THE ROAD TO SERVOMECHANISMS: THE INFLUENCE OF CYBERNETICS ON HAYEK FROM *THE SENSORY ORDER* TO THE SOCIAL ORDER

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ABSTRACT

This paper explores the ways in which cybernetics influenced the works of F. A. Hayek from the late 1940s onward. It shows that the concept of negative feedback, borrowed from cybernetics, was central to Hayek's attempt to explain the principle of the emergence of human purposive behavior. Next, the paper discusses Hayek's later uses of cybernetic ideas in his works on the spontaneous formation of social orders. Finally, Hayek's view on the appropriate scope of the use of cybernetics is considered.

Keywords: Cybernetics, F. A. Hayek, Norbert Wiener, Garrett Hardin, Ludwig von Bertalanffy.

JEL Codes: B25; B31; C60

> When I began my work I felt that I was nearly alone in working on the evolutionary formation of such highly complex self-maintaining orders. Meanwhile, researches on this kind of problem – under various names, such as autopoiesis, cybernetics, homeostasis, spontaneous order, self-organisation, synergetics, systems theory, and so on – have become so numerous that I have been able to study closely no more than a few of them. (Hayek, 1988, p. 9)

1. INTRODUCTION

Recently, the new approach of complexity economics has gained a significant number of followers. Some authors, such as Colander et al. (2004), claim that a "new orthodoxy" is gradually emerging inside the mainstream of economics and that this orthodoxy will be founded on the vision of the economy as a complex system. The optimism of these authors regarding the growth of complexity economics might be regarded as an overstatement but, given the current trends in economics discussed by them, it is nevertheless reasonable to expect that the complexity approach will have an important role in the future of economics.

These new developments enhance the relevance of investigating the early interactions between economists and complexity theorists. Among the first economists to emphasize the centrality of the issue of complexity to the study of social phenomena was the Austrian F. A. Hayek (Rosser, 1999; Gaus, 2006; Barbieri, 2013). However, in the 1950s, when Hayek began to explicitly incorporate elements of complexity into his work, "complexity theory" as it then existed was rather different from what we understand by the term today. At that time, the peculiar scientific movement of cybernetics was arguably the most important complexity-related development (Mitchell, 2009, pp. 295-300).[1]

It is widely recognized in the literature that Hayek formed his views on complexity with great influence from cybernetics[2] (Vaughn, 1999b; Caldwell, 2004a; Rosser, 2010). This belief is

[1] Other important developments were general system theory, chaos theory, and catastrophe theory. For more on these other precursors of complexity, see Rosser (2009, pp. 171-175).

[2] In this work we will focus mainly on the so-called "old" or "first-order" cybernetics. There is no evidence of significant influence on Hayek from the "new" or "second-order" cybernetics.

justified for various reasons. First, there was explicit and positive reference to the contributions of cybernetics in Hayek's works from the 1950s onward. Moreover, Hayek maintained contact with some of the individuals associated with this approach such as Heinrich Klüver,[3] Garrett Hardin[4] and Ilya Prigogine.[5] Despite the widespread recognition of the relevance of the Hayek-cybernetics connection, to my knowledge there has been no work that explores in detail how cybernetics is related to Hayek's ideas. The present paper aims to fill this gap in the literature.

For several reasons, our investigation will start with Hayek's book on "theoretical psychology", *The Sensory Order* (1952). First, *The Sensory Order* (TSO) was the first work in which Hayek made references to authors associated with cybernetics. Second, the book's introduction was written by the Gestalt psychologist Heinrich Klüver, who was an active participant of the Macy Conferences of cybernetics. Finally and most importantly, we will see that the ideas of cybernetics do not appear in a peripheral way, but constitute a central part of the argument of the book. Surprisingly, this fact has not been noted by previous commentators.

In section 2, we will provide a brief exposition of some basic concepts of cybernetics. Section 3 carries out an exploration of the influences from this discipline on TSO. We will focus mainly on Hayek's attempt to explain the emergence of purposive behavior. In section 3, we analyze Hayek's uses of cybernetics in his later works on social theory. It will be shown, specifically, how he tried to address the "knowledge problem" that he had formulated decades

[3] Heinrich Klüver was a psychologist and an important figure of the Macy Conferences of cybernetics. He was professor at University of Chicago during the 1950s, when Hayek worked on the Chicago Committee of Social Thought. Correspondence available between Hayek and Klüver suggests that they became close friends during this period. A letter from Klüver to Hayek in 1970 indicates that cybernetics was one of their main mutual interests: "If you were here there would be much to talk about. The American scene is rather interesting at the present time (to say at least) – economically, politically, psychologically and even cybernetically (although Warren McCulloch has seen fit to leave us forever on Sept 24 last year)" (Hayek Collection, Box 31, Folder 4).

[4] Garrett Hardin was a biologist and ecologist whose work had cybernetics as one of its inspirations. He is widely known in the economics circles as the formulator of the problem of "The Tragedy of the Commons".

[5] Ilya Prigogine was a physicist of the Free University of Brussels and associated with the cybernetics approach. Rosser (1999, p. 185) states that he learned of Hayek's approach to the "Brussels School" of cybernetics from Peter M. Allen, a student of Prigogine's

before by using new concepts and ideas drawn from this theory. We will also consider in this section Hayek's view on the appropriate scope of the use of cybernetics. Final remarks and conclusions are made in section 4.

2. CYBERNETICS: BASIC CONCEPTS AND IDEAS

Cybernetics – a neo-Greek expression that means "steersman" – was defined by Wiener (1948a, p. 11) as the entire field of control and communication in the animal and the machine. Though cybernetics started by being closely associated in many ways with physics,[6] it does not depend in any essential way on the laws of physics. *Au contraire*, the cyberneticians saw it as having its own foundations, which could be used to understand the workings of the most diverse kinds of systems – physical, biological and socioeconomic. With a single set of concepts, we would be able represent automatic pilots, radio sets and cerebellums and draw useful parallelisms between machine, brain and society (Ashby, 1956, pp. 1-4).

One of the main concepts employed by cybernetics is that of feedback. Consider a machine composed of two different parts (M_1 and M_2). Each part receives inputs ($I_1\ and\ I_2$) and converts them into outputs ($O_1\ and\ O_2$) according to well-defined transformation functions ($f_1\ and\ f_2$). In isolation, M_1 and M_2 could be represented as in figure 1:

[6] Cybernetics was explicitly inspired in the design of servomechanisms (or feedback-control systems) and in statistical mechanics (as we will see, information is defined as negative entropy).

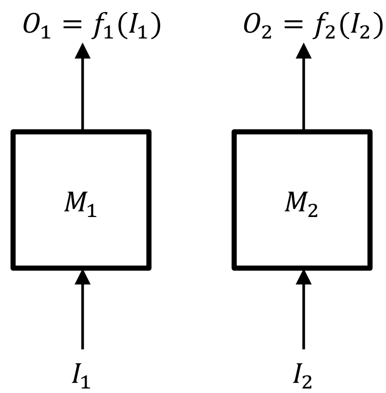

Figure 1. System with isolated parts.

Though we have full knowledge of the parts of the system, we still cannot determine the behavior of the system as a whole unless we specify the way these parts are coupled. It could be the case that the parts are independent of each other, so that the analysis of the whole is reducible to the analysis of its parts in isolation, as in figure 1. But it could also be the case that one part's output is connected to the other's input. If M_1's output is linked to M_2's input, but not the other way around, then we say that M_1 dominates M_2. When both outputs are connected to both inputs, *feedback* may be said to be present.

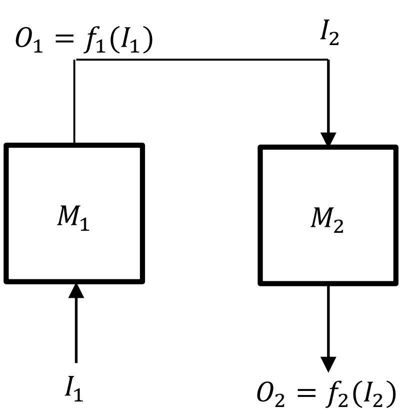

Figure 2. System in which $\boldsymbol{M_1}$ dominates $\boldsymbol{M_2}$.

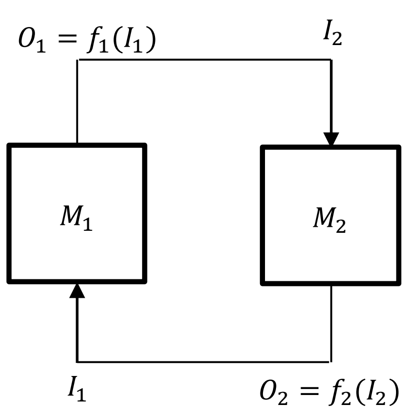

Figure 3. Feedback system.

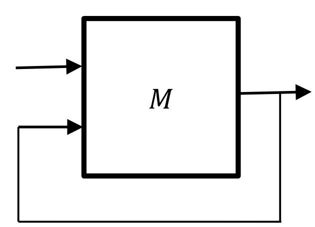

Figure 4. Feedback system seen as a whole.

