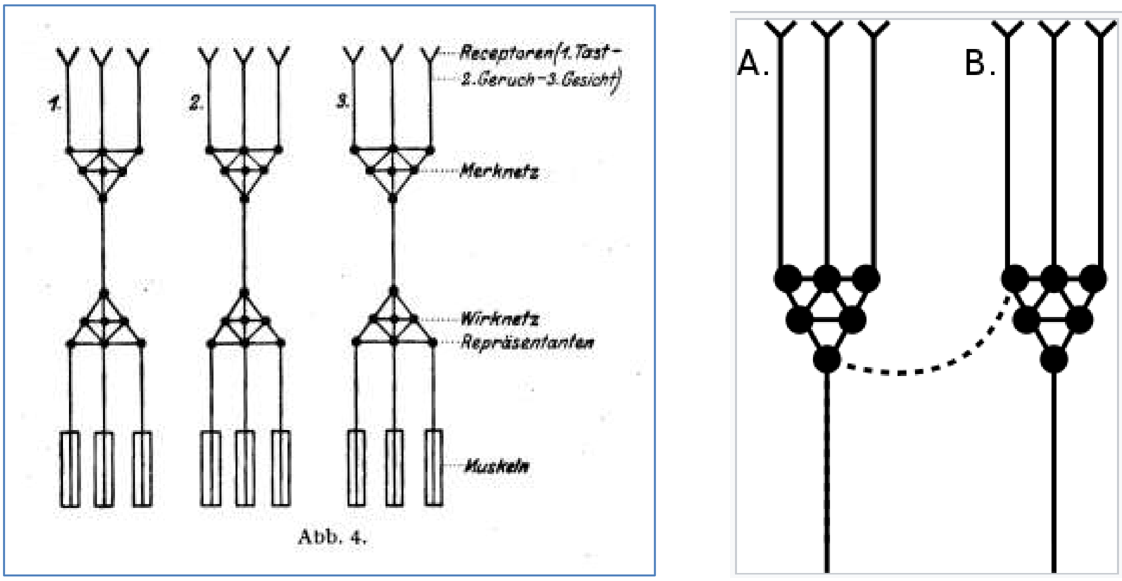
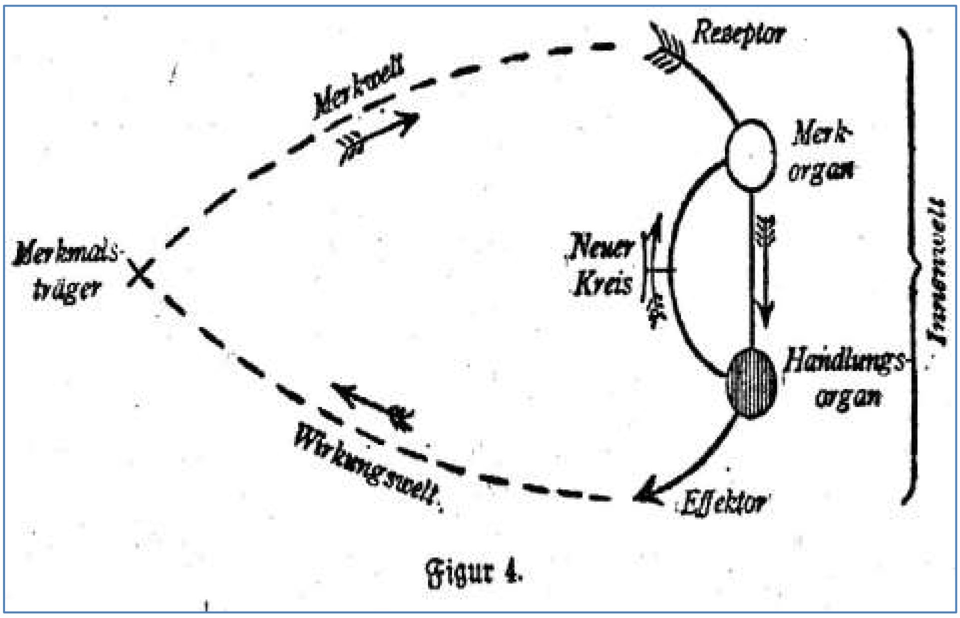
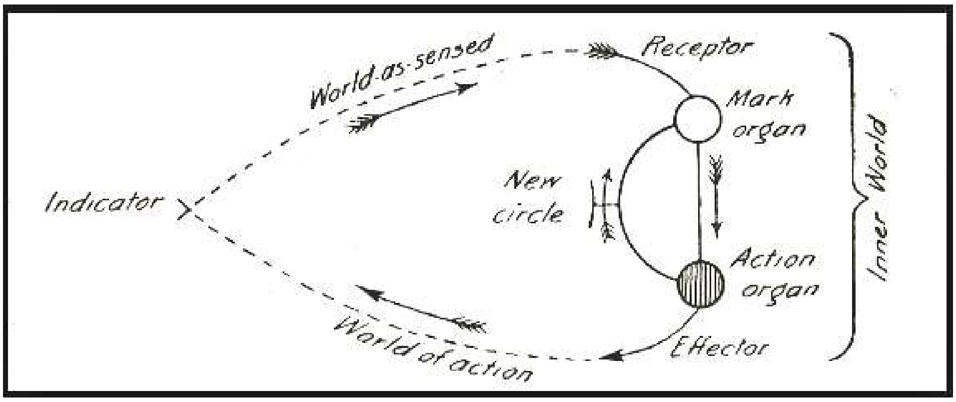


