

UNIVERSIDADE DE SÃO PAULO

Faculdade de Economia, Administração e Contabilidade

Programa de pós-graduação em Economia

**Hayek and complexity: coordination, evolution and methodology in
social adaptive systems**

**Hayek e a complexidade: coordenação, evolução e metodologia em sistemas sociais
adaptativos**

Gabriel Oliva Costa Cunha

São Paulo

2016

Prof. Dr. Marco Antonio Zago
Reitor da Universidade de São Paulo

Prof. Dr. Adalberto Américo Fischmann
Diretor da Faculdade de Economia, Administração e Contabilidade

Prof. Dr. Hélio Nogueira da Cruz
Chefe do Departamento de Economia

Prof. Dr. Márcio Issao Nakane
Coordenador do Programa de Pós-Graduação em Economia

GABRIEL OLIVA COSTA CUNHA

**Hayek and complexity: coordination, evolution and methodology in
social adaptive systems**

**Hayek e a complexidade: coordenação, evolução e metodologia em sistemas sociais
adaptativos**

Dissertação apresentada ao Departamento de
Economia da Faculdade de Economia,
Administração e Contabilidade da Universidade de
São Paulo (FEA-USP) como requisito parcial para a
obtenção do título de Mestre em Ciências.

Orientador: Prof. Dr. Jorge Eduardo de Castro Soromenho

Versão Corrigida

(versão original disponível na Biblioteca da Faculdade de Economia, Administração e Contabilidade)

São Paulo

2016

FICHA CATALOGRÁFICA

Elaborada pela Seção de Processamento Técnico do SBD/FEA/USP

Cunha, Gabriel Oliva Costa

Hayek and complexity: coordination, evolution and methodology in social adaptive systems / Gabriel Oliva Costa Cunha. – São Paulo, 2016.

115 p.

Dissertação (Mestrado) – Universidade de São Paulo, 2016.

Orientador: Jorge Eduardo de Castro Soromenho.

1. Economia 2. Complexidade 3. Hayek, F.A. 4. Teoria geral do sistema I. Universidade de São Paulo. Faculdade de Economia, Administração e Contabilidade. II. Título.

CDD – 330

Resumo

A afinidade entre a obra do economista austríaco Friedrich A. Hayek e a abordagem da Economia e Complexidade é amplamente reconhecida pela literatura. Apesar disso, ainda há grande carência de estudos que busquem analisar de forma aprofundada a relação entre Hayek e a complexidade. Esta dissertação é uma contribuição para o preenchimento dessa grande lacuna na literatura. Na primeira parte do trabalho, os diversos períodos no desenvolvimento da visão de complexidade de Hayek são analisados, evidenciando-se como tal visão está fortemente presente em seus trabalhos sobre conhecimento, competição, metodologia, evolução e ordem espontânea. Na segunda parte, exploramos como Hayek foi influenciado por dois dos principais precursores da moderna teoria da complexidade – a cibernética e a teoria geral do sistema – desde o período em que estava trabalhando no seu livro sobre psicologia teórica, *The Sensory Order* (1952), até o final de sua carreira intelectual.

Palavras-chave: Economia e Complexidade, F. A. Hayek, Cibernética, Teoria Geral do Sistema
Códigos JEL: B59, B25, B41

Abstract

The affinity between the work of the Austrian economist Friedrich A. Hayek and the approach of Complexity Economics is widely recognized by the literature. In spite of this, there still is a lack of studies that seek to analyze in depth the relationship between Hayek and complexity. This dissertation is a contribution to the filling of this large gap in the literature. In the first part of the work, we analyze the various periods in the development of Hayek's vision of complexity, showing that this vision is strongly present in his works on knowledge, competition, methodology, evolution, and spontaneous order. In the second part, we explore how Hayek was influenced by two of the main precursors of modern complexity theory – cybernetics and general system theory – from the time he was working on his book on theoretical psychology, *The Sensory Order* (1952), until the end of his intellectual career.

Keywords: Complexity Economics, F. A. Hayek, Cybernetics, General System Theory

JEL Codes: B59, B25, B41

Agradecimentos

Este trabalho só foi possível graças à contribuição de diversas pessoas e instituições que me ajudaram nos últimos anos. Gostaria, primeiramente, de agradecer ao meu orientador, Jorge Soromenho, por sua dedicação, seu apoio e seus bons conselhos ao longo do processo de escrita desta dissertação. Aprendi imensamente com o Jorge, que orientou minhas pesquisas desde os tempos da graduação.

Agradeço ao *Center for the History of Political Economy* (CHOPE) da Universidade de Duke pelo apoio e infraestrutura fornecidos durante o período em que fui *research fellow* do centro. Sou especialmente grato ao professor Bruce Caldwell, que me ajudou crucialmente na elaboração da segunda parte deste trabalho.

Agradeço aos professores Eleutério Prado, Fabio Barbieri, Pedro Garcia Duarte e José Chiappin, os quais participaram das minhas bancas de qualificação e avaliação de progresso, trazendo críticas e comentários pertinentes ao trabalho. Também agradeço aos participantes da *HOPE Workshop*, aos participantes da *10th Annual Conference on the History of Recent Economics* (HISRECO), e a Jack Birner, Barkley Rosser e demais participantes do *INET Young Scholar Online Seminar in the History of Economic Thought and Philosophy of Economics* pelos comentários ao trabalho.

Sou grato pelo apoio financeiro fornecido pela Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) por meio da bolsa de mestrado (processo nº 2014/16125-0) e da bolsa de estágio em pesquisa no exterior (2015/00352-0).

Agradeço ao espólio de F. A. Hayek por me conceder a permissão para citar seus materiais não publicados.

Agradeço a meus pais, que sempre confiaram em mim, tiveram paciência e apoiaram meus planos e decisões, mesmo que eles envolvessem mudar para longe.

Agradeço, por fim, à minha amada esposa, Elisa, pelo apoio, carinho e compreensão nos momentos críticos, especialmente no período em que estive longe nos Estados Unidos.

Acknowledgements

This work was only possible thanks to the contribution of many individuals and institutions that helped me over the last years. I would like first to thank my advisor, Jorge Soromenho, for his dedication, support and good advice during the process of writing this dissertation. I learned immensely from Jorge, who has supervised my research since I was an undergraduate student.

I thank the Center for the History of Political Economy (CHOPE) at Duke University for the support and infrastructure provided during the period I was a research fellow of the center. I am especially grateful to Professor Bruce Caldwell, who crucially helped me in the development of the second part of this work.

I thank Professors Eleuterio Prado, Fabio Barbieri, Pedro Garcia Duarte and José Chiappin, who took part of my prospectus defense committees, providing valuable criticism and comments on my work. I also thank the participants of the HOPE Workshop, the participants of the 10th Annual Conference on the History of Recent Economics (HISRECO), and Jack Birner, Barkley Rosser and the other participants of the INET Young Scholar Online Seminar in the History of Economic Thought and Philosophy of Economics for their comments on my work.

I am grateful for the financial support provided by the São Paulo Research Foundation (FAPESP) through the master's scholarship (grant #2014/16125-0) and through the research internship abroad (grant #2015/00352-0).

I thank the Estate of F. A. Hayek for granting me permission to quote from his unpublished materials.

I thank my parents, who have always trusted me, had patience and supported my plans and decisions, even if they involved moving far away.

Finally, I thank my beloved wife, Elisa, for her support, affection and understanding in the critical moments, especially during the period I was in the United States.

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.

F. A. Hayek

Hayek was an early and independent developer of complexity theory in something resembling its current form, albeit without computers.

John Barkley Rosser Jr.

[...] Hayek offers a system of sophisticated and complex analyses; because the theories of complexity, spontaneous order, evolution, mind, and rule following form their own complex pattern, commentators are apt to focus on just one or two elements which, not too surprisingly, they find inadequate. It is only when we appreciate the genius of Hayek's linking of complexity theory, spontaneous ordering, social evolution, and neural networks into an overall account of mind and human society that we will be, finally, in a position to see the true difficulties of his system of ideas, and move beyond, by building on, his great work.

Gerald Gaus

Table of Contents

List of Figures	15
List of Tables.....	17
1. Introduction	19
1.1. On the Meaning of Complexity	21
1.2. Hayek's Complexity.....	23
2. The Development of Hayek's Ideas on Complexity	25
2.1. Knowledge and competition	25
2.2. Methodology of complex phenomena	35
2.3. Evolution and spontaneous order	45
3. Cybernetics and General System Theory.....	62
3.1. Cybernetics and GST: basic concepts	63
3.1.1. Cybernetics.....	63
3.1.2. Bertalanffy's General System Theory	71
3.2. Cybernetics and GST in <i>The Sensory Order</i>	78
3.2.1. TSO and the quest for purposive behavior.....	80
3.2.2. Theoretical psychology and non-reductionism	84
3.2.3. Purposive behavior once again: The Within Systems' manuscript	89
3.3. Cybernetics and GST in the social order.....	92
3.3.1. Brain, society, and the knowledge problem	92
3.3.2. Hardin and the invisible hand of evolution	96
3.3.3. Bertalanffy and the structural dynamic foundations of social order.....	101
4. Concluding Remarks	106
References	108

List of Figures

Figure 1: Isolated parts	64
Figure 2: M1 dominates M2	64
Figure 3: Feedback system	64
Figure 4: Feedback system seen as a whole	64
Figure 5: The components of a feedback control system	66
Figure 6: The classification of behavior	69
Figure 7: The cybernetic system of price regulation in classical economics	97
Figure 8: The cybernetic system of trait regulation in Darwinian evolution	97

List of Tables

Table 1 - Overview of economists' change in ranking	24
Table 2 - Deliberate orders (taxis) vs. spontaneous orders (cosmos)	52
Table 3 - Deliberate orders (organizations) vs. spontaneous order in society	53

1. Introduction

Recently, the new approach of complexity economics has gained a significant number of followers. Some authors, such as Colander, Holt and Rosser (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 their discussion of the current trends in economics, 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. This is recognized by both contemporary complexity theorists and Austrian economists alike. The complexity researcher Barkley Rosser, for instance, claimed that Hayek was “an early and independent developer of complexity theory in something resembling its current form, albeit without computers” (ROSSER, 1999, p. 185). In the same spirit, one of the most respected complexity economists, Brian Arthur, reported in an interview that:

Right after we published our first findings, we started getting letters from all over the country saying, ‘You know, all you guys have done is rediscover Austrian economics’ [...] I admit I wasn’t familiar with Hayek and von Mises at the time. But now that I’ve read them, I can see that this is essentially true (TUCKER, 1996).

The Austrian Karen Vaughn set herself the task of investigating to what degree Brian Arthur’s claim was “essentially true,” concluding that “Hayek's account of the catallaxy was a verbal statement of a complex, adaptive system as the term is understood today” (VAUGHN, 1999, p. 252). The Hayek-complexity connection is recognized by several other authors, such as Lavoie (1989), Vriend (2002), Caldwell (2004), Gaus (2006), Koppl (2009), Lewis (2012), and Barbieri (2013). Despite this widespread general recognition, a lot of research still remains to be done regarding how exactly complexity enters into Hayek’s writings in the different periods of his intellectual career.