There are two different kinds of feedback: negative and positive. Negative feedback is self-correcting, i.e., it tends to bring the system back to a previous state after an exogenous shock. Therefore, when the feedback of a system is negative, the system tends to be stable. Positive feedback, on the other hand, is self-reinforcing. This means that a shock is magnified by the operation of the feedback mechanism, leading the system away from the previous *status quo*. The system, thus, exhibits explosive behavior.

One example of the operation of negative feedback is given by the temperature regulation process that occurs in the interior of homoeothermic or warm-blooded animals. If the temperature of the animal is too high, the organism reacts taking measures to ensure that more heat is liberated from the body to the environment (through the flushing of the skin and the evaporation of increasing sweat) and less heat is generated inside the body (by reducing the metabolism). Similarly, if the temperature of the animal is too low, the organism takes measures in the opposite direction such as shivering, increasing muscular activity, and secreting adrenaline (Ashby, 1960, p. 59). Therefore, by means of negative feedback, the body is able to keep its temperature within limits. In general, a system which regulates variables in order to maintain the stability of its internal conditions is said to display the property of *homeostasis*.[7]

But cybernetics shall not live by feedback alone. As Wiener's definition of the field suggests, other essential concepts include communication, control, and information. The concept of control is tightly linked to that of feedback. Control systems are those that regulate the behavior of other systems. This can be done by means of an open loop process, by which the control system's outputs are generated based solely on inputs, or by a closed loop process, in which feedback from the system's output is also used. For this reason, closed loop control systems are also called feedback control systems or *servomechanisms*.

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[7] The term homeostasis was coined by the physiologist Walter Cannon (1932). Besides the temperature-regulating mechanism in a homoeothermic animal, other examples of homeostasis are the regulation of glucose and pH levels in the human blood.

In feedback control systems, there is a desirable state (desirable variable), an actual state (controlled variable), and a measure of the difference between these two (error). The actual state is influenced by a manipulated variable, determined by the action of the controller, and also by disturbances or exogenous shocks. The error of the system is fed back to the controller, which acts on the manipulated variable in order to approach the desired state (Ahrendt and Taplin, 1951, p. 5).

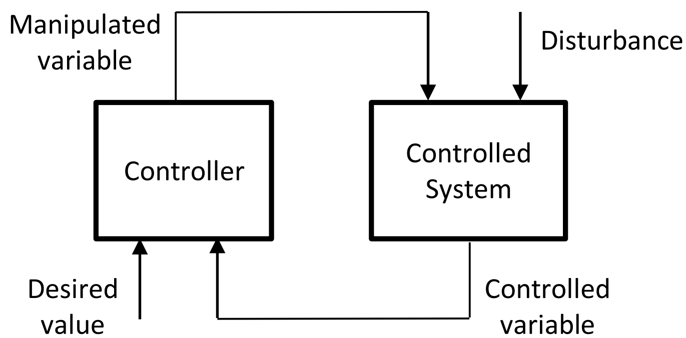

Figure 5. The components of a feedback control system. Adapted from Ahrendt and Taplin (1951, p. 5).

The two last fundamental concepts of cybernetics are the intertwined ones of communication and information. Communication may be broadly defined as the exchange or transmission of information. In this connection, three different levels of communication problems can be pointed out: (a) the technical problem of accurately transmitting symbols of communication, (b) the semantic problem of conveying precisely a desirable meaning by the transmitted symbols, and (c) the effectiveness problem of affecting the conduct of the receptor of communication in a desired way (Weaver, 1964, p. 4) Claude Shannon's seminal article "A Mathematical Theory of Communication" (1948) explicitly deals only with the technical problem. As he puts it:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. (Shannon, 1948, p. 379)

If we restrict ourselves to the technical problem of communication, information can be precisely measured. What it measures is the uncertainty associated with a specific probability distribution. Thus, the information conveyed by a degenerate probability distribution– e.g., two possible events with $p_1 = 1$ and $p_2 = 0$ – is zero, once the outcome is known with certainty. The exact measure of information proposed by Shannon (1948) is given by equation 1.

$$H = -k \sum_{i=1}^{n} p_i \log(p_i);\ with\ k > 0 \qquad (1)$$

In his paper, Shannon proved that this was the only equation that satisfied a set of desired properties.[8] Because this formula is the same as the expression for entropy in statistical mechanics, he used the terms information and entropy interchangeably.[9] The unit of measurement of information is determined by the choice of the base of the logarithm. If the base two is chosen, then it will be measured in bits (binary units). Using this expression, Shannon was able to give formulas for the channel capacity of a transmission line (in bits per second) and the amount of redundancy needed in order to send with fidelity a given signal through a noisy channel.

Wiener was working at the same time on similar lines as Shannon's and reached almost the same conclusions as him (Wiener, 1948a, pp. 60-94). There were, though, two significant

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[8] These properties were:
(1) $H(p_1, p_2, \dots, p_n)$ should be continuous for each p_i;
(2) if $p_i = \frac{1}{n}$ for every i, then H should be a monotonic increasing function of n;
(3) $H(p_1, p_2, \dots, p_n) = H(p_1 + p_2, p_3, \dots, p_n) + (p_1 + p_2) H\left(\frac{p_1}{p_1 + p_2}, \frac{p_2}{p_1 + p_2}\right)$.
Note also that, when $p_i = 0$ for some i, $p_i \log(p_i)$ is not defined, but as $\lim_{p_i \to 0^+} p_i \log(p_i) = 0$, we can redefine $0 \log(0) = 0$ and preserve the property of continuity (Kapur and Kevasan , 1992, p. 28).

[9] According to Kapur and Kevasan (1992, p. 8), it was John von Neumann who supposedly advised Shannon to use the term entropy by saying that "First, the expression is the same as the expression for entropy in thermodynamics and as such you should not use two different names for the same mathematical expression, and second, and more importantly, entropy, in spite of one hundred years of history, is not very well understood yet and so as such you will win every time you use entropy in an argument!". Avery (2003, p. 81) and Tribus and McIrvine (1971) report similar quotes from von Neumann.

differences between them. First, unlike Shannon, Wiener was eager to extend the concept of information to semantic and effectiveness problems. Second, while Shannon quantified information as positive entropy, Wiener thought *negative* entropy was the appropriate definition of information. Though from a strictly mathematical point of view this difference was only a matter of the sign of the expression, it had important implications for the newly created field of cybernetics.

In equating information with negative entropy, Wiener conceived the amount of information of a system as a universal measure of its degree of organization, in the same way entropy measured a system's degree of disorganization (Wiener, 1948a, p. 11). Order – in the mechanical, living, and social worlds – could only be created maintained if a sufficient quantity of information is produced so as to oppose the tendency of increasing entropy.

Defined in this way, information fit neatly into Wiener's general cybernetic framework. Negative feedback control systems are regulated by information which "is fed back to the control center [and] tends to oppose the departure of the controlled from the controlling quantity" (Wiener, 1948a, p. 118). Thereby, (closed-loop) control was reinterpreted by Wiener as communication (of information) with (negative) feedback, thus putting together all the conceptual pieces of cybernetics.

The historical origins of cybernetics can be traced to Wiener's work during World War II,[10] when the allies were seeking more effective methods to defend themselves against air attacks. Invited by Vannevar Bush, Norbert Wiener – who would later found cybernetics – started working with the engineer Julian Bigelow for the National Defense Research Committee (NDRC) on how to design a better way to control anti-aircraft artillery. In order to accomplish

[10] Wiener, in turn, based his work on the pre-war literature on control engineering and communication engineering and, in particular, on servomechanisms.

that, firing would have to aim at the best prediction of the future position of the enemy's plane based on the information available about its past path.

This prediction was not a simple matter because the pilots were trained to take evasive actions, such as zigzag courses, to avoid the allied artillery. Predicting the course of the planes, then, would require a *simulation* of the pilot's reaction to the shooting, for which Wiener and Bigelow employed servomechanisms. Unsurprisingly, after a while, they would find a problem with their prototype: sometimes the mechanism overcompensated its course corrections and oscillated violently due to positive feedback. Because of the urgency of the wartime needs and the practical difficulties involved in ensuring that the feedback mechanism would be of the negative type, Wiener's wartime project was terminated in 1943 without being effectively used by the allied forces (Conway and Siegelman, 2005, p. 88).

The end of Wiener's period in the military was immediately followed by the beginning of his work to take to the next level the analogy between servomechanisms and human behavior. He and Bigelow teamed up with the physiologist Arturo Rosenblueth in order to draw connections between the feedback mechanism they encountered in their anti-aircraft project and the one found in the electrical networks of the human brain.

Rosenblueth, Wiener and Bigelow (1943) interpreted all goal-directed action as being governed by a negative feedback processes. As a goal is being pursued, the course of action is constantly corrected by comparing the current distance from the goal with its anticipated position. If, for example, my goal is to pick up a pencil, my movements will be guided by the feedback provided by "the amount by which we have failed to pick up the pencil at each instant" (Wiener, 1948a, p. 7). In this view, a pathological condition such as purpose tremor (also called intention tremor) is interpreted as being caused by a malfunction of the feedback mechanism, leading the ill individual to undershoot or overshoot his target in an uncontrollable oscillation.