Figure 5. (a) Two of Von Uexküll's figures, closely resembling neural nets: (a) the general scheme of receptor, net and muscles; (b) the growing of one net from another as a result of experience

Perhaps the most important of Von Uexküll's physiological feedback ideas is illustrated in Figures 6 and7. Here he gives signal flow diagrams of an organisms and its relationship with the environment [4, 5]. Feedback is clearly indicated. This is perhaps the clearest view of a pre-WW2 feedback system in a biological context.



(a)



(b)

Figure 6. (a) An organism and its relationship to the 'innerworld' and its environment. (b) The English version in the first translation (1926).

The captions on the English translation are translated rather literally, but in modern systems terms we can identify feedback loops, physiological sensors and actuators (muscles, etc), and so on. Figure7 is even clearer, in which the organism is shown acting interacting with an 'object' through sensing, feedback and actions within its environment.

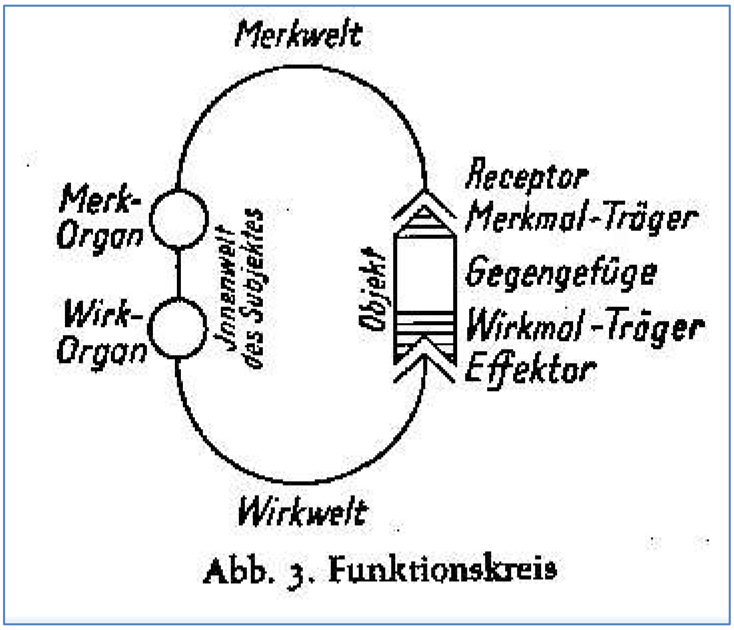


Figure 7. A closer look at the relationship between an organism and its closed loop relationship with the environment.