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 the term to be today. At that time, the peculiar scientific movements of cybernetics and general system theory were arguably the most important complexity-related developments (MITCHELL, 2009, p. 295-300).¹ Besides, it is widely recognized in the literature that Hayek formed his views on complexity with great influence from both cybernetics and general system theory, and the latter, in particular, through its creator, the Austrian biologist Ludwig von Bertalanffy (VAUGHN, 1999; CALDWELL, 2004; ROSSER, 2010).

When I started to work on this project, no work to my knowledge existed that explored in detail how either cybernetics or general system theory was related to Hayek's ideas. Only recently did appear Lewis' (2015) contribution on the relationship between Hayek and Bertalanffy and my own contribution (OLIVA, in press) on the Hayek-cybernetics connection. These pioneering contributions are valuable, but further research is needed. In particular, it will be shown that the influences from cybernetics and general system theory (GST) are better understood if considered together, for they constitute similar theories and started appearing at the same time and in complimentary ways in Hayek's works.

The present work intends to be a contribution to this literature on the relationship between Hayek and complexity. More specifically, our contribution is divided into two parts. In the first part of the work, we analyze the various periods in the development of Hayek's vision of complexity, showing that this vision is strongly present in his works on knowledge, competition, methodology, evolution, and spontaneous order. In the second part, we explore how Hayek was influenced by two of the main precursors of modern complexity theory – cybernetics and general system theory – from the time he was working on his book on theoretical psychology, *The Sensory Order* (1952), until the end of his intellectual career.

Thus, in chapter 2, we will explore the way complexity appears in Hayek's works in three different moments of his career. We will first consider in section 2.1 Hayek's works on knowledge and competition in the 1930s and 1940s. In this period, complexity is implicit in his vision of the economy as a decentralized, self-organizing, dynamic and novelty-generating system. Later in the 1950s and 1960s, as we will see in section 2.2, Hayek already displayed familiarity with the then incipient literature on complexity. In this period, he explicitly dealt with

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

complexity in his methodological works, in which he tries to create – in his own words – a “theory of complex phenomena” (HAYEK, [1964] 2014). Finally, from the late 1960s onward, Hayek developed a comprehensive complex theory of social order through the elaboration of the concepts of evolution and spontaneous order. This period will be analyzed in section 2.3.

In section 3.1, we will provide a brief exposition of some basic concepts of cybernetics and GST that are relevant for the posterior discussion. Section 3.2 carries out an exploration of the influences from these disciplines on Hayek’s book *The Sensory Order*. We will focus mainly on Hayek’s attempt to explain the emergence of purposive behavior and on his non-reductionist conception of theoretical psychology. In section 3.3, we analyze Hayek’s uses of cybernetics and GST 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 before by using new concepts and ideas drawn from these theories. Final remarks and conclusions are made in chapter 4.

1.1. On the Meaning of Complexity

Defining complexity is no simple task. The physicist Seth Lloyd, for instance, listed over forty different definitions of complexity used in the literature (HORGAN, 1997, p. 303). Limiting our attention to the researchers associated with the Santa Fe Institute does not make the situation much better. Mitchell (2009, p. 94-5) reports a round table discussion with prominent researchers of the institute² in 2001, in which each participant proposed a different definition of complexity.

Discussing what is the best definition of complexity is not the aim of this work. We cannot, however, evade the task of exposing the general vision of complexity that will guide the whole discussion. In a broader sense, complexity is a new vision of science that opposes the mechanicism and reductionism that largely characterize modern science. Complexity theorists thus emphasize issues such as *emergence*, *self-organization*, and *adaptation*. Emergent properties are those properties that exist in the system as a whole but are not found in the system’s parts when considered in isolation. Self-organization refers to a process where a structure or order is

² Among the present at the event were Dooyne Farne, Jim Crutchfield, Stephanie Forrest, Eric Smith, John Miller, Alfred Hübler and Bob Eisenstein (MITCHELL, 2009, p. 94).

formed from the bottom up by the interaction among parts, and not imposed from the top down by the action of some organizing “authority.” Finally, adaptation is a process by which the configuration of the parts of a system is changed so as to promote the self-maintenance of the system in the face of a changing environment.

Complexity researchers come from different fields, such as physics, mathematics, biology, and the social sciences, and tend to be interdisciplinary. They stress the need of collaboration across disciplines with the purpose of finding common principles in different fields and of better integrating them into unifying frameworks (possibly displaying emergent properties not found in each discipline taken in isolation). The most important center of complexity research is the Santa Fe Institute, on whose website we learn that:

Complex systems research attempts to uncover and understand the deep commonalities that link artificial, human, and natural systems. By their very nature, these problems transcend any particular field; for example, if we understand the fundamental principles of organization, we will gain insight into the functioning of such systems as cells in biology, markets and firms in economics, and phase transitions in physics and human social systems. This research relies on theories and tools from across the sciences (SANTA FE INSTITUTE, 201-?).

We can also describe complexity by the kind of tools, models, and theories commonly used by complexity researchers. In general, complex models are either analytically intractable or display multiple solutions. Computer simulations for different ranges of initial conditions are thus usually used instead of direct analytical solutions. Non-linear dynamics, evolutionary game theory, information theory, network theory, and agent-based modeling are widely used by complexity researchers.

The application of complexity theory to study the economy gives rise to the field of complexity economics. Arthur, Durlauf and Lane (1997, p. 4-5) list six distinctive characteristics of complexity economics: (1) dispersed interaction among heterogeneous agents; (2) absence of a central controller that manages the interactions (controls and constraints *emerge* from the competition and cooperation among agents); (3) cross-cutting hierarchical organization (the economy possesses various levels of organization and interaction that are interrelated); (4) continual adaptation (behaviors, actions, strategies and outputs are revised continually as agents accumulate experience); (5) perpetual novelty (new niches are continually created through new markets, behaviors, technologies and institutions); (6) out-of-equilibrium dynamics (due to perpetual novelty, the economy always stays far from any global optimum).

The distinction between the complexity approach and orthodox economics can, therefore, be summarized in the following way:

The CA [Complexity Approach] in economics [...] models markets as adaptive systems in which over time (not statically), coordination patterns (not necessarily equilibria) emerge (it is not assumed) that show continuous adaptation to change (not optimality). These patterns are obtained by decentralized interaction (not coordinated by a Walrasian auctioneer) between heterogeneous agents (not by representative agents), with partial (not perfect) knowledge, the result of a learning process from which unanticipated results or novelty frequently arises. Additionally, agents act according to a set of rules (rather than maximization of known functions) (BARBIERI, 2013, p. 49).

A famous precursor of this approach is Schelling's (1971)³ model of the emergence of racial segregation. In this model, a city is represented by a checkered rectangle. Each agent resides in a square, belongs to one of two groups (whites or blacks), and makes decisions about where to live based on local interactions. The conclusion of this model is that even a low level of racial discrimination (i.e., agents possessing a slight preference to live in neighborhoods composed by other agents of the same color) can lead to a city with a high level of spatial segregation (MILLER and PAGE, 2007, p. 143-4). It is important to emphasize that this model exhibits a global structure that emerges from strictly local interactions (ROSSER, 1999, p. 177).

1.2. Hayek's Complexity

If complexity economics really assumes the importance some people claim it will have, the historiography of economic thought will also change. Colander (2009) provides an example of a history of economic thought that highlights the contributions of different economists from various schools of thought from the perspective of the complexity vision of economics. Table 1 summarizes his judgment about how the work of some important economists would be revaluated by this new perspective. According to him, Smith, Mill, Marx, Marshall, and Hayek would be more valued in a complex history of economic thought, Ricardo and Walras would be less valued, and Malthus and Keynes would be as valued as they currently are.

³ Schelling (1971) is recognized by Rosser (1999, p. 176) as a precursor of the complexity approach even though the former did not make use of computational simulations in his original paper.

Table 1 - Overview of economists' change in ranking [reproduced from Colander(2009, p. 420)]

Economist	Change in Ranking
Smith	Up
Malthus	Neutral
Ricardo	Down
Mill	Up
Marx	Up
Walras	Down
Marshall	Up
Hayek	Up
Keynes	Neutral

In part, the present work may be considered as a contribution to this new perspective on the historiography of economic thought. However, in an important sense, writing about “Hayek and complexity” is a different enterprise from writing about “Smith and complexity” or “Marx and complexity.” Hayek, in contrast to all the other economists in Colander’s table, lived to see the birth and development of complexity theory as we know it today; his last book, *The Fatal Conceit*, was published in 1988 and he only died in 1992.⁴ When writing about Hayek and complexity, we cannot simply interpret and evaluate his ideas retrospectively in the light of contemporary complexity theory. It must be recognized not only that Hayek read carefully the early literature on complexity, but also that these readings influenced the development of his own ideas on complexity.

The present work, therefore, is not so much about making a complex interpretation of Hayek as it is about understanding Hayek’s own conception of complexity. It would be a mistake to take for granted the point of view of modern developments as the last word on complexity and then go on to judge Hayek’s writings based on what he anticipated or failed to anticipate. Of course, Hayek did indeed “anticipate” many topics discussed by modern complexity theorists. But he also developed, or at least sketched, his own theory of complex phenomena, as the title of his 1967 article indicates. The aim of this work is to make Hayek’s theory of complexity intelligible in terms of the evolution of his intellectual career.

⁴ Keynes, in contrast, died in 1946, when cybernetics and general system theory were in their beginnings. Wiener published his book *Cybernetics* in 1948, and Bertalanffy made his first public presentation on general system theory at the 1947 Alpbach Symposium (POUVREAU, 2014, p. 176).

2. The Development of Hayek's Ideas on Complexity

In this chapter, we will make a reconstruction of the development of Hayek's views on complexity. I arbitrarily divide his career into three stages, according to the type of complex topics he was emphasizing during each period. First, in his works on the nature of knowledge and competition from the late 1930s to the 1940s, Hayek implicitly showed a complex vision of the economy by stressing issues such as self-organization, agent-heterogeneity, out-of-equilibrium dynamics, constant adaptation, and the emergence of novelty. Second, in the 1950s and 1960s, Hayek explicitly developed a concept of complexity and a methodology for complex phenomena. Finally, from the late 1960s onward, Hayek worked extensively on the twin ideas of evolution and spontaneous order, which he considered the main conceptual tools to adequately deal with complex phenomena.

We intentionally will not deal in this chapter with one central work in the development of Hayek's conception of complexity: his book on theoretical psychology, *The Sensory Order* (1952). As this work plays a central role in the use Hayek makes of the ideas of cybernetics and general system theory, we will discuss it only in chapter 3, where the ideas of these precursors of modern complexity and their influence on Hayek are explored.