From this discussion, the authors drew some very interesting conclusions. First, there is no contradiction in systems being deterministic and teleological at the same time if a negative feedback mechanism is present. Second, teleology and purposeful behavior in general are possible both in the realms of the human and the machine. Goal-seeking behavior, thus, should not be viewed as a distinctly human feature. Third, as a consequence, organisms and machines could be described with the same vocabulary and studied by the same methods. As Gerovitch(2002) summarizes it, Wiener, Rosenblueth, and Bigelow "undermined the philosophical oppositions between teleology and determinism, between voluntary acts and mechanical actions, and ultimately between men and machines" (p. 62).

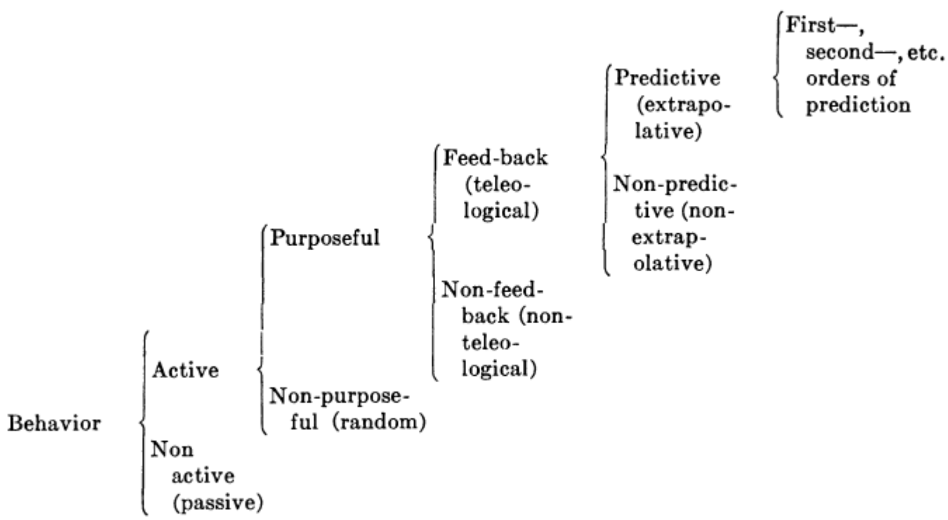

Figure 6. The classification of behavior (Rosenblueth, Wiener and Bigelow, 1948, p. 11).

In 1942, Rosenblueth presented the ideas he was developing with Wiener and Bigelow in a conference on "Cerebral Inhibition", sponsored by the Josiah Macy Foundation.

Rosenblueths's talk made quite an impact on the diversified audience, composed of psychiatrists like Warren McCulloch and social scientists such as Gregory Bateson and Margaret Mead.[11]

McCulloch would soon become a leading figure of the cybernetics movement. At that time, he was working with his younger colleague Walter Pitts in a project that aimed at understanding the brain as an electrical machine that performed logical calculations in a way similar to digital computers. The new ideas of circular causation and communication presented by Rosenblueth in the conference were fundamental to the paper McCulloch and Pitts would publish the next year. In this work, they conclude that systems with negative feedback can generate purposive behavior and that "activity we are wont to call mental are rigorously deducible from present neurophysiology" (McCulloch and Pitts, 1943, p. 132).

Similar ideas were being developed independently by the English psychiatrist William Ross Ashby, who would also join the cybernetics club later. In a sequence of three articles, Ashby (1945; 1947a; 1947b) aimed to understand the phenomena of self-organization and to apply his theory to the analysis of the brain. His conclusion was that "a machine can be at the same time (a) strictly determinate in its actions, and (b) yet demonstrate a self-induced change of organization" (Ashby, 1947a, p. 125). In fact, he maintained that the brain was an important example of such a machine.

Cybernetics would rapidly develop into a hot new field of research and would drag the attention of scholars from the most diverse areas of knowledge. From 1946 to 1953, some of these scholars gathered around in a series of ten meetings – the Macy Conferences – specifically devoted to discuss the new interdisciplinary field of control and communication that would become known as cybernetics. This group of researchers included prominent figures in the fields

[11] Margaret Mead reported being so excited with what she heard at the conference that she did not notice she had broken one of her teeth until the conference was over (Conway and Siegelman, 2005, p. 95).

of mathematics (Norbert Wiener, John von Neumann, Walter Pitts), engineering (Julian Bigelow, Claude Shannon, Heinz von Forster), philosophy (Filmer Northrop), neurophysiology (Arturo Rosenblueth, Ralph Gerard, Rafael Lorente de Nó), psychiatry (Warren McCulloch, Lawrence Kubie, Henry Brosnin), psychology (Heinrich Klüver, Kurt Lewin, Alex Bavelas, Joseph Licklider), biology (W. Ross Ashby, Henry Quastler), linguistics (Roman Jakobson, Charles Morris, Dorothy Lee), and the social sciences (Gregory Bateson, Lawrence Frank, Paul Lazarsfeld, Margaret Mead) (Heims, 1993, pp. 255-6).

Limited space precludes us from going through a more detailed inspection of the history of the cybernetics movement.[12] Suffice it to say that the influence of cybernetics extended far beyond the limits of the Macy Conferences, reaching some highly unsuspected audiences. In this context, it did not take long before the Austrian economist F. A. Hayek took note of cybernetic ideas and began to employ them in his works.

3. CYBERNETICS IN THE SENSORY ORDER

3.1. The Sensory Order and the quest for purposive behavior

In 1945, a year after publishing his popular book *The Road to Serfdom*, Hayek's journey on the road to servomechanisms would begin. This was the year he started to work on his book on theoretical psychology, *The Sensory Order*, which was based on a manuscript Hayek himself had written as a law student in 1920.

One important motivation for writing this book was to counter behaviorism, a doctrine that conceived psychology as the science of environmentally-determined behavior and opposed the use of concepts that made reference to "mental" states (Caldwell, 2004b, pp. 246-8). Hayek,

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[12] For a comprehensive history of the cybernetics movement, see Kline (2015). Mirowski (2002) is the seminal work on the influence of cybernetics and related developments on economics.

on the other hand, held the view that the facts of the social sciences could not be described in terms of the external environment and the physical properties of things, but only through the (subjective) belief that individuals formed about the objects of their environment.[13] One of his main tasks in TSO was to justify the use of mentalist concepts in the social sciences using arguments drawn from the natural sciences.

In the period between his first manuscript and the completion of the book, there were independent works that corroborated the conclusions previously reached by Hayek and which also provided him with conceptual tools to think through the problems he wanted to address. Among these works, we can highlight those authored by Wiener, Rosenblueth, McCulloch, Pitts, and Ashby, pioneer researchers in the field that would become known as cybernetics. As we will see, these works, grounded in the findings of the natural sciences, provided Hayek with fundamental evidence he would use in his explanation of purposive behavior.

Hayek's starting point in TSO is the existence of two different orders: the physical and the sensory order. In the physical order, objects are classified as similar or different according to their producing similar or different external events. But in the sensory order, objects are classified according to their sensory properties (colors, sounds, etc.). That these are two distinct orders is shown by the fact that there is no one-to-one correspondence between them.[14] Objects classified as of the same kind in the sensory order may be classified as of different kinds in the physical order and vice-versa (Hayek, 1952, pp. 1-3).

[13] "Take such things as tools, food, medicine, weapons, words, sentences, communications, and acts of production – or any one particular instance of any of these. I believe these to be fair samples of the kind of objects of human activity which constantly occur in the social sciences. It is easily seen that all these concepts (and the same is true of more concrete instances) refer not to some objective properties possessed by the things, or which the observer can find out about them, but to views which some other person holds about the things.[...] They are all instances of what are sometimes called 'teleological concepts,' that is, they can be defined only by indicating relations between three terms: a purpose, somebody who holds that purpose, and an object which that person thinks to be a suitable means for that purpose" (Hayek, 1943/2014, p. 80).

[14] That was the reason why he rejected Mach's theory according to which there existed such a one-to-one correspondence, with sensory qualities being all that ultimately existed.

What Hayek wanted to explain was how "the existence of a phenomenal world which is different from the physical world" (Hayek, 1952, p. 28) could be reconciled with the fact that ultimately the sensory order is a part of the physical order, i.e., that the brain is made of physical matter which also obeys the same laws of physics as any other physical event. The constitution of mind, then, was to be explained by means of physics: "We want to know the kind of process by which a given physical situation is transformed into a certain phenomenal picture" (Hayek, 1952, p. 7).

This is a particular way of formulating what in philosophy is known as the mind-body problem. Two aspects of this problem are often emphasized by philosophers of mind: those of qualia and intentionality. Qualia refer to subjective features of conscious experience; feelings and sensations that are only accessible to the person himself. Intentionality denotes the directedness shown by many mental phenomena that have meaning in the sense that they are about something else.