Applications to the state and to economics

Both Von Uexküll and another German biologist, Richard Wagner also applied their developing systems thinking to social issues. In a little-known work *The Biology of the State* Von Uexküll likened the state to an organism, with analogies within the state to the ‘nutrition’, ‘physiology’, ‘diseases’, ‘parasites’, and so on of an organism [6].

Staatsbiologie

(Anatomie – Physiologie – Pathologie des Staates)

Von

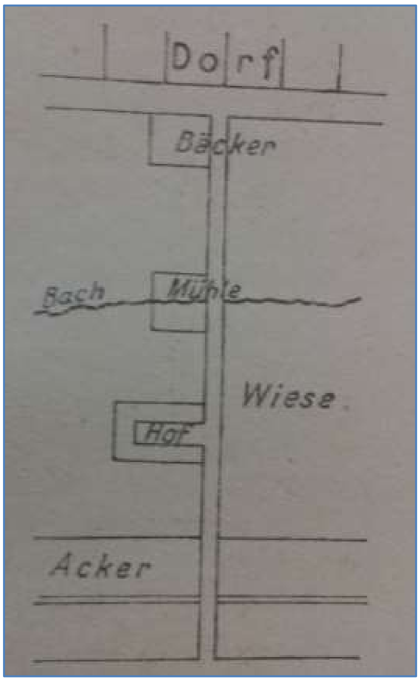
J. v. Uexküll

„Deutsche Rundschau"
Herausgegeben von Rudolf Pechel
Sonderheft

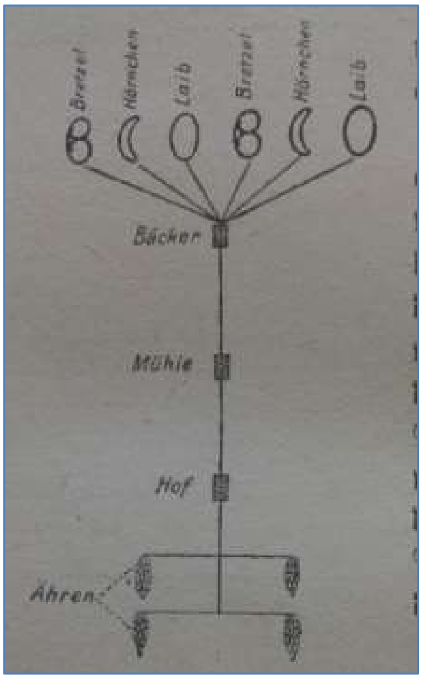
Berlin
Verlag von Gebrüder Paetel
(Dr. Georg Paetel)
1920

Figure 8. The opening page of Staatsbiologie, which was to cover the anatomy, physiology and pathology of the State

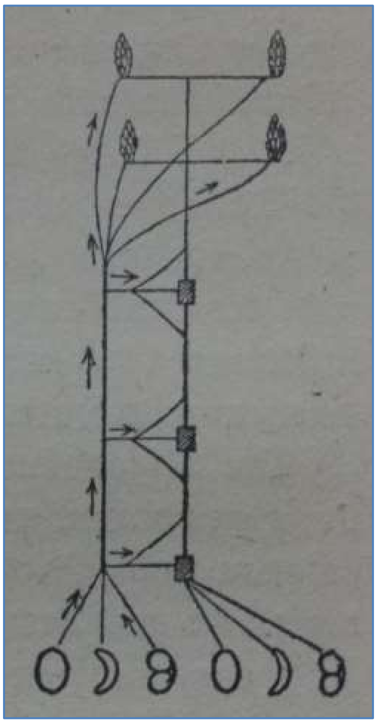
Although not explicit, given Von Uexküll’s use of signal flows in biology, many subsequent ideas about ’information’ are implicit in this work. Certainly, he adopts a typical systems abstraction, as shown in Figure 9.