2.1. Knowledge and competition

The reflection on the nature of the knowledge possessed by the agents and the way in which this knowledge is transmitted and used is a recurring theme in the work of Hayek. The key article that marks the beginning of Hayek's explicit discussion of this issue is certainly "Economics and Knowledge" (1937). Authors that hold the most diverse views regarding the meaning of this article in Hayek's career, such as Hutchison (1981), Caldwell (1988) and Birner (1994), emphasize the relevance of this work.⁵ We find in this seminal paper the formulation of

⁵ For Hutchison (1981), *Economics and Knowledge* marks an essentially methodological "U turning point" of Hayek, who would have converted from Misesian apriorism to Popperian falsificationism. Caldwell (1988), on the other hand, argues that this article is fundamental in the transformation of Hayek's views on the limitations of

the research programs that would occupy Hayek in the following decades and which would lead him to seek answers outside economics *strictu sensu*. As he puts it:

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 of the spontaneous order of which liberal economists have so long been talking (HAYEK, [1965] 2014, p. 49-50)

In this paper, we find a reflection on the meaning of the concept of equilibrium. Moreover, Hayek discusses the proper scope of equilibrium analysis in face of the fact that the knowledge of economic agents has a subjective character.

According to Hayek, the idea of equilibrium is used in two different contexts: in the analysis of the actions of an individual and in the analysis of the interaction among the actions of different individuals in society. In the context of the analysis of the individual, equilibrium has clear meaning. The actions of an individual are in equilibrium with each other if they can be considered part of the same plan. The individual, based on a subjective assessment of the circumstances, rationally articulate his actions, forming a plan to achieve his purposes⁶ (HAYEK, [1937] 2014, p. 60).

In the context of the individual, equilibrium has an entirely subjective character. The circumstances or data on which the formulation of the plan is based are not objective facts, but the perception or subjective beliefs that the individual form about them. Because the equilibrium

equilibrium analysis, and that this transformation was mainly stimulated by the socialist calculation debate. Finally, Birner (1994), although emphasizing the continuity Hayek’s works display in relation to certain methodological principles, characterizes this article as providing the explicit expression of Hayek’s research program of coordination.

⁶ In the Austrian thinking, rational action is distinguished from instinctive action (or animal reaction) because it is a conscious or purposeful behavior, i.e., it is aimed to the attainment of purposes. The author who best developed this theme was Mises (2010, p. 35-9). Hayek, in *Economics and Knowledge*, mentions Mises in his discussion of individual equilibrium (HAYEK, [1937] 2014, p. 60).

of the individual is described in terms of this subjective data, such equilibrium does not depend on the correspondence between subjective perceptions and objective facts. As Caldwell correctly points out:

The Austrian consumer does not have objectively given knowledge; all he has is his own subjective perceptions. He is in equilibrium at any point in time given those perceptions, but the perceptions may be *wrong*. Error is possible in the Austrian case (CALDWELL, 1988, p. 527-8).

In other words, the equilibrium of the individual requires only the *internal consistency* of the plan inside the agent's mind. No matter how unreal and fanciful the beliefs that underlie the plan are, they do not prevent the equilibrium in this sense. The agent who based his plan on the expectation of riding unicorns on a rainbow is as much in equilibrium as one who correctly anticipates all conditions for the realization of his plan.

The correct perception of the circumstances, however, becomes relevant when the individual starts to put his plan in practice. If the actual circumstances reveal to be too different from those expected by the agent at the time of formulating the plan, the plan can be revised. In this connection, Hayek distinguishes between two kinds of circumstances: the external events and the plans of other agents (HAYEK, [1937] 2014, p. 61).

Soromenho (1994, p. 25-7) interprets the Hayekian concept of external events as being similar to the concept of the state of nature in neoclassical theory, making the caveat that Hayek is not consistent in the use of the term. An isolated man (or a man whose plan is independent of the actions of other individuals) may have the execution of his plan frustrated if the plan is based on significantly incorrect anticipations of external data.

When we move from the analysis of the individual to the analysis of society (i.e., when different people formulate their plans simultaneously and independently), two new problems appear. First, the plans may be based on conflicting expectations of external data, and therefore there is no set of external events that allows the execution of all the plans (HAYEK, [1937] 2014, p. 61). If, in the same region and date, one farmer anticipates a rainy day and the other anticipates a sunny one, it is clear that both plans cannot be performed simultaneously⁷ (SOROMENHO,

⁷ From the point of view of the latest developments in neoclassical theory, this incompatibility generated by external data could be resolved by the hypothesis of complete markets (i.e., the existence of future markets for every possible contingent good). This way of conceiving uncertainty within the context of general equilibrium, however, is posterior to Hayek's 1937 article, and apparently was first exposed by Debreu (1959).

1994, p. 26). The second problem is the possibility of the plans of different agents being incompatible by themselves, regardless of the external data. For example, a company may overestimate the demand for its product, frustrating its profit projection.

Therefore, two conditions must be met in order to exist plan compatibility: (i) each plan must be based on correct knowledge about the planned action of other individuals on which the plan depends and (ii) all plans are based on the same expectations regarding the external data. Hayek then defines the equilibrium state as the situation in which the plans of individuals are mutually compatible:

For a society, then, we can speak of a state of equilibrium at a point of time-but it means only that the different plans which the individuals composing it have made for action in time are mutually compatible. And equilibrium will continue, once it exists, so long as the external data correspond to the common expectations of all the members of the society (HAYEK, 1937 [2014], p. 64).

Society is in equilibrium at a given instant when these plans are mutually compatible and, consequently, it is possible to conceive a set of external events that allows the execution of these plans without disappointment of expectations. If there is no such compatibility, at least some plans should be revised: endogenous disturbances are inevitable (HAYEK, [1937] 2014, p. 63-4).

According to Hayek, the only justification for the concern with equilibrium states is the assumption that there is a tendency toward equilibrium. What he calls "traditional equilibrium theory," however, does not deal with this issue in a valid way. According to this theory, the assumption required for the achievement of equilibrium is the one of "perfect knowledge," i.e., that all individuals equally know all the "data" of the economy. Hayek raises two objections to this proposition.

First, by postulating perfect knowledge, we incur in a confusion regarding the meaning of the word "data," which can denote: (i) the data in the subjective sense, possessed by agents of the economy and (ii) the data in the sense of objective facts, supposedly known by the observing economist. In the context of the equilibrium of the individual, the meaning of the word data is clearly subjective: the agent is in equilibrium with respect to the facts inside his mind. However, in the social context, as previously seen, equilibrium is defined in terms of the relationship among the subjective data of different individuals and the objective facts, and this relationship is obscured by the perfect knowledge assumption (HAYEK, [1937] 2014, p. 68).

The second objection that Hayek raises against the idea that perfect knowledge is an assumption required to the reaching of equilibrium is that such proposition involves circular

reasoning. The concept of equilibrium is *defined* in terms of the forecast of the agents: as seen, plan compatibility exists when the agents correctly predict the actions of others on which their plans depend. In essence, therefore, what these theoreticians were saying is that the precondition for the attainment of equilibrium is the existence of equilibrium.

A non-tautological way to assert a tendency toward equilibrium, on the other hand, would be the following:

[...] 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 correct (HAYEK, [1937] 2014, p. 68).

Note that this tendency to equilibrium postulated by Hayek has a different nature compared to the one obtained through the action of a hypothetical Walrasian auctioneer. In the world of the Walrasian auctioneer, agents formulate plans contingent to prices and the auctioneer searches for a vector of prices that reconciles all these plans. Transactions out of equilibrium (under 'false' prices) are prohibited. The plans are executed only after the conditions for their compatibility are established. The agents neither learn nor make mistakes: there is no revision of plans.

By contrast, in the Hayekian world, the tendency toward equilibrium would be achieved through the constant revision of the plans of agents operating out of equilibrium. The agents revise their plans because they acquire new knowledge, either accidentally or as a necessary consequence of the frustration of their initially incompatible plans. The relevant equilibrium for Hayek is not one that could be obtained instantly by a fictitious auctioneer before agents interact, but one that emerges from the very interaction of individuals in disequilibrium and is contingent upon the knowledge the individuals acquire in this process.

In "Economics and Knowledge," Hayek criticizes the equilibrium theory of his time, making explicit some elements of the complex vision of social phenomena he would later develop. According to Hayek, economists should investigate the dynamics of the tendency towards equilibrium, which is by definition an out-of-equilibrium process. This tendency toward equilibrium involves a coordination problem: how agents, which are heterogeneous in their knowledge, can spontaneously form a global order. Or, as Hayek puts it:

How can the combination of fragments of knowledge existing in different minds bring about results which, if they were to be brought about deliberately, would require a knowledge on the part of the directing mind which no single person can possess? (HAYEK, [1937] 2014, p. 76)

In a later article, “The Use of Knowledge in Society” (1945), Hayek continues to explore the coordination problem in connection with the economic field. In Hayek’s view, the economic problem is wrongly characterized when it is stated as how to best allocate given resources to given ends, because the facts of society are never given to a single mind, but are inescapably dispersed (HAYEK, [1945] 2014, p. 93-4)

Hayek distinguishes between two types of knowledge: scientific knowledge and the knowledge particular circumstances of time and place. While scientific knowledge deals with general laws, the second type of knowledge refers to particular individuals, local conditions and specific circumstances.

Professionals like the real estate agent (who makes his living by exploiting temporary opportunities) and arbitrator (who profits from local price differentials) are based almost entirely on the possession of privileged knowledge of particular circumstances of time and place. This, however, is not a unique feature of these professions. Virtually all individuals have, to a greater or lesser degree, unique information that can be used beneficially, if decision making power is given to them (HAYEK, [1945] 2014, p. 95).

It is not far-fetched to assume that scientific knowledge of a society could be largely concentrated in a committee of selected experts.⁸ As to the knowledge of the particular circumstances, however, the opposite would be true.⁹ Even if this knowledge could be made explicit in its entirety, it would be lost to the extent that its summarization in statistics was attempted. This would occur because disregarding small differences among the elements that compose a class is part of the nature of statistics. However, by treating as homogeneous resources that differ (even slightly) in their locality, quality, etc., we lose characteristics that may be of great relevance to numerous specific decisions (HAYEK, [1945] 2014, p. 98-9).

⁸There still remains the problem of how to select these experts.

⁹ Hayek ([1969] 2014, p. 317-8) would only later develop a justification for this statement that the knowledge of particular circumstances could not be centralized. Such knowledge, he said, is of tacit nature (in the terms of Michael Polanyi) and is often inarticulable by the person that possesses it (this knowledge is, so to speak, of *knowing how* kind instead of *knowing what*, according to Gilbert Ryle’s distinction).

Hayek considers the knowledge of the particular circumstances of time and place to be of fundamental importance for the problem of building a rational economic order. The solution to this problem, therefore, should take into account that such type of knowledge does not exist in a concentrated and integrated way, but exists only as dispersed bits of incomplete and frequently contradictory knowledge that diverse individuals possess (HAYEK, [1945] 2014, p. 93-4).