> Qualia are considered philosophically problematic insofar as it is difficult to see how their subjectivity can be explained in terms of the objective features of the brain and nervous system. […] Intentionality is problematic insofar as it is difficult to see how processes in the brain could have any more intrinsic meaning than squiggles of ink on paper or noises generated by the larynx. (Feser, 2006, pp. 308-9)

Let us consider first how Hayek dealt with qualia. According to him, the central nervous system displays a structure of fibers that enables the *classification* of neural impulses, converting them into the order of sensory qualities. For Hayek, then, the emergence of qualities is not due to original attributes of individual impulses, but results from the whole system of neural connections through which this impulse is transmitted. This "structure of fibers" or "system of neural connections" is developed in the course of the evolution of the species and the development of the individual:

> […] it is thus the position of the individual impulse or group of impulses in the whole system of such connexions which gives it its distinctive quality; that this system of connexions is acquired in the course of the development of the species and the individual by a kind of 'experience' or 'learning'; and that it

> reproduces therefore at every stage of its development certain relationships existing in the physical environment between the stimuli evoking the impulses. (Hayek, 1952, p. 53)

Hayek's solution to the problem of qualia, then, presupposes the concept of classification. As Feser (2006) noted however, classification "seem[s] clearly to be an intentional process, insofar as the classifications performed are taken to have meaning or significance rather than being mere mechanical operations" (p. 299). Therefore, in Hayek's thought, the existence of qualia presupposes the existence of intentionality,[15] which we will now consider.

Consider first Hayek's take on the relatively simple problem of intentional body movements. He fully endorsed the explanation of motor coordination given by cybernetics (as illustrated by Wiener's example of picking up a pencil). For him, (negative) feedback is present in the interaction between the proprioceptive (sense of strength of movement and relative position of nearby body parts) and exteroceptive (perception of the outside world) impulses.

> The choice of a kind of behaviour pattern and its continued control, modification, and adjustment while it takes place, will be a process in which the various factors act successively to produce the final outcome. […] In connexion with these continuous adjustments, made while the movement proceeds, the interaction between the exteroceptive and the proprioceptive impulses and the operation of the 'feed-back' principle become of special significance. […] [A]t first the pattern of movement initiated will not be fully successful. The current sensory reports about what is happening will be checked against expectations, and the difference between the two will act as a further stimulus indicating the required corrections. The result of every step in the course of the actions will, as it were, be evaluated against the expected results, and any difference will serve as an indicator of the corrections required. (Hayek, 1952, p. 95)

In fact, in a footnote placed in the same page as the above-quoted passage, Hayek refers his readers to the works of Wiener (1948a, 1948b), McCulloch (1948), and Ashby (1947, 1948, 1949), all of whom were important members of the cybernetics movement. Not only did he expresses approval of these authors' descriptions of the working of body movements, he also endorsed their vision that purposeful behavior is not a peculiar attribute of living beings, but could also be found in some types of machines.

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[15] In the passage quoted, Feser uses the term "mere mechanical operations" as the opposite of intentional or directed behavior. This usage, however, is somewhat misleading because, as we will see, Hayek sees some "mechanical" systems as displaying purposive behavior.

According to Hayek, a system displays purposive behavior if: (i) it can make some kind of representation (or "model") of the possible and desirable outcomes of different courses of action in a given existing situation and (ii) its actions are the result of a process of selection among the different courses of action that have desirable outcomes. In the case of the human brain, patterns of impulses in the nervous system form a model of the environment that pre-selects, from among the effects of alternative courses of action, the desirable ones. Then, the effective course of action that takes the "path of least resistance" (i.e., the course whose representation is associated with more attractive and less repellant qualities) is chosen from among these pre-selected courses of action. Moreover, this model (which determines what is possible, pre-selected, and selected) constantly evolves with experimentation and the contrast between expectation and reality (Hayek, 1952, pp. 124-6).

The human brain, though, is not unique in its capacity of generating purposive behavior. Much more simple organisms and machines exist and can be built which, by acting according to (i) and (ii), also display purposiveness. Here Hayek has in mind machines such as Wiener's anti-aircraft gun.

> That such guidance by a model which reproduces, and experimentally tries out, the possibilities offered by a given situation, can produce action which is purposive to any desired degree, is shown by the fact that machines could be produced on this principle (and that some, such as the predictor for antiaircraft guns, or the automatic pilots for aircraft, have actually been produced) which show all the characteristics of purposive behavior. (Hayek, 1952, p. 126)

Such machines are very primitive in comparison to the human brain. For instance, they can take account of much fewer facts in their environment, they do not have the capacity of learning from experience, and they do not display the feature of consciousness. But regarding purposiveness, Hayek sees them as differing from the human brain in degree, but not in kind.[16]

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[16] Besides cybernetics, Hayek (1952) also mentions an alternative approach to the explanation of purposive behavior given by "the more recent and most promising work of L. von Bertalanffy" (p. 83). He, however, did not make direct use of this approach in his argumentation in TSO.

He, however, maintained that a fully satisfactory explanation of human purposiveness required further research:

> […] it should be pointed out, however, that in one respect in which the task which we are undertaking is most in need of a solid foundation, theoretical biology is only just beginning to provide the needed theoretical tools and concepts. An adequate account of the highly purposive character of the action of the central nervous system would require as its foundation a more generally accepted biological theory of the nature of adaptive and purposive processes than is yet available. (Hayek, 1952, p. 80)

Hayek, therefore, did not believe that the "highly purposive" behavior of the human brain could be adequately explained solely by means of the concept of negative feedback. He nevertheless endorsed it as providing a good, even though not fully satisfactory, explanation of relatively *simple* purposeful behavior. Before we move on, it is important to clarify that I do not contend that Hayek drew his fundamental views on purposive behavior from cybernetics. In fact, it seems that his views were already formed before he had any contact with the ideas of this intellectual movement.[17] What I do contend is that Hayek's use of negative feedback in TSO was important because it gave scientific evidence in favor of his theory of the existence of multiple degrees of purposiveness, ranging from simple machines to the human brain.

In the beginning of the twentieth century, behaviorism was very influential in psychology, and its proponents claimed that mentalist descriptions of events – like those of subjectivist economists – had no place in rigorous scientific analysis. One of Hayek's tasks in TSO was to show that a description of human behavior in subjective terms could be scientifically legitimate. In order to support this claim, Hayek would tackle the mind-body problem, using both philosophical arguments and *scientific* ones he borrowed from, among other

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[17] Already in the first manuscript of "What is Mind?" dated in 1945, in which no sign of influence from cybernetics is found, Hayek writes that "it would seem to follow from our thesis that the difference between purely 'mechanical' and mental processes is not one of kind but merely one of degree, and that between the purely mechanical process of the simplest reflex type and the most complex mental process […] there can be an almost infinite number of intermediate types […] It is not likely that we shall be able to understand the peculiar character of conscious processes until we have got a little further in understanding the working of the probably much more extensive basis of mental but not-conscious processes on which the super-structure of conscious processes rests" (Hayek Collection, Box 128, Folder 34, p. 30).

sources, cybernetics. By identifying human purposive behavior as having the same nature as the behavior of negative feedback systems, Hayek was able to claim that the existence of subjective qualities and purposes was grounded in the rigorous findings of the natural sciences.[18]

3.2. Purposive behavior once again: The Within Systems' manuscript

Did Hayek succeed in giving a satisfactory solution to the mind-body problem? Not quite, for there is a clear gap in his thesis. This gap lies in his claim that the difference between simple purposive systems such as Wiener's anti-aircraft machine and more complex ones like the human brain was only a matter of degree. In what sense could both be regarded as the same kind of phenomena, if human purposiveness displays important features such as communicating meaning, which seems to be lacking in any conceivable machine?

Although Hayek sketched an explanation of the emergence of purposive behavior in general, he did not explain – not even in principle – the "higher" types of purpose that we encounter in the human brain, but not in simple machines. As we have already pointed out, Hayek showed awareness of this problem in TSO when he wrote that:

> An adequate account of the highly purposive character of the action of the central nervous system would require as its foundation a more generally accepted biological theory of the nature of adaptive and purposive processes than is yet available. (Hayek, 1952, p. 80)

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[18] However, the similarities between human purposive behavior and negative feedback systems should not be overstated. From Hayek's perspective, the basic difference between systems such as Wiener's anti-aircraft machine and the human brain lies not in their nature, but in their different degrees of complexity. According to Hayek, a difference in degree of complexity can generate a difference in the kind of explanation appropriate to account for the phenomena. Both the anti-aircraft machine and the human brain are purposive and, in principle, entirely reducible to physics. However, as the human brain itself is the apparatus of explanation, we can only explain in detail phenomena having a degree of complexity lower than that of the human brain. Therefore, it is practically impossible to reduce the human brain to its physical properties. This is only possible with respect to simpler purposive systems like the anti-aircraft machine. On this, see Hayek (1952, pp. 184-190). Koppl (2005) interprets this aspect of TSO as a "scientific defense of methodological dualism" (p. 389). The opposite view – that TSO represents a de-emphasis of subjectivism in favor of a methodology more oriented to complexity – is advocated by Caldwell (2004a).