(a) topographical



(b) a systems approach



(c) the distribution of the produce

Figure 9. The conversion of a topographical diagram into systems diagrams

Figure 9(a) shows a simple map, with the locations of fields, meadows, farmyard, mill, stream, baker and village. Part (b) however links these components in a functional way, with no particular topographical relationship. The harvested wheat passes through the farm to the mill and the baker, who then produces various types of bread: pretzels, croissants and loaves in the figure! Finally the produce is distributed, as shown in part (c). Information irrelevant to the production and distribution processes is omitted.

Von Uexküll also considers how the biological notions of symbiosis and parasitism can be applied to the State. His discussion leads us rather too far from the thrust of this paper to be considered in detail, but it is worth including one short quotation. Recall, however, that this was written in 1929, so before the mid twentieth century's rise of fascism in Europe. It is important, therefore, not to interpret it ahistorically, even though the expression of some of the ideas is rather disconcerting to readers nearly a century later:

> All those racially foreign inhabitants of a State can, because of a strong feeling of racial identity, remain closely connected with each other and easily congregate communally, leading to the continuation of a foreign way of life within the State. Even if the structure of such a way of life is loose, the participants will support each other, leading to a certain opposition towards other citizens. Such racially foreign inhabitants tend to live in a state of symbiosis, justified by the usefulness which they bring to the State through their labour. […] If the State is attacked by an external enemy, symbionts play an important role in the national movement to demonstrate their identification with the State. They become particularly pronounced in their abhorrence of the enemy that threatens to destroy the State, and do not shy away from the greatest sacrifices of life and property to save the State to which they are bound for good or ill. It is quite different where parasites are concerned. They thrive in a sick State, which can defend itself only weakly against them. They seek, therefore, to undermine the national feeling, demonstrating the lack of their own State, finding a thousand excuses for the attacks of the enemy. They avoid sacrifice – exploiting, rather, the weaknesses of the State and seeking to obtain decisive positions for themselves. They are thus soon identified as parasites, and ultimately neutralised, once the State regains its power of resistance.

Richard Wagner was another German biologist who explicitly discussed feedback systems [7]. Following medical studies in Munich and Innsbruck, he was professor at a number of Austrian and German Universities; he joined the Nazi party in 1938. From the mid-1920s he studied control processes in living organisms, but later made some rather excessive priority claims for certain cybernetics ideas, becoming somewhat marginalised in the German cybernetics community as a result [8].

Most interestingly for the present paper, however, is the fact that he was the anonymous author of a short 1932 publication [9] entitled *Unemployment and deflation in the body economic from the point of view of biological law*, even less well known than Von Uexküll's *Staatsbiologie*! In Wagner's intriguing text, which has only recently been examined in detail, he proposed solutions to the economic crisis based on biological metaphors including feedback and control loop structure. Beginning with an analysis of the late 1920s economic crisis, and with the aid of many biological metaphors and arguments based on the technical notions of feedback and control loops, he attempted to apply such ideas to economics, stating in the foreword:

> "The current shortcomings of the economic situation recall in many ways the effects of sickness on a human or animal organism. Just as the biological laws governing the cellular state are little known to economists, so biologists lack a knowledge of the inevitabilities so important in the economic behaviour of society."