The economic problem of society is thus more accurately described as the need to quickly adapt to changes in the particular circumstances of time and place. For Hayek, it appears natural that the solution to this problem must involve the decentralization of the decision-making power to the people who have direct contact with those circumstances. But this is not enough because this dispersed knowledge must be somehow communicated to the other individuals so there may be *coordination* among their actions (HAYEK, [1945] 2014, p. 98-9).

The problem of coordination of the decentralized actions of the various agents is not trivial. Almost everything that takes place on the planet has an effect on the decision that an individual should take to best adapt to new circumstances. If the agents needed to know all these particular events in order for their actions to be coordinated, decentralization would be as impossible as centralization. Logically, the same reasons that advocate against the possibility of concentration of all knowledge of society in a single mind also make it impossible that several individuals should possess such knowledge in its entirety.

Hayek argues, however, that coordination does not require that much knowledge. Everything an agent needs to know in order to coordinate his actions is the relative scarcity of the particular goods that interest him (because he consumes and/or produces them, because they are substitutes to the goods he consumes and/or produces, etc.). The communication of this relevant knowledge would be made through the price system, which would work as an economizer of knowledge by reducing how much each individual needs to know directly in order to make correct decisions ¹⁰ (HAYEK, [1945] 2014, p. 99-101).

Suppose someone discovers a new valuable use for tin and attracts a certain amount of this resource that was previously used for other purposes. In doing so, he causes an increase in the price of tin. Now the tin consumers know they should economize the resource and producers

¹⁰ This coordination generated by the price system, of course, would not be perfect (HAYEK, [1945] 2014, p. 100).

know their business has become more profitable, potentially enabling a larger output. In this process, also affected are the uses of tin substitutes, of substitutes of its substitutes, and so on. All this happens without the vast majority of these agents, whose actions promote the adaptation of the system to the new conditions, having to know what the initial cause of these changes were (HAYEK, [1945] 2014, p. 99-100).

In this example, we see coordination emerging not because an agent concentrates all the knowledge of society, but because the limited knowledge of the different agents overlaps, thus allowing the relevant information to be communicated to everyone through a series of intermediaries (HAYEK, [1945] 2014, p. 100). In this spontaneous way, an adjustment is obtained that could only be deliberately achieved by a mind possessing all the knowledge dispersed among the agents involved in the process.

In “The Use of Knowledge in Society,” Hayek continued to discuss the problem of spontaneous emergence of order through the interaction of agents with heterogeneous knowledge. In this article, he qualifies that the type of knowledge he considers to be the most relevant in this process is the knowledge of the particular circumstances of time and place. In his characterization of the acquisition, use and transmission of such knowledge, Hayek stresses the importance of *local interactions* of agents with each other and with the environment. Moreover, Hayek describes the economic problem as consisting not in optimization but in the constant need to *adapt* quickly to changes. Finally, Hayek mentions that the price system is just one of the human formations that facilitate coordination, pointing to the relevance of social institutions.

In “The Meaning of Competition” (1948), Hayek criticizes the static conception of competition underlying the neoclassical models of competition. In his view, the theory of perfect competition¹¹ assumes to exist as a starting point a state of things that could only be brought (or approximated) by a competitive *process*. In his interpretation, such a theory discusses the ultimate results of the competition and not competition itself.¹² In particular, the underlying assumption of perfect knowledge is criticized for preventing the analysis of the process by which agents obtain the knowledge of the relevant facts of economy (HAYEK, 1948 [2014], p. 105-7).

¹¹ The criticism actually is not limited to perfect competition, but also applies to imperfect or monopolistic competition (HAYEK, [1948] 2014, p. 115).

¹² In the terminology of Blaug (1997), neoclassical theory conceives competition as an end state, while Hayek conceives it as a process.

How do the producers discover (i) new products, (ii) less costly forms of production and (iii) what will be the demand for its products given each price? How do consumers (i) become aware of the existence of products (especially the new ones) and (ii) form and modify their preferences as his knowledge evolves? These are some of the questions that arise when the assumptions of perfect rationality and knowledge are abandoned.

Hayek thinks the answers to such questions could only be found in the analysis of the competitive process. It becomes evident, therefore, that such theories distinguish themselves crucially by the underlying idea of rationality. In the neoclassical world, firms know how to maximize their profits given the market conditions. In the Hayekian world, nothing is given a priori; "data" is to be discovered little by little, in a process much more of experimentation and adaptation than of optimization. In the first case, we have perfect rationality; in the second, bounded rationality.

According to Hayek, the conception of competition as state adopted by the neoclassical theory excludes all that is described by the word "compete" and all that is regarded as competition by the common sense. Advertising, promotion, enhancement ("differentiation"¹³) of goods and services are excluded by definition. Perfect competition actually means total absence of competitive activity (HAYEK, [1948] 2014, p. 109).

The effectiveness of competition should not be evaluated according to its ability to make given goods sold at given marginal costs because neither one thing nor the other is given a priori. Which varieties of goods exist and at what costs they will be produced are facts that will only be determined during the competitive process and that depend crucially on the institutional context in which competition operates. If we discard the hypothesis that the knowledge of the agents is perfect and homogeneous, the issue of which institutions allow the best use of the knowledge dispersed in society becomes central because this knowledge will determine, among other things, what will be the types of goods sold and the production costs. Free competition¹⁴ is thus defended by Hayek as the institutional arrangement that makes it more likely that unknown persons who

¹³ Here, Hayek implicitly refers to the work of Chamberlain (1933) on the product differentiation.

¹⁴ Free competition in this context must be understood in the classical sense: as Smith's "system of natural liberty," i.e., as the absence of institutional barriers to competition. Indeed, for authors such as Machovec (1995), Blaug (1997) and McNulty (1967), classical economists generally conceived competition as a process and not as a final state.

have knowledge specially suited to a particular task will be attracted to this task (HAYEK, [1948] 2014, p. 107-8).

For example, a person who has knowledge of how to reduce the cost of production of a good in 50% would provide a great service to society by entering in the market, even if he only reduces the price by 25%.¹⁵ For Hayek, however, it is only through competition that we can assume this cost reduction will take place (HAYEK, [1948] 2014, p. 112). The fact that prices can differ from marginal costs is, according to Hayek, a much less serious a problem than the fact that, with a guaranteed monopoly via legal barriers, costs tend to be much larger than necessary (HAYEK, [1948] 2014, p. 115).

In the article “The Meaning of Competition,” Hayek explores a key aspect of the dynamic process of coordination: competition. Understood by him as a process out of equilibrium by definition, competition has two fundamental aspects. Competition is, on the one hand, an equilibrating force that allows a tendency toward the results of “perfect competition.” On the other hand, competition is a process that allows the introduction of *novelty* in the economy: new technologies, new products, etc. In short, for Hayek, competition is a force responsible both for the origin and for the transformation of economic order. Finally, the proper functioning of both aspects of competition depends on the institutional context in which it operates. Hayek defends free competition as the institutional arrangement that best favors the introduction of novelty because it allows the greater use of the dispersed knowledge in society.¹⁶

We have seen in this section that Hayek, in his works on knowledge and competition from the end of the ‘30s to the ‘40s, displays a complex vision of the economy by emphasizing issues like self-organization, agent heterogeneity, out-of-equilibrium dynamics, constant adaptation and the emergence of novelty. From the mid-‘50s onward, however, Hayek began to *explicitly* address the issue of complexity, linking the economics to the other disciplines that study phenomena which he considered essentially complex.

¹⁵ It is worth pointing out that there is gain not only through the price reduction, but also through the rest of cost reduction.

¹⁶ Later, Hayek better developed the topic of the introduction of novelties through the competitive process in the article “Competition as a Discovery Procedure” (1978). In this article, he argues that the use of the competitive mechanism is justified by its capacity of generating novelty or, as he puts it, by its ability to function as a discovery process.

As we will see in detail in chapter 3, a relevant part of this transition is explained by the contact Hayek had with cybernetics and general system theory since the late 1940s, when he starts the research that would result in his book *The Sensory Order* (1952). Another important influence on Hayek's conception of complexity was the work of the American mathematician Warren Weaver. The inspiration that Hayek had in Weaver is quite clear in Hayek's articles on methodology since the mid-'50s, to which we will now turn our attention.

2.2. Methodology of complex phenomena

In the previous section we saw that Hayek argued that the knowledge of the economist must be distinguished from the knowledge subjectively possessed by the agents of the economy. This second type of knowledge is necessarily dispersed among the several individuals of society and cannot be concentrated by anybody and, in particular, can be known in its totality by neither the economist, nor by a central planner. One of the fundamental problems of economic theory is to investigate the process by which agents with heterogeneous, limited and contradictory knowledge can coordinate their actions with each other, i.e., to explain how a tendency to equilibrium can be obtained from the dynamics of disequilibrium.

Competitive activity is a crucial element of out-of-equilibrium dynamics. However, models that conceive competition as an equilibrium state are limited to the analysis of the hypothetical final results of competition. By assuming that knowledge is given objectively to the agents and the economist, these equilibrium models are unable to elucidate the nature and importance of the competitive process. Competition is an out-of-equilibrium process whose importance lies precisely in the fact that the knowledge which will guide the actions of competitors is not given a priori to anyone but is only discovered by them throughout the competitive process.

All Hayek's articles discussed in the previous section have in common the recognition of the limits to human knowledge, which also have implications regarding what the analyst can know. If it is true that the economist is necessarily ignorant of many facts important in determining the economic order, what kind of scientific knowledge (if any) can be produced in this subject? Are economics and the social sciences in general special in this respect, or does part

of the natural sciences also suffer from this problem of limitation of knowledge? Hayek tries to provide answers to these questions in his works on the methodology of complex phenomena in the '50s and '60s.¹⁷

Hayek begins his discussion by expressing agreement with Karl Popper regarding some of the key points of the latter's vision of science as a hypothetical-deductive system. The theoretical sciences are essentially deductive. There can be no such thing as an "inductive logic" that necessarily leads from observed facts to general rules. The conclusions of the scientific theories are of a negative nature; they prohibit certain types of events and hence cannot be "verified" but only refuted (HAYEK, [1955] 2014, p. 196-7).

Hayek, however, disagrees with the narrow characterization of what constitutes a scientific prediction commonly derived from this vision. He defines 'scientific prediction' as the use of rules or laws to derive propositions about what will happen from propositions about what the existing conditions are. Similarly, a 'scientific explanation' is defined as the use of the same rules to derive propositions about the preceding conditions from propositions about the facts that occurred. The simplest form of a prediction is given by the proposition "if x, then y," combined with the claim that x is satisfied in a given time and place. What usually is not explicit in this type of discussion, according to Hayek, is how specific the descriptions of x and y should be in order for such a statement to be called a prediction. Of course, this issue is not relevant when we can specify all the aspects of the problem with any degree of accuracy necessary.