Karl Popper's reaction to TSO just after it had been published makes explicit this weakness in Hayek's position. In a letter to Hayek in the same year the book was published, Popper writes:

> I am not sure whether one could describe your theory as a casual theory of the sensory order. I think, indeed, that one can. But then, it would also be the sketch of a casual theory of the mind. But I think I can show that a causal theory of the mind cannot be true (although I cannot show this of the sensory order); more precisely, I think I can show the impossibility of a casual theory of the human language [...]. I am now writing a paper on the impossibility of a casual theory of the human language, and its bearing upon the body-mind problem, which must be finished in ten days. (Hayek Collection, Box 44, Folder 1)

In the promised article, published in 1953, Popper argued that a causal theory of the human mind could not explain some of the functions displayed by human language. Drawing from the psychologist and linguist Karl Bülher, Popper said that it was possible to distinguish at least four different functions of language. From the lower to the higher level, they were: (1) the expressive or symptomatic function; (2) the stimulative or signal function; (3) the descriptive function and (4) the argumentative function. One of the main theses of the paper was that "Any causal physicalistic theory of linguistic behaviour can only be a theory of the two lower functions of language" (Popper, 1953).

Hayek's theory of the mind was a causal physicalistic one that claimed that all mental phenomena (including linguistic behavior) could be in principle – though not in practice – reduced to physical ones. In order to counter Popper's claims, Hayek would have to further elaborate his theory with the aim of providing an explanation of the principle of these phenomena. It seems that it was this that motivated him to write the unfinished manuscript entitled "Within Systems and About Systems: A Statement of Some Problems of a Theory of Communication":

> If our aim is to be achieved, we must succeed in producing models which produce in kind such mental functions as "thinking" or "having an intention" or "haming"[sic], or "describing", or "communicating a meaning", or "drawing an inference" and the like [...]. It will be sufficient if we can construct an instance which possesses all the characteristics which are common to all the instances to which we commonly apply any one of these terms. (Hayek Collection, Box 129, Folder 7, p. 3)

In this paper, he postulates systems (which could be organisms or machines) capable of the same process of classification he described in TSO. After a long preliminary discussion of the features of the system and of its isolated interaction with its environment, Hayek proceeds to analyze the communication between two systems of the kind described. These two systems possessed identical structures and differed only in their respective short-term memories. Hayek's strategy here is to consider this simple case in order to provide an explanation of the principle for the first three of the four levels of langue discussed by Popper.

A system expressing its inner state to another similar system (the first function of language) involves no greater complication than a system interacting with its environment. In the same way that a classifying system can learn to interpret and predict events in its environment, it can also learn to interpret and predict the actions of a system expressing its inner state. The second function of language (the stimulative one) is performed when a system communicates a signal which regularly causes a particular response from another system (or a response belonging to a particular class).

Again, the situation in this second case is not significantly different from the one of a system interacting solely with its environment. This was illustrated in the same paper by an example Hayek gave of a cybernetic system that regulates its stock of fuel through negative feedback. When the stock of fuel is low, the system responds so as to get more fuel from its environment. No additional difficulty arises if we suppose that the information about the fuel level is conveyed by another system. This second system would communicate a signal that could trigger a reaction from the first system, thus performing the stimulative function of language.

With his general scheme, then, Hayek was able to generate the first two functions of language. The paper ends abruptly, though, in the middle of his attempt to explain the third (descriptive) function of language, i.e., explaining the communication of a symbol that evokes the same class of responses both in the emitter and the receiver. Even worse: Hayek does not mention the argumentative function, leaving unexplained two of Popper's four functions of language. Therefore, in his unfinished manuscript, Hayek "had failed to explain one or more higher functions of language within his theory – *as Popper had predicted!*" (Birner, 2009, p. 189, emphasis in the original).

Hayek ultimately did not succeed in explaining the principle of the highly purposive behavior displayed by human beings as illustrated by their uses of language. It seems like negative feedback was not enough to account for the workings of human purpose, which left a technically limited Hayek helpless when confronted with this huge challenge. Hayek's use of cybernetics, however, did not end there. When Hayek, after learning about this intellectual movement, turned his attention from the sensory order back to the social order, he saw that he could restate and further elaborate his old ideas using the same concepts he employed in TSO. Self-regulating machines and organisms, which Hayek had previously used as analogs for the human brain, would later be used by Hayek as analogs for human society.

4. CYBERNETICS IN THE SOCIAL ORDER

4.1. Brain, society, and the knowledge problem

What does the human brain have in common with human society? A lot, Hayek would answer. After finishing TSO, he would use many ideas he developed in this book in the study of social phenomena and the methodology of science. However, we must avoid the temptation of describing TSO as some kind of foundation for his later works. The relationship between TSO and Hayek's other works is much more complicated. As Hayek himself pointed out, influences flow not only from TSO to his other works, but also the other way around:

> My colleagues in the social sciences find my study on *The Sensory Order* uninteresting or indigestible … But the work on it helped me greatly to clear my mind on much that is very relevant to social theory. My conception of evolution, of a spontaneous order and of the methods and limits of our endeavours to explain complex phenomena have been formed largely in the course of work on that book. As I was using the work I had done in my student days on theoretical psychology in forming my views on the methodology of the social science[s], so the working out of my earlier ideas on psychology with the help of what I had learnt in the social science helped me greatly in all my later scientific developments. (Hayek, 1979, p. 199)

It is important to clarify this in order to guard against possible misunderstandings of the discussion that will be offered in this section. In the present work, we are not interested in tracing every relationship between TSO and Hayek's later works.[19] Our aim is the more humble one of analyzing this issue solely from the point of view of the ideas and concepts of cybernetics. Restricting the scope of analysis in this way, and recalling that Hayek makes no reference to this theory before he started working on TSO,[20] it becomes evident that the use of its ideas proceeded chronologically from TSO to his other works. Our task, therefore, will be to describe how the ideas of cybernetics, initially used by Hayek to understand the sensory order, became part of the way he would conceive of social orders (and spontaneous orders in general).

In 1977, Hayek was invited to present on "The Sensory Order After 25 Years" at a conference organized by psychologists interested in his long neglected book on theoretical psychology.[21] In the discussion that followed the presentation, a member of the audience asked Hayek to elaborate on the parallels between the human brain and the economic system that were implicit in his theory. His response was the following:

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[19] The interested reader should refer to the extensive discussion made by various authors in Butos (2010a), a volume of the book series *Advances in Austrian Economics* tiled *The Social Science of Hayek's 'The Sensory Order'*. Also relevant to this theme are Butos and Koppl (2007) and Gick and Gick (2001).

[20] Interestingly, references to cybernetics are not to be found either in *The Constitution of Liberty* (1960/2011), the project Hayek started just after finishing TSO and which was published eight years after his book on theoretical psychology.

[21] Walter B. Weimer, the cognitive psychologist who organized this conference, had an important role in bringing more attention to the relevance of *The Sensory Order* to modern cognitive psychology and to the social sciences. On this, see Butos (2010b, pp. 2-4).

> In both cases we have complex phenomena in which there is a need for a method of utilizing widely dispersed knowledge. The essential point is that each member (neuron, or buyer, or seller) is induced to do what in the total circumstances benefits the system. Each member can be used to serve needs of which he doesn't know anything at all. Now that means that in the larger (say, economic) order, knowledge is utilized that is not planned or centralized or even conscious […] In our whole system of actions, we are individually steered by local information – information about more facts than any other person or authority can possibly possess. And the price and market system is in that sense a system of communication, which passes on (in the form of prices, determined only on the competitive market) the available information that each individual needs to act, and to act rationally. (Hayek, 1982, pp. 325-6)

According to Hayek, then, both society and the brain are complex self-organizing systems. But the keyword here is *information* – or, alternatively, *knowledge* (Scheall, 2015; Hayek, 1973, p. xvii-xix). These are systems in which the information possessed by the whole is dispersed among its numerous parts and in which each part could not possibly grasp all the knowledge of the whole. In both systems, the mutual coordination of the parts (neurons or individuals) is reached not by each part's explicit mastery of a large amount of information of the system (brain or society), but by the tacit use of information implicitly conveyed by the operation of the rules that constrain the relationship between the parts (such as the structure of neural firing paths and the price system).[22]

This leads us back to Hayek's seminal article, "Economics and Knowledge" (1937/2014), in which he explicitly introduced the broad and interdisciplinary research program of coordination he would pursue until the end of his life.