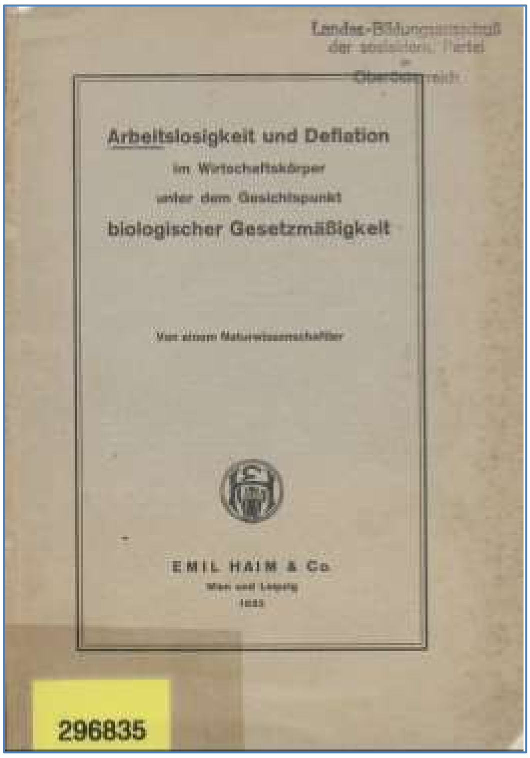


Figure 10. The cover of Unemployment and deflation in the body economic …

Figure 10 shows the cover of this short book. As it appears to be unavailable except for inspection in a few libraries in German-speaking areas, my brief account is based on Dittmann (7).

The publication had a very small distribution. In 1961 Wagner admitted authorship and claimed that the book was suppressed soon after appearance by the "new rulers" of Germany. The publisher, too, is a bit of a mystery. Born in Bohemia in 1875, Emil Haim founded his small publishing company in 1910. The fact that he had abandoned Judaism in 1919 and died in 1937, did not save his business from confiscation the following year after the Austrian *Anschluss*.

Conclusion

Significant early German work in biological areas was associated with information ideas. There is certainly a need to avoid post-hoc over-interpretation; nevertheless, the early recognition of the importance of feedback loops in the control of the functions of living organisms was a huge step, as was the recognition of the wider application of systems ideas, including early system flow diagrams. To the modern reader, the work of Uexküll is the most interesting, and of great significance for the development of the application of information and systems ideas to both biological and social systems. It is worth concluding with two of his philosophical ideas from [6]:

> All reality is a subjective phenomenon - this must form the great fundamental recognition of biology. It is quite pointless to search the entire world for reasons independent of the subject; we shall always encounter objects which owe their structure to the subject.
>
> The vastness [of the world] forms the invisible canvas on which the panorama surrounding every one of us is painted in the color of the local signs and forms […] An objective picture of the world, appropriate to all subjects, must necessarily remain a phantom.

It must be noted that much of the work discussed here was unknown to later information and cybernetics pioneers, both in Germany and elsewhere. From the early 1940s onwards there was a significant German 'proto-cybernetics' movement – the major figure being Hermann Schmidt, predating Wiener in the United States. Some of Wiener's seminal work was slow to appear in German. His 1948 book *Cybernetics: or Control and Communication in the Animal and the Machine* was not translated into German until 1963, a decade after the translation in 1952 of his *Human Use of Human Beings* (Wiener, 1950) aimed at a less specialised audience.

Schmidt's group, established in the early 1940s, had interests in flight control and ship stabilization, precision engineering, process control, biological questions relating to the regulation of temperature, blood pressure and circulation, pulse rate, movement and posture, metabolism, and the economic, socio-political and cultural implications of the emerging control field. This later history, however, is not within the scope of this paper, and has been considered by the author in some detail elsewhere [8]. The subject matter has also been considered, albeit cursorily, in introductory sections in Aumann's book on the history of cybernetics in the Federal Republic of Germany, which naturally concentrates on later developments [9]. Finally, for a more general (but mostly Anglophone) history of systems thinking the reader is referred to Ramage & Shipp's excellent *Systems Thinkers* [10].

At the time the scholars discussed in this paper were active, many biologists were beginning to broaden their outlook away from the individual organism to groups of organisms, the wider environment, and even the application of theoretical systems ideas to society in general. The fact that they have become known only fairly recently certainly does not detract from the significance of their work, ranging from the application of highly technological notions such as feedback towards the wider, but much later, development of the concept of a sociotechnical system.

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