But when a problem involves a lot of interdependent variables, and only some of them can be individually observed in practice, we would be in a different situation. In such cases, if we already knew the relevant laws and values of the variables of the system, we could predict in detail the future state of the system. But this may not be feasible because: (i) these variables are numerous, (ii) infinite ways in which these variables interact are conceivable, and (iii) some of these variables may be non-observable.

¹⁷In the present work, we will focus on the articles "Degrees of Explanation" (1955) and "The Theory of Complex Phenomena" (1964), which are Hayek's more mature methodological works and are also better informed by the distinction between simple and complex phenomena. Previously, as in Hayek ([1952] 1979), the fundamental dichotomy made by the author was between natural sciences and social sciences. On Hayek's earlier methodology, see Lawson (1997) and Caldwell (2004, p. 423-438).

Some would characterize such situations as being beyond what the scientific method can handle given the existing state of observational technique. For Hayek, this is a problematic statement because there is no reason to assume that someday we will be able to specify the details of certain complex phenomena with the precision needed to escape the problems (i), (ii), and (iii). Moreover, the mere absence of these "ideal conditions" of scientific exploration does not eliminate the possibility that we may acquire valuable knowledge, albeit limited, about these phenomena.

Theories in themselves define types or classes of patterns. The particular configuration of a pattern described by a theory, however, also depends on the particular circumstances given by the initial conditions of the system. For Hayek, the description of an abstract pattern by a theory has value in itself, even if we cannot specify all the data with the precision needed to make a prediction of particular events. According to him, the prediction that, under certain conditions, a pattern of a particular class will manifest is also a relevant and falsifiable prediction.

We should therefore distinguish between two types of empirical scientific predictions: specific predictions, which refer to the appearance of a particular pattern of a certain class, and *pattern predictions*, which refer to the appearance of any pattern that belongs to a given class (HAYEK [1964] 2014, p. 259-60). Similarly, we should contrast between explanations of the detail, which seek to specify particular conditions preceding observed facts, and explanations of the principle, which only express the general conditions for the occurrence of these facts.

For Hayek, some examples of scientific fields that make use of pattern predictions and explanations of the principle are the new areas of cybernetics, theory of cellular automata, communication theory and general system theory. Among the more established fields of research, the theory of evolution is the best example of a theory that provides only explanations of the principle. This theory does not intend to make specific predictions of particular events, nor is it based on hypothesis in the sense that we seek to falsify them through observation. What is sought in this connection is to test whether the particular combination of assumptions is appropriate to arrange the facts in a meaningful order (HAYEK, [1955] 2014, p. 203-4).

Finally, according to Hayek, the Walrasian theory of general equilibrium should be reinterpreted as being limited to pattern predictions and explanations of the principle because we cannot determine the values of all the variables that determine the particular manifestation of equilibrium. If we knew all the preferences, technologies and other economic data, we could

calculate the prices and quantities of all goods, but this is never the case, as one of the founders of this theory had recognized by stating that the aim of it was not to reach the numerical calculation of prices, because it would be absurd to suppose that we could gather all the necessary data (PARETO, 1927, p.223-4 apud HAYEK, [1964] 2014, p. 270-1).

According to Hayek, when we deal with patterns with a high degree of complexity, we can only make pattern predictions and explanations of the principle. But how do we measure the complexity of a pattern? As Hayek himself acknowledges on various occasions,¹⁸ the way he defines complexity was considerably influenced by the discussion of the evolution of science made by Warren Weaver in his article “Science and Complexity” (1948). Thus, a brief discussion of this article and, in particular, of his concept of “organized complexity,” helps us to understand Hayk’s definition of complexity.

According to Weaver, during the seventeenth, eighteenth and nineteenth centuries, physicists had learned to work only with *problems of simplicity*, i.e., problems involving the analysis of only two (or only a few) variables. When a variable may be described with high accuracy by taking into account only how it depends on a second variable (and by thus ignoring minor effects from other factors), we can construct theories and experiments that are easy to handle and that impose low computational requirements (WEAVER, 1948, p. 536-7).

Then, mainly since the twentieth century, scientists have developed techniques related to probability theory that allow us to deal with the other extreme of the spectrum of the number of variables. In these *problems of disorganized complexity*, we have a large number of variables possessing individually erratic (or random) behavior, but whose system as a whole has regularities analyzable via statistical methods. Statistical mechanics, thermodynamics, the laws of genetic inheritance and actuarial science are examples of fields that deal with this kind of problem (WEAVER, 1948, p. 537-8).

The analysis and prediction of the movement of a ball on a pool table would be, according to Weaver, an example of a simple problem that can be treated by classical mechanics.

¹⁸ For example, according to Hayek, specific predictions are possible only “where we have to deal with what has been called by Dr. Warren Weaver (formerly of the Rockefeller Foundation), with a distinction which ought to be much more widely understood, ‘phenomena of unorganized complexity’, in contrast to those ‘phenomena of organized complexity’ with which we have to deal in the social sciences” (HAYEK, [1975] 2014, p. 365). See also: “In the convenient terms suggested by Warren Weaver, they are neither ‘problems of simplicity’ nor ‘problems of disorganized complexity’ but ‘problems of organized complexity’.” (HAYEK, [1961] 2014, p. 378).

With greater difficulty, we can analyze the movement of two or three balls using the same classical tools. But if we increase the amount of balls to more than ten, the problem becomes unmanageable, not because there are theoretical difficulties, but because the work required to deal in detail with so many variables is overwhelming.

Suppose, on the other hand, that we have millions of balls in a large pool table moving and colliding with each other and with the walls. This would be, according to Weaver, an example of a problem of disorganized complexity. In a sense, the problem is simpler than the previous one, because now the statistical mechanical methods are applicable. Of course, we cannot trace the detailed history of a specific ball, but we can answer with a high degree of precision questions like: on average, how many balls hit a particular wall per second? How much, on average, does a ball move before colliding with another ball? On average, how many collisions per second does a ball experience? (WEAVER, 1948, p. 537).

The intermediate type of problem would still remain virtually unexplored by science. The main property of this third type of problem, however, is not the mere number of variables – larger compared to simple problems and smaller compared to problems of disorganized complexity – but the fact that its variables are interrelated into an organic whole (i.e., they do not display random behavior). Because they have as their distinctive characteristic the feature of organization, Weaver referred to this third type as *problems of organized complexity*. Most of the problems of the fields of biology, economics and social sciences would belong in this category (WEAVER, 1958, p. 13-5).

What makes an evening primrose open when it does? Why does salt water fail to satisfy thirst? Why can one particular genetic strain of microorganism synthesize within its minute body certain organic compounds that another strain of the same organism cannot manufacture? Why is one chemical substance a poison when another, whose molecules have just the same atoms but assembled into a mirror-image pattern, is completely harmless? Why does the amount of manganese in the diet affect the maternal instinct of an animal? What is the description of aging in biochemical terms? What meaning is to be assigned to the question: Is a virus a living organism? What is a gene, and how does the original genetic constitution of a living organism express itself in the developed characteristics of the adult? Do complex protein molecules "know how" to reduplicate their pattern, and is this an essential clue to the problem of reproduction of living creatures? All these are certainly complex problems, but they are not problems of disorganized complexity, to which statistical methods hold the key. [...] On what does the price of wheat depend? This too is a problem of organized complexity. A very substantial number of relevant variables is involved here, and they are all interrelated in a complicated, but nevertheless not in helter-skelter, fashion (WEAVER, 1948, p. 539).

Given that Hayek mentions Weaver as inspiration in his distinction between simple and complex phenomena, it is worthwhile to do a little comparison between Hayek's simple/complex dichotomy and Weaver's simplicity/disorganized complexity/organized complexity tripartite classification. According to Hayek, the appropriate criterion for measuring complexity is the minimum amount of elements required to produce a pattern of the class being analyzed:

The distinction between simplicity and complexity raises considerable philosophical difficulties when applied to statements. But there seems to exist a fairly easy and adequate way to measure the degree of complexity of different kinds of abstract patterns. The minimum number of elements of which an instance of the pattern must consist in order to exhibit all the characteristic attributes of the class of patterns in question appears to provide an unambiguous criterion (HAYEK, [1964] 2014, p. 260)

At first sight, it is not obvious how the “minimum number of elements of which an instance of the pattern must consist” (Hayek's criterion to measure the degree of complexity) is connected to the distinction between disorganized and organized complexities. Given Hayek's emphasis on the number of elements, it may be thought that Hayek's concept of complexity includes both disorganized and organized complexity, since both involve many elements. The truth, however, is that Hayek sees disorganized complexity as belonging to the category of simple phenomena:

Modern physics has of course resorted to statistics to deal with systems of very large number of variables, but this does not appear to me to be in conflict with the observation in the text. The statistical technique is in effect a manner of reducing the number of separate entities, connected by laws which have to be stated, to comparatively few (namely the statistical collectives) and not a technique for dealing with the interplay of a large number of such significantly independent variables as individuals in a social order. The problems of complexity to which the further discussion refers are of the kind which Warren Weaver has described as ‘problems of organized complexity’ as distinguished from those ‘problems of disorganized complexity’ with which we can deal by statistical techniques (HAYEK, [1955] 2014, p. 195-6).

In short, in the problems of disorganized complexity, we have a large number of elements, but the *minimum* number of variables required to produce them is small: only a few statistical collectives are required for this. Thus, it is clear why Hayek classifies problems of disorganized complexity as being simple phenomena: “It is, indeed, surprising how simple in these terms, i.e., in terms of number of distinct variables, appear all the laws of physics [...] when we look through a collection of formulae expressing them” (HAYEK, [1964] 2014, p. 261). This type of simple phenomenon, which we can satisfactorily describe using few statistical variables, is contrasted by Hayek with complex phenomena, such as biological feedback systems, which require many

different variables in their explanation (that are distinct, in particular, by the location or position they occupy in the structure of the whole).

Thus, the great majority of the laws of physics (especially the laws of mechanics) would be simple, for its formulas involve a small minimum amount of elements. On the other hand, the operation of feedback systems (which are particularly widespread in biological phenomena) is complex because it requires the combination of physical structures producing a general order with emergent properties not present in any part taken separately. As illustrated by this example, the so defined complexity of patterns is closely linked to the concept of emergency. The patterns themselves are emergent properties because they only exist in "wholes" consisting of a certain minimal amount of parts.

The “emergence” of “new” patterns as a result of the increase in the number of elements between which simple relations exist, means that this larger structure as a whole will possess certain general or abstract features which will recur independently of the particular values of the individual data, so long as the general structure (as described, e.g., by an algebraic equation) is preserved. Such “wholes,” defined in terms of certain general properties of their structure, will constitute distinctive objects of explanation for a theory, even though such a theory may be merely a particular way of fitting together statements about the relation between individual elements (HAYEK, [1964] 2014, p. 261-2).