> Though at one time a very pure and narrow economic theorist, I was led from technical economics into all kinds of questions usually regarded as philosophical. When I look back, it seems to have all begun, nearly thirty years ago, with an essay on "Economics and Knowledge" in which I examined what seemed to me some of the central difficulties of pure economic theory. Its main conclusion was that the task of economic theory was to explain how an overall order of economic activity was achieved which utilized a large amount of knowledge which was not concentrated in any one mind but existed only as the separate knowledge of thousands or millions of different individuals. But it was still a long way from this to an adequate insight into the relations between the abstract overall order which is formed as a result of his responding, within the limits imposed upon him by those abstract rules, to the concrete particular circumstances which he encounters. It was only through a re-examination of the age-old concept of freedom under the law, the basic conception of traditional liberalism, and of the problems of the philosophy of the law which this raises, that I have reached what now seems to be a tolerably clear picture of the nature

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[22] Although society and brain are organized on similar principles, "society is not a brain and must not be represented as a sort of super-brain" (Hayek, 1967a/2014, p. 286). Contrary to the brain, which directs the organism, society does not work as a directing center.

> of the spontaneous order of which liberal economists have so long been talking. (Hayek, 1965/2014, pp. 49-50)

In this article, Hayek considers the difficulties for the concept of equilibrium posed by the subjectivity and dispersion of knowledge. At the level of society, equilibrium means mutual compatibility of individual plans. This compatibility, in turn, requires that each individual possess correct knowledge about the planned actions of others on which the execution of his plan depends. Hayek asks how this state of affairs is realized. How, starting from a situation of disequilibrium, is equilibrium approached? What process accounts for the acquisition and communication of "more correct" knowledge that enables a tendency to equilibrium? (Hayek, 1937/2014).

In "The Use of Knowledge in Society" (1945/2014), Hayek would make a first step in the direction of providing an answer to this problem by considering "the price system as such a mechanism for communicating information" (p. 100). The execution of the plans of the individuals determine the existing relative market prices. As these plans are based on each individual's knowledge of his particular circumstances of time and place, the price system is a reflection of private information dispersed among the many components of a society. Thus, prices implicitly convey important information to individuals that they could not acquire otherwise.

Cybernetics, with its emphasis on the relationship between information and organization, seemed to Hayek to provide a good approach to his problem of the emergence of social coordination. The way cybernetics was initially applied to the analysis of society, however, would not be very satisfactory from Hayek's perspective. None other than Wiener, the most central figure of the cybernetics movement, explicitly ridiculed the view that the market exhibited any self-regulating mechanism.

> There is a belief, current in many countries, which has been elevated to the rank of an official article of faith in the United States, that free competition is itself a homeostatic process: that in a free market, the individual selfishness of the bargainers, each seeking to sell as high and buy as low as possible, will result in the end in a stable dynamics of prices, and with redound to the greatest common good […] Unfortunately, the evidence, such as it is, is against this simple-minded theory […] There is no homeostasis whatever. We are involved in the business cycles of boom and failure, in the successions of dictatorship and revolution, in the wars which everyone loses. (Wiener, 1948a, p. 159)

Given Wiener's central role in the field of cybernetics, it is instructive to further explore his social theory and compare it to Hayek's. In spite of his critical remarks on free competition, Wiener's discussion of the cybernetics of society hints at some very important Hayekian points. Just as any organism, a society is held together "by the possession of means of acquisition, use, retention, and transmission of information" (Wiener, 1948a, p. 161). Besides, the information available to society has to be distinguished from the information available to the individual. Contrary to the information available only to the individual, the information available to society "can be recognized as a distinct form of activity by other members of the race, in the sense that it will in turn affect their activity, and so on" (Wiener, 1948a, p. 157).

The implications Wiener drew from all of this, however, were very different from Hayek's. The means of communication of a society too large for direct contact among its members, according to Wiener, would be the written word (books and newspapers), the radio, the telephone system, the telegraph, the posts, the theater, the movies, the schools, and the church. Each of these, besides their primary function as means of communication, also serves secondary functions determined by the private interests of their controllers (owners, administrators, advertisers, etc.). In a society strongly based on private property and monetary transactions, these secondary functions tend to encroach on the primary one of communication, thus making less information available at the social level and, consequently, hindering the attainment of social homeostasis (Wiener, 1948a, p. 161).

Contrasting Wiener's perspective with Hayek's, what attracts one's attention is not only their ideological differences, but what each of them took to be the main communication mechanisms that would promote social order. Wiener's discussion deals solely with *deliberately-created* information and its vehicles of communication. It seems like he did not consider that there existed important non-designed and tacit means of communication among men. What about, say, the price system? Despite its flaws, does it not convey indispensable information about the relative scarcities of different goods in an economy? From a Hayekian point of view, it could be said that Wiener took the explicit knowledge tip of a big tacit knowledge iceberg as if it was the whole thing.

4.2. Hardin and the invisible hand of evolution

As we have seen, Hayek did not profit much from Wiener's particular views on social cybernetics. Closer to him on this issue was the cybernetic-inspired biologist and ecologist Garrett Hardin. In his famous book on the history of the theory of evolution, *Nature and Man's Fate* (1959), Hardin interpreted the Darwinian adaptation process as a cybernetic system and compared it to the natural price doctrine of classical economists such as Adam Smith and David Ricardo. He maintains that "In the Darwinian scheme, the concept of the 'fittest' has the same normalizing role as that played by the 'natural' process of commodities or labor in economics" (Hardin, 1959, p. 55).

Both systems are organized not by the intentional action of its components, but by spontaneous regulating forces that act as negative feedback, as shown in figures 7 and 8. When a variable (market price or species' trait) deviates from its norm (natural price and fittest trait) in one direction, counteracting forces push this variable in the opposing direction, generating a tendency of gravitation towards the norm. In short, Smith's "invisible hand" was actually a "cybernetic hand", which had a very close analog in the Darwinian adaptation process.

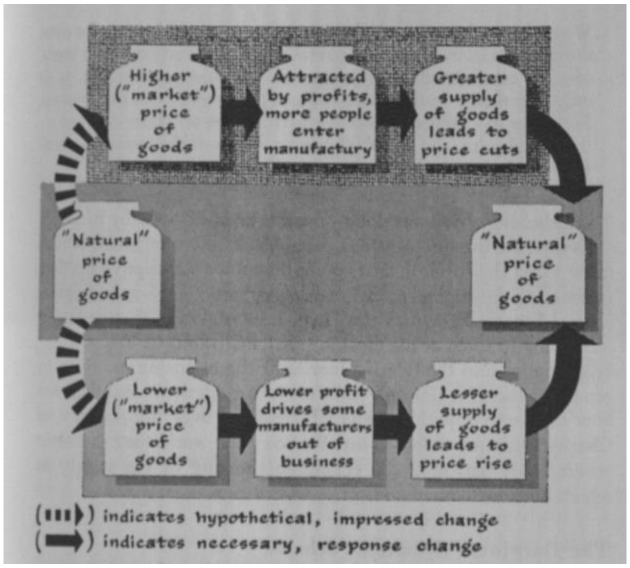

Figure 7. The cybernetic system of price regulation in classical economics (Hardin, 1959, p 53).

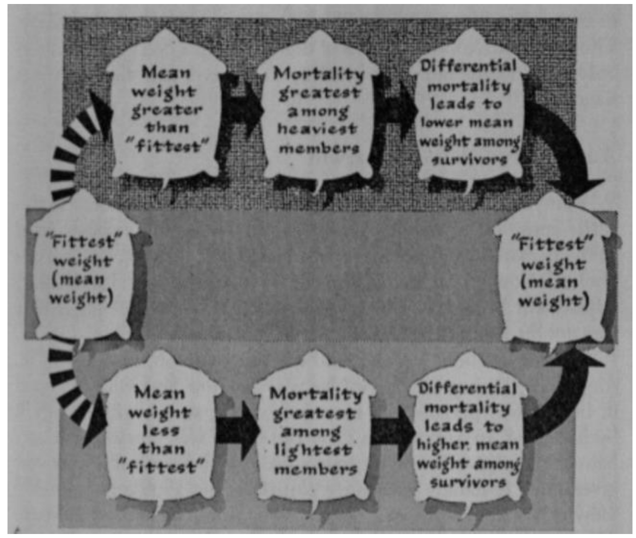

Figure 8. The cybernetic system of trait regulation in Darwinian evolution (Hardin, 1959, p. 55).

These adjustment processes are not costless. They incur "waste" in the form, say, of bankruptcy of businesses and the death of fitness-deviating specimens. An infinitely wise designer could get rid of this waste by substituting the direct control of the variable (setting it to the level of its norm) for the indirect operation of the process of adaptation. But, as this wise designer is not to be found in either case, we must resort to the cybernetic scheme of adaptation and accept that the existence of some waste is not only inevitable, but a necessary condition for the regulation of the system.

> The first glimmerings of the importance of waste are quite old, but waste did not really come into its own until the last of the eighteen century, with the work of economists, particularly of Adam Smith (and later Ricardo). Before them, many economists dreamed of a world made perfect and waste-free through law – through regulations governing the prices of commodities, for example. […] In effect, Smith said that the world is best and most equitably governed when waste governs it. It does not matter if some men place too high and others too low a price on a commodity. The former goes bankrupt from too little business, the latter from too much; their wiser competitors survives. Through waste, we learn what is the "right" price. [...] That which man's poor intellect may be incapable of creating directly can be produced indirectly through the waste-actuated Smith-Ricardian cybernetic system. It was Darwin's genius to show that the same system would explain the fact of biological adaptation. (Hardin, 1959, pp. 326-7)[23]

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[23] Compare: "If anyone really knew all about what economic theory calls the *data*, competition would indeed be a very wasteful method of securing adjustment to these facts […] Against this, it is salutary to remember that […]

The apparently incredible claim of evolution is that "In order to make a perfect and beautiful machine, it is not requisite to know how to make it… Design emerges from blind Waste*"* (Hardin, 1959, pp. 301-2). But why is this waste not quickly eliminated by the selection process? The first reason why is that mutations constantly occur, although not with a high frequency. The second and more important reason is that the selection process is not perfect because it lumps together genetically and environmentally determined variations.

> Everyone knows that the size of an adult animal is determined by both its heredity and its environment, particularly by the nutrition received during youth […] But the individual who successfully runs the gantlet can pass on to his offspring only what he possesses in the way of hereditary capabilities, divested of environmental "luck". This makes for a certain inexactness in the selective process; some might even use the word "injustice". Be that as it may, Nature's confounding of heredity and environment in the selective process is one of the explanations of the continuing variability of succeeding generations. [...] The generation of error is without end. (Hardin, 1959, p. 63)

Hayek read Hardin's[24] book and made very similar remarks about how the price mechanism operated as a cybernetic system. This would constitute an important part of the answer to the coordination problem he formulated in his 1937 article. Indeed, Hayek would argue that the mutual adjustment of individual plans he had previously talked about "is brought about by what, since the physical sciences have also begun to concern themselves with spontaneous orders, or 'self-organizing systems', we have learnt to call 'negative feedback' " (Hayek, 1968/2014 p. 309).[25] Besides, as some "intelligent biologists" like Hardin had

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competition is valuable *only* because, and so far as, its results are unpredictable and on the whole different from those which anyone has, or could have, deliberately aimed at" (Hayek, 1968/2014, pp. 304-5).

[24] Hardin was also familiar with Hayek's works. There are a couple of letters from Hardin to Hayek in the Hayek Archives at the Hoover Institute. In one of them, dated in 1978, Hardin thanks Hayek for sending a copy of "The Three Sources of Human Values" (part of the postscript of *Law, Legislation and Liberty*), saying that he profited a lot from reading it. He also mentions a presentation by Hayek on a Sociobiology meeting where the audience was "unequipped to appreciate the wisdom" of the speaker (Hayek Collection, Box 23, Folder 22). Later, Hardin wrote a review of Hayek's book *The Fatal Conceit*, mainly criticizing it for not taking seriously the population problem (Hardin, 1989).

[25] See also: "It was the great achievement of economic theory that, 200 years before cybernetics, it recognized the nature of such self-regulating systems in which certain regularities (or, perhaps better, 'restraints') of conduct of the elements led to constant adaptation of the comprehensive order to particular facts" (Hayek, 1970/2014, p. 345) and "in the language of modern cybernetics, the feedback mechanism secures the maintenance of a self-

recognized, "the idea of the formation of spontaneous or self-determining orders, like the connected idea of evolution, has been developed by the social sciences before it was adopted by the natural sciences" (Hayek, 1968/1978, p. 74).

At least in part because of his lack of adequate technical training,[26] Hayek would never develop a formal cybernetic model of the price system. The work in which he would best develop the understanding of price changes as conveying negative feedback is *Law, Legislation and Liberty*:

> The correspondence of expectations that makes it possible for all parties to achieve what they are striving for is in fact brought about by a process of learning by trial and error which must involve a constant disappointment of some expectations. The process of adaptation operates, as do the adjustments of any selforganizing system, by what cybernetics has taught us to call negative feedback: responses to the differences between the expected and the actual results of actions so that these differences will be reduced. This will produce an increased correspondence of expectations of the different persons so long as current prices provide some indications of what future prices will be, that is, so long as, in a fairly constant framework of known facts, always only a few of them change; and so long as the price mechanism operates as a medium of communicating knowledge which brings it about that the facts which become known to some, through the effects of their actions on prices, are made to influence the decision of others. (Hayek, 1976, pp. 124-5)

Here Hayek goes beyond Hardin, developing his own theory of spontaneous plan coordination in cybernetic terminology. In this passage, he seems to be trying to provide an answer to the question he posed thirty years earlier about what are the conditions for a tendency to equilibrium.[27] Compare this to the following quote from "Economics and Knowledge":

> … the assertion that a tendency towards equilibrium exists … can hardly mean anything but that, under certain conditions, the knowledge and intentions of the different members of society are supposed to come more and more into agreement or, to put the same thing in less general and less exact but more concrete terms, that the expectations of the people and particularly of the entrepreneurs will become more and more

generating order. It was this which Adam Smith saw and described as the operation of the 'invisible hand' - to be ridiculed for 200 years by uncomprehending scoffers" (Hayek, 1978, p. 63).

[26] "By the late 1950s it appears that Hayek began to realize that he simply lacked the mathematical background to formalize his ideas within psychology. He then tried to express them within economics […] again with at best limited success. Ultimately, he decided to express his ideas verbally by identifying a variety of fields that studied complex orders, and from which he drew conclusions about their characteristics" (Caldwell, 2015, p. 29).

[27] Except that in LLL he substitutes the concept of order for the one of equilibrium. The difference between the two is that while equilibrium requires a perfect compatibility of plans, order requires only partial compatibility, so we "can meaningfully speak about an order being approached to various degrees, and that order can be preserved throughout a process of change" (Hayek, 1968/2014, p. 308). For a great discussion about Hayek's concept of order and its implications for economics, see Vaughn (1999a).

> correct. In this form the assertion of the existence of a tendency towards equilibrium is clearly an empirical proposition, that is, an assertion about what happens in the real world which ought, at least in principle, to be capable of verification […] The only trouble is that we are still pretty much in the dark about (a) the *conditions* under which this tendency is supposed to exist and (b) the nature of the *process* by which individual knowledge is changed. (Hayek, 1937/2014, p. 68)

Thirty years later, he was no longer "pretty much in the dark" about (a) and (b). The nature of the process of change of individual knowledge would be provided by negative feedback, i.e., by the error correction that follows the contrast between expectations and reality. The conditions for the existence of a tendency to spontaneous ordering enumerated by Hayek, however, are in need of further clarification.

First, the price mechanism can only function properly as a "medium of communicating knowledge" if prices are let free to fluctuate according to the existing market conditions. Price controls undermine the knowledge-coordinating function of the price system because they restrict the amount of knowledge used in the determination of prices to that possessed by the few bureaucrats in charge. For this reason, we should not dispense with the free operation of the price mechanism, even when it leads to some unwanted outcomes:

> The frequent recurrence of such undeserved strokes of misfortune affecting some group is, however, an inseparable part of the steering mechanism of the market: it is the manner in which the cybernetic principle of negative feedback operates to maintain the order of the market. It is only through such changes which indicate that some activities ought to be reduced, that the efforts of all can be continuously adjusted to a greater variety of facts than can be known to anyone person or agency, and that that utilization of dispersed knowledge is achieved on which the well-being of the Great Society rests. (Hayek, 1976, p. 94)

Just as the actual fitness of a specimen is determined by the combination of its hereditary capabilities and its environmental luck, the reward of an individual in the market is the product both of his skills and of his individual luck. The market is no "meritocracy." On the contrary, often we see undeserving people being highly rewarded and deserving ones receiving very little remuneration. The attempt to remedy these seemingly unfair outcomes by interfering with the price system, however, is misguided, for it ignores that we cannot know enough to dispense with the coordination brought by freely adjusting prices.

> It may be difficult to understand, but I believe there can be no doubt about it, that we are led to utilize more relevant information when our remuneration is made to depend indirectly on circumstances we do not know. It is thus that, in the language of modern cybernetics, the feedback mechanism secures the maintenance of a self-generating order […]. It is indeed *because* the game of catallaxy disregards human conceptions of what is due to each, and rewards according to success in playing the game under the same formal rules, that it produces a more efficient allocation of resources than any design could achieve. […] It is not a valid objection to such a game, the outcome of which depends partly on skill and particular individual circumstances and partly on pure chance, that the initial prospects for different individuals, although they are all improved by playing that game, are very far from being the same. (Hayek, 1978, p. 64)

The second clarification regards what Hayek has in mind when he talks about the need of a fairly constant *framework* of known facts. Here he is referring to the institutional background of a society – its systems of laws, social norms, and customs – that may enable the individual to anticipate the likely outcomes of his actions (Vaughn, 1999a, p. 140). The degree of effectiveness of the price mechanism depends crucially on the society's system of rules of conduct, which can promote or preclude social coordination. For example, no one would deny the important role in the social order played by the enforcement of private property rights and contracts or by the degree in which people can be trusted to be honest and keep the promises they make.

To sum up: the existence and character of social orders in general (and of price-coordination in particular) depend on the *structure* of rules of conduct observed in society. Therefore, a satisfactory explanation of social order would need to address how these rules of conduct were originated, and how they are maintained or changed over time. This leads us to Hayek's theory of cultural evolution, in which he tries to explain exactly the origins and development of social rules of conduct.