We can now consider why Hayek says we are limited to pattern predictions in the study of complex phenomena. The more complex the phenomenon being studied, the higher the minimum amount of elements necessary to produce the characteristic patterns, and the harder the determination of the data necessary to carry out specific predictions. This difficulty in gathering the data may consist either in insurmountable practical obstacles giving the existing observational technology, or in an absolute theoretical impossibility.

The proposition that there exists an absolute impossibility of assertion of all the data needed to determine the particular manifestations of very complex patterns was proposed by Hayek in his book on psychology, *The Sensory Order* (1952). In this book, Hayek (1952, p. 184-90) argues that there are absolute limits to the explanatory power of the human brain. According to him, the essence of an explanation is the joint (or simultaneous) classification of the various elements of a system, and a classifying apparatus must necessarily possess a higher degree of complexity than the one possessed by the objects it classifies. Thus, the human brain would not

be able to explain in detail its own functioning, much less the operation of even more complex structures.¹⁹

Hayek believes satisfactory explanations of complex phenomena must be based on theories that can produce similar patterns possessing the same degree of complexity: “But a simple theory of phenomena which are in their nature complex [...] is probably merely of necessity false – at least without a specified *ceteris paribus* assumption, after the full statement of which the theory would no longer be simple” (HAYEK, [1964] 2014, p. 263). Attempting to oversimplify the representation of complex phenomena would lead to an illegitimate assumption of the constancy of variables when we have no reason to believe the factors in question are actually constant (HAYEK, [1955] 2014, p. 207).

In this brief presentation of Hayek’s methodology of complex phenomena, we see two peculiarities if we compare the discussion to the canons of scientific methodology. First, by postulating that complex phenomena cannot be represented by simple theories, Hayek apparently contradicts the idea that simplification is the essence of scientific explanation. He certainly would not disagree that every model is a simplified representation of reality. At the same time, however, the author claims that the complexity of the phenomena may impose limits to how simplified their representations can be.

If, in order to produce complex patterns of a certain class, we need a given minimum number of elements, then a theory that resorts to less elements than this minimum would not be able to provide adequate explanations for such patterns. In particular, Hayek criticizes the idea that the aim of theoretical science is the search for “scientific laws,” i.e., rules that connect two phenomena in accordance with the principle of cause and effect. For him, the demand for laws in this sense is not a characteristic of scientific enterprise in general, but is only a special feature that is particular to the sciences that study simple phenomena. In the social sciences, for example,

¹⁹ Koppl (2010, p. 860-1) interprets this argument as showing the computational limits of knowledge, a subject addressed by the modern field of computational complexity. For him, Hayek’s reasoning is analogous to the Cantor’s diagonal argument, in the context of Gödel’s incompleteness theorems. Rosser summarizes Koppl’s interpretation as follows: “The mind operates as a rule-following classifier system. However, as such it is subject to the laws of logic, and among those laws are the theorems of Kurt Gödel that imply incompleteness of logical systems. This incompleteness is deeply tied to selfreferencing by systems, and Hayek in particular cited the diagonal proof method to argue that the mind cannot know itself” (ROSSER, 2010, p. 169).

Hayek claims that there are no scientific laws, but only theories of social structures (HAYEK, [1964] 2014, p. 265-6).

The second peculiarity of Hayek's methodology, which is closely related to the first, is the claim that certain theories, because of the very complex nature of the phenomenon under study, must necessarily have less empirical content (i.e., it must be more difficult to falsify them). This proposition comes somewhat into conflict with the Popperian methodology, which regards the formulation of increasingly falsifiable theories as a virtue, to the extent that it sets limits to the degree of falsifiability of certain sciences. Hayek explicitly recognizes that the advancement of science must involve both the increase of degree of falsifiability of certain theories and the decrease in the falsifiability of others.²⁰

The advance of science will thus have to proceed in two different directions: while it is certainly desirable to make our theories as falsifiable as possible, we must also push forward into fields where, as we advance, the degree of falsifiability necessarily decreases. This is the price we have to pay for an advance in the field of complex phenomena (HAYEK, [1964] 2014, p. 264)

Of course, the use of low empirical content theories in the sciences that study complex phenomena is not without its problems. The elimination of inferior rival theories would be a slow activity and there would be room for serious abuses when erroneous theories are advocated by individuals with great persuasive skill. Although there is no simple way to remedy these problems, Hayek considers it a mistake to conclude from this that we should replicate in the study of complex phenomena the procedures less subject to error used in the simple sciences. If, in some fields of knowledge, the best we can achieve are hardly falsifiable explanations of the principle, then the search for detailed explanations is futile. To increase the degree of falsifiability of theories beyond what the complexity of the phenomenon allows is the same as replacing the possibility of error by its certainty (HAYEK, [1955] 2014, p. 210-211).

Statistics, which could be seen as the best way to understand complex phenomena, is considered by Hayek to be "powerless" in dealing with this kind of phenomenon. Because it treats individual elements as if they were not systematically connected (i.e., because it assumes the elements of the sample are independent), statistics eliminates the complexity of the

²⁰ This is one of the reasons why Caldwell (2006) claimed that Popper had no significant influence on Hayek, despite Hayek claiming to be a follower of Popper's methodology.

representation of the pattern. If the relative position of each element in the structure is critical to the understanding of the system, then we must conclude that a method which ignores the relationships among these elements is useless. However, the statistical method would have some use when we use the complex structures, and not its components, as the elements.²¹ In this sense, information on the frequency of certain properties in different languages or economic systems could be scientifically relevant²² (HAYEK, [1964] 2014, p. 265-266).

Again in this connection, Hayek was inspired on Weaver's discussion on organized complexity (CALDWELL, 2004). According to Weaver, problems of organized complexity could not be adequately tackled by the use of statistical techniques, which are successfully applied in the analysis of problems of disorganized complexity. The key to understanding these phenomena would not be in the description of the average behavior of their components, but rather in the elucidation of the way in which these elements are interrelated (i.e., the way in which the system is organized as a whole). In the pool example, if someone organized the millions of balls so they always took parallel paths, then the statistical methods would not apply: the balls would only collide with two of the four sides of the table and no ball would collide with another one (WEAVER, 1948, p. 538).

As pointed out by Caldwell, Weaver's argument against using statistical methods of the problems of disorganized complexity to the analysis of problems of organized complexity was naturally welcomed by an author like Hayek, a longtime critic of the use of aggregates as substitutes for the description of economic structures.

Weaver's argument that statistical methods were inappropriate for the study of phenomena of "organized complexity" provided an independent basis for the long-standing Austrian distrust of aggregates and of attempts to provide numerical estimates for the variables in a Walrasian system of equations. From this time forward, Hayek's "take" on the use of mathematical methods in the social sciences more or less stabilized. Mathematics was useful for describing the general character of the patterns that constitute the complex structure of social phenomena, but statistical techniques were "impotent" in the face of such pattern complexity (CALDWELL, 2004, p. 305).

²¹ Assuming there is some independent criterion for identifying the type of structure.

²² Paqué (1990, p. 285) dismisses Hayek's criticism of statistics because Hayek, according to his interpretation, mistakenly believed that social scientists should also explain the (possibly erratic) behavior of individuals, and not only the aggregate behavior of society and markets. Hayek, however, believes that in order to explain complex "wholes," it is indispensable to examine how their heterogeneous individual elements are structurally related, and Paqué does not explain what is wrong with Hayek's argument.

In this section, we discussed the conception of complexity that Hayek proposed in the '50s and '60s, and the methodological implications the author derives from it. During this period, we find explicit reference to the notion of complexity, in contrast to what we see in his works from the '30s and '40s previously analyzed. In his methodological works, Hayek identifies as complex not only economics and the social sciences in general, but also part of the natural sciences, as illustrated by some cutting edge scientific developments at the time, such as cybernetics, general system theory, and the theory of cellular automata. All these theories, according to Hayek, study problems of organized complexity (in Weaver's terms) or simply complex phenomena (in the terminology proposed by Hayek himself).

Hayek tells us, however, that the best illustration of a theory of complex phenomena is given by the theory of evolution. It was no coincidence that Hayek gradually incorporated evolutionary elements in his theories of a type of complex phenomenon that has always occupied him: the spontaneous formation of social orders. In his more mature works, such as the *Law, Legislation and Liberty* (1973; 1976; 1979) trilogy and *The Fatal Conceit* (1988), the complex investigation of social phenomena becomes virtually synonymous with the joint application of the ideas of evolution and spontaneous order.

2.3. Evolution and spontaneous order

Throughout his career, Hayek repeatedly refers to the importance of what he calls the "twin ideas of evolution and spontaneous order."²³ Even more interesting for the purposes of this work, Hayek says evolution and spontaneous order are the main tools for understanding the complex phenomena that emerge from human interaction (HAYEK, 1988, p. 146). Hayek speaks of "twin ideas" because, in his view, evolutionary processes and the formation of spontaneous orders are closely connected, so that we cannot satisfactorily understand one without understanding the other. Let us thus explore carefully both concepts and their relationships.

²³ E.g.: "the twin conceptions of evolution and the spontaneous formation of an order" (HAYEK, [1973] 1998, p. 23), "the twin ideas of evolution and of the spontaneous formation of an order" (HAYEK, [1967] 1978, p. 250) and "the twin concepts of the formations of spontaneous orders and of selective evolution" (HAYEK, 1988, p. 146).

Hayek defines the general concept of order (not necessarily of the spontaneous kind) as follows:

By 'order' we shall throughout describe a state of affairs in which a multiplicity of elements of various kinds are so related to each other that we may learn from our acquaintance with some spatial or temporal part of the whole to form correct expectations concerning the rest, or at least expectations which have a good chance of proving correct. (HAYEK, [1973] 1998, p. 36).

It is interesting to note how similar this definition of order is to the concept of equilibrium that Hayek himself developed in *Economics and Knowledge*. As we have seen, in the social context, Hayek defines equilibrium as compatibility among the plans of the different agents. In order for such compatibility exist, it is necessary that each individual, which has only a small fraction of all the knowledge (of the particular circumstances of *time* and *place*) of the society, forms *correct expectations* regarding the planned actions of the other agents on which his plan depends.

Therefore, we can interpret the Hayekian concept of order as a generalization of the concept of equilibrium he developed decades earlier in two respects. First, the concept of order can be applied to non-economic fields, including the natural sciences. Second, while expectations must be correct in order for equilibrium to exist, the presence of order only requires that expectations have a "good chance" of being correct.

Possibly because he was now dealing with phenomena beyond the strict economic sphere, Hayek saw the need to use a broader concept than the one of equilibrium that could be useful in the analysis of other fields of knowledge. Moreover, as previously seen, Hayek had relativized the importance of equilibrium analysis in economics itself. He sees out-of-equilibrium dynamics as central to the validation of equilibrium analysis itself by exploring the conditions for a tendency toward equilibrium. Initially, Hayek argued that the concept of equilibrium is indispensable in out-of-equilibrium analysis to the extent that it serves as a useful "contrast":

The direction in which an entrepreneur will have to revise his plans will depend on the direction in which events prove to differ from his expectations. The statement of the conditions under which individual plans will be compatible is therefore implicitly a statement of what will happen if they are not compatible.