4.3. Bertalanffy and the appropriate scope of cybernetics

Given Hayek's endorsement of Hardin's analogies between the price mechanism and the Darwinian process of selection, one could expect that Hayek would also conceive cultural evolution as a cybernetic process regulated by negative feedback. Nowhere does he do that however. The reason for this seems to be that he had learned from his “Viennese friend” Ludwig von Bertalanffy that dynamic processes such as evolution could not be adequately analyzed solely with the tools of cybernetics.

Bertalanffy was an Austrian biologist and philosopher who created general system theory, a field of research aimed at extending analogies between disciplines even beyond those made by cybernetics. While the aim of cybernetics was to study systems that involved control and communication in the animal and machine, general system theory intended to study general properties that applied to systems *in general*.

We cannot go into detail here about the project of general system theory beyond pointing out its relationship with cybernetics as seen by Bertalanffy.[28] The relevant distinction here is between the cybernetician's view of goal-seeking behavior as the result of information and negative feedback, and the general system theoretician's view of equifinality as a result of open systems feeding from negative entropy.

According to the second law of thermodynamics, closed systems display a general tendency towards maximum entropy or disorder. In contrast, in the living world, there seems to exist a tendency to higher order, as organisms evolve and develop. How can both things be conciliated? Bertalanffy answers this question by conceiving living organisms as open systems. Differently from closed systems, where there is no exchange of matter between its inside and outside, open systems import and export materials from their external environment. Thus, by “importing complex organic molecules, using their energy, and rendering back the simpler end

[28] For more on Bertalanffy and general system theory, see Drack and Pouvreau (2007, 2015) and Pouvreau (2014). For a great discussion on the relationship between Hayek and Bertalanffy, readers should refer to Lewis (2015).

products to the environment" (Bertalanffy, 1950b, p. 26), the organism feeds from negative entropy.

For Bertalanffy, an important difference between open and closed systems is that the former can display equifinality. In closed systems, the final state of the system is always determined by its initial conditions. In this case, if initial conditions or the process are changed, so is the final state. In contrast, equifinality may be said to be present in a system where the same final state can be reached from different initial conditions and in different ways – i.e., it does not presuppose a predetermined structure or mechanism. Only open systems, by exchanging materials with the environment and importing negative entropy, can display equifinal behavior (Bertalanffy, 1950b, p. 25). One example of equifinality is the growth of larvae, in which "the same final result, namely a typical larva, is achieved by a complete normal germ of the sea urchin, by a half germ after experimental separation of the cells, by two germs after fusion, or after translocations of the cells" (Bertalanffy, 1950a, p. 157).

Bertalanffy was aware of the cybernetics literature on goal-seeking behavior in feedback systems, but maintained that his concept of equifinality in open systems was the more general one. According to him, implicit in the explanation of purposive behavior as a result of feedback was the assumption of a fixed structure that guaranteed the desired result (Bertalanffy, 1950a, p. 159). This perspective, though, contrary to the open system's view, would not be adequate for dealing with cases where the structure itself evolves. In the case of organic systems, Bertalanffy differentiates between secondary regulations (due to feedback mechanisms) and primary regulations (due to equifinality in general):

> […] the *primary regulations* in organic systems, i.e., those which are most fundamental and primitive in embryonic development as well as in evolution, are of the nature of dynamic interaction. They are based upon the fact that the living organism is an open system, maintaining itself in, or approaching a steady state. Superposed are those regulations which we may call *secondary*, and which are controlled by fixed arrangements, especially of the feedback type […] Thus dynamics is the broader aspect, since we can

> always arrive from the general system of laws to machinelike function by introducing suitable conditions of constraint, but the opposite is not possible. (Bertalanffy, 1968, p. 44)

According to Bertalanffy, cybernetic models can only account for orders generated through the secondary regulations of a given fixed structure (in the case of Hayek's social theory, a given structure of rules of conduct). Those ordered processes that involve changes in the structure itself – such as evolution – should be conceived as the result of the primary regulations of open systems. In other words, negative feedback explained homeostasis, but not heterostasis:

> Concepts and models of equilibrium, homeostasis, adjustment, etc., are suitable for the maintenance of systems, but inadequate for phenomena of change, differentiation, *evolution*, negentropy, production of improbable states, creativity, building-up of tensions, self-realization, emergence, etc.; as indeed Cannon realized when he acknowledged, beside homeostasis, a "heterostasis" including phenomena of the latter nature. (Bertalanffy, 1968, p. 23, emphasis added)

Hayek makes very similar remarks about the limitations of homeostasis as a means of attaining and preserving order. Changes in the environment, says Hayek, sometimes require changes in the structure of rules of conduct if the order of the whole is to be preserved:

> From any given set of rules of conduct of the elements will arise a steady structure (showing '*homeostatic*' control) only in an environment in which there prevails a certain probability of encountering the sort of circumstances to which the rules of conduct are adapted. A change of environment may require, if the whole is to persist, a change in the order of the group and therefore in the rules of conduct of the individuals; and a spontaneous *change of the rules of individual conduct* and of the resulting order may enable the group to persist in circumstances which, without such change, would have led to its destruction. (Hayek, 1967a/2014, pp. 282-3, emphasis added)

Bertalanffy's conceptions of primary and secondary regulations had a counterpart in Hayek's discussion of what he called the twin ideas of evolution and spontaneous order. In short, the twin ideas thesis asserts that "the problem of the origin or formation and that of the manner of functioning of social institutions was essentially the same" (Hayek, 1967b/2014, p. 298). By that Hayek meant that the current structure of institutions of a group and the functions performed by those institutions are determined jointly by the evolutionary history of the group, in which structures of institutions that generated functional orders relative to the environment they encountered were selected instead of the competing ones.

Although Hayek attributes the original insight of the close relationship between evolution and spontaneous order to the thinkers of the Scottish Enlightment and to the later Carl Menger,[29] it was from Bertalanffy that he got the conceptual framework that enabled him to articulate and justify this alleged intimate relationship. Significantly, there is an apparent influence from Bertalanffy in the way Hayek links the "dynamics" of evolution to the "statics" of spontaneous orders. As Lewis pointed out:

> … some of the key components of the analytical framework in terms of which Hayek articulates and develops his Mengerian insight about the need to combine static and dynamic analysis—the conceptual glue that holds the notions of spontaneous order and evolution together, if you will—are, as we have seen, ones that Hayek obtains from Bertalanffy. […] Hayek used Bertalanffy's ideas to express and develop Menger's insight about the intimate connection between the origin and manner of functioning of social institutions in a modern idiom, namely the language of system theory. (Lewis, 2015, p. 22)

This influence from Bertalanffy had important consequences for the scope of cybernetics in Hayek's work. Just as Bertalanffy had argued before him, Hayek viewed cybernetics as enabling only the study of orders generated by a given static structure. According to Hayek, this is the case with respect to the price system, which, provided it is embedded in a larger framework of suitable social institutions, can maintain a reasonable degree of individual plan coordination These social institutions, in turn, are formed and changed over time through a larger dynamic process of cultural evolution.

5. CONCLUSION

[29] Hayek's linking of evolution to self-organization was not original even if we restrict ourselves to the cybernetics literature. Ashby (1947a; 1947b; 1948) had already made this connection and developed a complete theory of the relationship between both concepts in his paper "Principles of the Self-Organizing System" (Ashby, 1962). This paper was presented in the 1961 University of Illinois Symposium of Self-Organization, in which Hayek, Bertalanffy, and McCulloch were present. Unfortunately, Hayek did not present a work in this conference and the rather short transcripts of the discussions that followed the presentations do not contain any useful information regarding Hayek's opinions about the ideas exposed at the event. The symposium was organized by Heinz von Foerster and George Zopf Jr.

In this paper, we have seen how Hayek used cybernetic concepts and ideas from his book *The Sensory Order* in his later works on the nature and origins of social order. It was argued that Hayek's initial interest in this theory lay in its potential to explain purposive behavior and, thus, to provide a scientific justification for the subjectivist approach to the social sciences. This part of Hayek's project, however, could not be completed as Hayek was unable to provide a satisfactory answer to Popper's challenge.

Later, Hayek would use the framework of cybernetics to restate and further develop his ideas on the spontaneous formation of orders. One of the central institutions that allows social coordination – the price mechanism – would be described by Hayek as a cybernetic system. Consistent with Bertalanffy's assessment of the scope of cybernetics, Hayek's theory described the operation of feedback systems as depending on a given structure which is originated and changed by a dynamic process. Hayek's particular conceptualization of this dynamic process, in turn, would take the form of a theory of cultural evolution.

Recall that, in the epigraph of the present paper, Hayek said that investigations of the problem of complex self-organized orders had become so numerous that he had not been able to study more than a few of them closely. Among the few he did study closely were works from the field of cybernetics. By exploring how cybernetics influenced Hayek throughout his career, we hope to have contributed to a better understanding of Hayek's own conception of complexity and, ultimately, to a better understanding of Hayek's system of thought as a whole.

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