It will be seen that this extension of the equilibrium concept provides the bridge from equilibrium analysis to the explanation in terms of causal sequences, since it is designed to elucidate the factors which will compel entrepreneurs to change their plans and to help us to understand the way in which their plans will have to be changed (HAYEK, 1941, p. 22-3).

Subsequently, Hayek favors the use of the more general concept of order in disequilibrium analysis. This is the case study of the competitive process, seen by him as an out-of-equilibrium phenomenon by definition:

Economists usually ascribe the order which competition produces as an equilibrium - a somewhat unfortunate term, because such an equilibrium presupposes that the facts have already all been discovered and competition therefore has ceased. The concept of an 'order' which, at least for the discussion of problems of economic policy, I prefer to that of equilibrium, has the advantage that we can meaningfully speak about an order being approached to various degrees, and that order can be preserved throughout a process of change. While an economic equilibrium never really exists, there is some justification for asserting that the kind of order of which our theory describes an ideal type, is approached in a high degree (HAYEK, [1968] 2014, p. 308-9).²⁴

Therefore, the concept of order is more general (and certainly more imprecise) than the one of equilibrium. Moreover, while the idea of equilibrium allows us to classify a system in a binary way, either we have equilibrium or we do not have it, the concept of order allows an infinite range of categorizations. It is meaningless to say a system is in "half equilibrium" or "90% equilibrium," but we may say that orders vary in their degree of organization. Hayek claims that the degree of order of a system varies in two metrics: in the number of relationships among the elements that the order encompasses and in how often the regularities of the order manifest themselves:

It is important to note here that there are two different respects in which order may be a matter of degree. How well ordered a set of objects or events is depends on how many of the attributes of (or the relations between) the elements we can learn to predict. Different orders may in this respect differ from each other in either or both of two ways: the orderliness may concern only very few relations between the elements, or a great many; and, second, the regularity thus defined may be great in the sense that it will be confirmed by all or nearly all instances, or it may be found to prevail only in a majority of the instances and thus allow us to predict its occurrence only with a certain degree of probability. In the first instance we may predict only a few of the features of the resulting structure, but do so with great confidence; such an order would be limited but may still be perfect. In the second instance we shall be able to predict much more, but with only a fair degree of certainty. The knowledge of the existence of an order will however still be useful even if this order is restricted in either or both these respects (HAYEK, [1973] 1998, p. 42).

²⁴ I would not go so far as Fleetwood (1996, p. 738) who interprets this passage as a total abandonment of the concept of equilibrium in favor of the one of order. As we have seen, Hayek advocated the use of general equilibrium theory as a theory of complex phenomena four years before he wrote the passage quoted (HAYEK, [1964] 2014, p. 270), and he repeated the same arguments in his Nobel Prize acceptance speech a decade later (HAYEK, [1975] 2014, p. 365-6). In my interpretation, Hayek never fully rejected the concept of equilibrium, but only pointed out its inherent limits as a tool of analysis.

After defining the concept of order, Hayek explores the subcategories of that concept. According to him, the dichotomy between natural and artificial orders is false and is the source of a lot of confusion in the history of ideas. He traces the origin of this dichotomy to the Ancient Greeks, who distinguished between *physei* ("by nature") and *nomo* ("by convention") or *thesei* ("by deliberate decision"). Hayek's objection is that there is not only one important dichotomy, but two:

The distinction intended may be either between objects which existed independently and objects which were the results of human action, or between objects which arose independently of, and objects which arose as the result of, human design. The failure to distinguish between these two meanings led to the situation where one author could argue with regard to a given phenomenon that it was artificial because it was the result of human action, while another might describe the same phenomenon as natural because it was evidently not the result of human design (HAYEK, [1973] 1998, p. 20).

For Hayek, language, moral norms and the market would be examples of orders that result from human action but not from human design. Therefore, these orders would be simultaneously "artificial," because they were created by men, and "natural," in the sense that they are not the result of deliberate construction.

In order to escape from this ambiguity of the terms 'natural' and 'artificial,' Hayek uses another distinction that focuses on the criteria of presence or absence of design as the source of orders. Recurring again to the Greeks, he classifies orders in two types with respect to their sources: deliberate order (*taxis*) and spontaneous orders (*cosmos*). Deliberate orders are those made intentionally, arrangements produced by forces exogenous to the system. In the social context, we can refer to them as *organizations*. Spontaneous orders are those that arise unintentionally, formations generated by endogenous forces of the system. They may also be described as self-organizing or self-generated systems (HAYEK, [1973] 1998, p. 36-8).

By using the dichotomy between *cosmos* and *taxis*, Hayek was seeking to approximate the spontaneous orders of the social realm to the ones found in nature:

The study of spontaneous orders has long been the peculiar task of economic theory, although, of course, biology has from its beginning been concerned with that special kind of spontaneous order which we call an organism. Only recently has there arisen within the physical sciences under the name of cybernetics a special discipline which is also concerned with what are called self-organizing or self-generating systems (HAYEK, [1973] 1998, p. 36-7).²⁵

²⁵ Chapter 3 carries a brief exposition of the theory and history of cybernetics and explores the relationship between Hayek and the researchers associated with this scientific movement.

Even though there are examples of spontaneous orders in these various areas of knowledge, the claim that there are social orders not made by men is commonly viewed with suspicion. Hayek attributes the existence of this suspicion to the abstract character of spontaneous orders:

For the moment we are concerned only with the fact that an order not made by man does exist and with the reasons why this is not more readily recognized. The main reason is that such orders as that of the market do not obtrude themselves on our senses but have to be traced by our intellect. We cannot see, or otherwise intuitively perceive, this order of meaningful actions, but are only able mentally to reconstruct it by tracing the relations that exist between the elements. We shall describe this feature by saying that it is an abstract and not a concrete order (HAYEK, [1973] 1998, p. 38).

Made orders or *taxis* have their degree of complexity necessarily limited to what its creator can master. They also tend to be concrete, in the sense that it can be intuitively perceived by inspection. In addition, because they are made deliberately, they serve some purpose determined by its creator. Regarding spontaneous orders, the opposite is true. Its complexity is not limited to what a human mind can master. Its existence is not necessarily perceived by the human senses, but can be based on purely abstract relations that man can only reconstruct mentally.²⁶ Finally, a spontaneous order has no particular purpose, since it is not intentionally created (HAYEK, [1973] 1998, p. 38).

In this connection, Hayek opposes the belief that in order to properly deal with complex phenomena, we should plan and control them in their particular details. Although spontaneous orders are not necessarily complex, they may attain any degree of complexity, unlike deliberate orders. Many orders owe their high degree of complexity exactly to their spontaneous character:

One of our main contentions will be that very complex orders, comprising more particular facts than any brain could ascertain or manipulate, can be brought about only through forces inducing the formation of spontaneous orders (HAYEK, [1973] 1998, p. 38).

There are, in the natural realm, many examples of complex orders that we can only generate by creating the conditions for their spontaneous growth, and not by deliberately arranging their elements in particular positions. This would be the case, according to Hayek, of crystals and some complex organic compounds: we cannot produce them directly by arranging

²⁶ Spontaneous orders are abstract in the sense that they can preserve their general structure even though their concrete manifestation may change completely over time. It is important to emphasize that, albeit abstract, spontaneous orders are as real as any concrete object (HAYEK, 2013, p. 49).

their individual atoms. In such cases, we would only be able to provide the conditions for the formation of these chemical compounds, leaving the position of each individual atom to be determined by the process of the formation of the compound itself. The rules of conduct of individual atoms allow us to determine the general (abstract) character of the spontaneous order generated, but the particular configuration of the elements in this order will depend on all the initial conditions of the system and on the particular circumstances of the environment with which each atom interacts throughout the formation process (HAYEK, [1973] 1998, p. 40).

A spontaneous order forms as a result of its elements following certain rules in the interaction with their near environment. As it becomes clear in the aforementioned crystal example, the elements neither need to know these rules nor need to be able to explicit them in words. What matters is that they behave in accordance with these rules. This is true both for spontaneous orders in nature and in society. Indeed, for Hayek, man does not know all the rules that guide their actions in the sense of being able to explain them in words (HAYEK, [1973] 1998, p. 43).

It is important to emphasize, however, that not all the rules of conduct followed by the elements of a system ensure the existence of a global order. On the contrary, some individual rules may make it impossible to obtain a spontaneous order. According to Hayek, the most obvious example of this is the Second Law of Thermodynamics, which claims that the entropy of a closed system increases in time. Similarly, the issue of what properties the rules of conduct of the individuals must have in order to produce a global order is of central importance to the social sciences (HAYEK, [1973] 1998, p. 43-5). Hayek classifies the rules followed by individuals in three types:

Some such rules all individuals of a society will obey because of the similar manner in which their environment represents itself to their minds. Others they will follow spontaneously because they will be part of their common cultural tradition. But there will be still others which they may have to be made to obey, since, although it would be in the interest of each to disregard them, the overall order on which the success of their actions depends will arise only if these rules are generally followed (HAYEK, [1973] 1998, p. 45).

Among these types, the rules of law are especially interesting because they can be deliberately modified. Therefore, we seemingly arrive at a paradox: it is entirely possible that a spontaneous order is generated only by means of the enforcement of *deliberately created* rules of conduct. Hayek escapes this paradox by distinguishing between the spontaneous character of an order and the spontaneous origin of the rules that generate the order (HAYEK, [1973] 1998, p.

45-6). The deliberate control of the rules of conduct of spontaneous orders would not turn the spontaneous order into deliberate ones because the rules are only able to influence the general abstract character of the orders generated, but never plan their particular results:

Where our predictions are thus limited to some general and perhaps only negative attributes of what is likely to happen, we evidently also shall have little power to control developments. [...] And sometimes, though we may not be able to bring about the particular results we would like, knowledge of the principle of the thing will enable us to make circumstances more favorable to the kinds of events we desire. Of the different classes of events which are to be expected under various combinations of circumstances which we can bring about, some may with greater probability include desirable results than others. An explanation of the principle will thus often enable us to create such favorable circumstances even if it does not allow us to control the outcome. Such activities in which we are guided by a knowledge merely of the principle of the thing should perhaps better be described by the term 'cultivation', than by the familiar 'control' – cultivation in the sense in which the farmer or gardener cultivates his plants, where he knows and can control only some of the determining circumstances, and in which the wise legislator or statesman will probably attempt to cultivate rather than control the forces of the social process (HAYEK, [1955] 2014, p. 209-10).

Spontaneous order and deliberate organization coexist and complement each other in any minimally numerous human group. For some more limited tasks, organization is certainly the most effective and powerful means, for it allows the resulting order to be shaped in detail in order to better satisfy human desires. Where circumstances are too complex, however, resorting to spontaneous orders and being content with their limited power of controlling them would be the best alternative. In the so-called free societies, organizations (households, firms, government, NGOs, etc.) are immersed in a wider spontaneous order. Groups of men stand together in organizations for achieving particular ends, but the coordination of the activities of the different organizations (and of the different individuals) is brought through a global spontaneous order, called “society” (HAYEK, [1973] 1998, p. 46).

Just as spontaneous orders, organizations often resort to rules and for the same reason: the use of rules instead of commands allows the use of knowledge that no one has in its totality. The rules used in an organization, however, are different in nature because they ultimately must comply with assigned tasks. They are therefore subsidiary to commands, insofar as they fill the gaps left open by them, and they should be interpreted in the light of the purposes given by the commands. In addition, the rules of an organization will be different for each of its members, according to the role assigned to him by his superiors (HAYEK, [1973] 1998, p. 49).

In contrast with organizational rules, the rules governing a spontaneous order must be independent of purpose and be the same to whole classes of members not appointed individually

by name. These rules should be applied by the individuals in light of their own purposes, regardless of the existence of a common purpose or of the awareness of the individual that there is such a purpose.

In the terms we have adopted this means that the general rules of law that a spontaneous order rests on aim at an abstract order, the particular or concrete content of which is not known or foreseen by anyone; while the commands as well as the rules which govern an organization serve particular results aimed at by those who are in command of the organization (HAYEK, [1973] 1998, p. 50).

The more complex the order to be achieved, the greater the part of the separate actions of individuals determined by circumstances not known by those who direct the organization and, therefore, a greater scope should be attributed to rules rather than commands. Ultimately, orders of very high degrees of complexity can only be obtained by dispensing with commands and relying entirely on rules (that will necessarily be abstract because of the absence of commands to seek particular outcomes), i.e., by making use of spontaneous orders instead of organizations.

It is paradoxical, therefore, to say that modern society should be planned deliberately because it has become too complex. In fact, the opposite is true: man is not capable to plan society precisely because it has become too complex. An order of such a high degree of complexity cannot be preserved by giving direct commands to its members, but can only be indirectly maintained through the application and improvement of rules that lead to the formation of spontaneous orders.

Hayek also deduces the liberal argument against interventionism from the relationship between rules and commands in a spontaneous order. According to him, the imposition of commands on activities guided by the general rules of conduct of a spontaneous order is not capable of improving such an order, but may only disturb it. This would occur because the intervention aims to control a system of interdependent actions guided by information and purposes only known by the agents involved, and not by the intervening authorities. The intervention, to the extent that it is effective, deprives agents in some degree from the possibility to use their particular knowledge for the achievement of their own purposes (HAYEK, [1973] 1998, p. 51).

Finally, we can summarize our discussion on deliberate orders and spontaneous orders through the tables 2 and 3:

Table 2 - Deliberate orders (taxis) vs. spontaneous orders (cosmos)

	Deliberate order (taxis)	Spontaneous order (cosmos)
Description	Intentionally created by forces exogenous to the system (imposed order).	Unintended formations generated endogenously (self-organization).
Degree of complexity	Limited to what its creator can master.	Not limited to what any element of the system can master.
Kind	Usually concrete (can be perceived directly by the human senses)	Usually abstract (not perceived by the human senses, but only by mental reconstruction).
Purpose	Serve a purpose determined by its creator.	Do not serve a particular purpose.
Formation	Results from the planning by an authority.	Result from its elements following certain rules in the interaction with their immediate environment.

Table 3 - Deliberate orders (organizations) vs. spontaneous order in society

	Organization	Spontaneous order
Proper scope	Orders of limited complexity.	Orders of high complexity.
Ability of control	Greater ability to modify the order in detail with the aim of reaching particular results desired by the creator.	More limited power of influencing the abstract character of the order generated via modification of the rules of conduct; the control of their particular outcomes is impossible
Governed by ...	Commands and rules.	Only rules.
Nature of the rules	Rules are subsidiaries to commands, interpreted in the light of the purposes established by the commands; they are different according to the agent's position in the organization.	Rules are independent from commands and interpreted in the light of the purposes of the agents themselves; they are equal for all individuals or for whole classes of individuals.

After clarifying the nature and the defining characteristics of a spontaneous order (as opposed to a deliberate order), we are still in the dark about how a spontaneous order is formed and how it changes over time. Answering that spontaneous orders are constituted by elements following certain rules only makes us pose the same question at the level of the rules. Why, after all, the adopted rules are those allowing the formation of spontaneous orders that exists at a given moment instead of any other set of rules? According to Hayek, the answer to this question is

found in the evolutionary analysis. He postulates that principles of variation, selection and reproduction are sufficient to explain the formation of several spontaneous orders:

Such a combination into more complex structures, as it occurred with the hypothetical, primitive elements, will also occur with the more complex structures (and possibly with some of its composing parts). The result will be a cumulative process, which will generate a hierarchy of structures, of which those that have the greater coherency or elasticity will have the tendency to protect its components against destruction more effectively. To become a component of a greater structure will, therefore, increase the probability of continued existence of its parts and their progressive reproduction. From the atom, which is protected by the molecule, the cell, which is protected by the organism, to the individual, who is protected by society, we find a hierarchy of superimposed orders whose continued existence can be sufficiently explained by a process in which those random variations were selected, for which an encompassing structure provided a protective shell (HAYEK, 2013, p. 248).

Evidently, the most appropriate specific formulation of evolutionary theory depends crucially on the class of phenomena under study. The similarities among these processes are in their general logic, and not in their substantive details. As we shall see, Hayek is careful in pointing differences between biological and cultural evolution.

The self-maintenance of spontaneous orders can also only be properly understood as an evolutionary process. The *sine qua non* condition for the perpetuation of a complex abstract order is the constant adaptation of the particular configuration of its elements to the new circumstances:

We understand now that all enduring structures above the level of the simplest atoms, and up to the brain and society, are the results of, and can be explained only in terms of, processes of selective evolution, and that the more complex ones maintain themselves by constant adaptation of their internal states to changes in the environment. [...] These changes in structure are brought about by their elements possessing such regularities of conduct, or such capacities to follow rules, that the result of their individual actions will be to restore the order of the whole if it is disturbed by external influences. Hence what on an earlier occasion I have called the twin concepts of evolution and spontaneous order enables us to account for the persistence of these complex structures (HAYEK, [1973] 1998, p. 158).

The characterization of spontaneous order and evolution as twin ideas also helps to clarify the necessity of the distinction between the system of rules governing the behavior of the elements of an order and the order generated by these rules. It is both possible that the same general order is produced by different systems of rules, and that the system of rules produces different orders (or produces no order at all) depending on external circumstances. What matters to preserve the set of elements that make up the order, however, are not the rules of conduct *per se*, but rather the viability of the generated order for them under the circumstances.

The evolutionary selection of different rules of individual conduct operates through the viability of the order it will produce, and any given rules of individual conduct may prove beneficial as part of

one set of such rules, or in one set of external circumstances, and harmful as part of another set of rules, or in one set of rules in another set of circumstances (HAYEK, [1967a] 2014, p. 280).

To ignore that the patterns of human activities are developed through an evolutionary process is, for Hayek, an intellectual error that can lead to deeply wrong conclusions. This would be the vision of what Hayek called *constructivist rationalism*, which states: (i) that human institutions only serve human purposes if they have been deliberately created having these purposes in mind, (ii) that the fact that a human institution exists is an evidence that it was created for some purpose, and (iii) that we should redesign society and its institutions so that our actions are guided by known purposes. For Hayek, all these propositions are demonstrably false and have their original roots in the primitive human propensity to interpret all phenomenal regularities in an anthropomorphic way, i.e., as the result of the design of a thinking mind (HAYEK, [1973] 1998, p. 8-9).

In contrast to constructivist rationalism, the view that Hayek calls *evolutionary rationalism* recognizes that the order in society stems not only from institutions created for this purpose. On the contrary, according to this view, social order is largely due to an evolutionary process in which rules initially adopted for other reasons, or even in a purely accidental way, are preserved because they allowed the rise of groups that adopted them relative to other groups.

According to Hayek, the fundamental error of constructivist rationalism is to postulate a kind of rationality that simply could not exist in a complex world. In order for all of man's actions to effectively serve purposes known to him, he would need to have a complete rationality that allowed him to always know, under the most diverse particular circumstances, what would be the most appropriate course of action to achieve his ends. But such complete rationality requires perfect knowledge of a large number of particular facts on which a successful action depends, and these facts cannot be known in their entirety by anyone (HAYEK, [1973] 1998, p. 12).

Man, therefore, necessarily acts in ignorance of many facts that he would need to know to rationally justify his action in light of his purposes. The rationality possible in this context must be of a more limited kind, one that requires less knowledge from the agent. The type of limited rationality conceived by Hayek results from the ability to follow rules that have proven to be adapted to the world in which man lives through an evolutionary process of rule selection.

Man is as much a rule-following animal as a purpose-seeking one. And he is successful not because he knows why he ought to observe the rules which he does observe, or is even capable of stating all these rules in words, but because his thinking and acting are governed by rules which have by a

process of selection been evolved in the society in which he lives, and which are thus the product of the experience of generations (HAYEK, [1973] 1998, p. 11).²⁷

In other words, for Hayek, human reason itself must be understood as the result of an evolutionary process that man himself would not be able to fully comprehend. Moreover, such rationality is embodied in rules of conduct that the individual follows without understanding the reason why and without being able to prove deductively that they are effective.

A difference between all purposive action and norm-guided action exists only in so far as in the case of what we usually regard as purposive action we assume that the purpose is known to the acting person, while in the case of norm-guided action the reasons why he regards one way of acting as a possible way of achieving a desired result and another as not possible will often be unknown to him. Yet to regard one kind of action as appropriate and another as inappropriate is as much the result of a process of selection of what is effective, whether it is the consequence of the particular action producing the results desired by the individual or the consequence of action of that kind being conducive or not being conducive to the functioning of the group as a whole. The reason why all the individual members of a group do particular things in a particular way will thus often not be that only in this way they will achieve what they intend, but that only if they act in this manner will that order of the group be preserved within which their individual actions are likely to be successful (HAYEK, [1973] 1998, p. 80).

If we take seriously this limited nature of human rationality, we must also recognize that the beneficial character of human culture and institutions depends crucially on them being adapted to many facts that man is ignorant of. According to Hayek, culture is also the result of a complex evolutionary process in which human practices that were best suited to the circumstances were selected.

Reason and culture are not the result of two independent evolutionary processes. On the contrary, the evolution of one cannot be properly understood without taking the other into account; reason and culture *co-evolve*. Culture is not determined by the use of a previously and independently developed reason. The causation between them is not unidirectional, but mutual. The success of rules of conduct that define reason also depends on them being adapted to the pre-existing culture, and the success of institutions also depends on them being adapted to the rationality developed by man (which is necessarily limited in nature).

²⁷ Hayek's conception of bounded rationality can be traced back to his studies on psychology as a young man, which later resulted in *The Sensory Order* (1952). In this book, Hayek develops a theory of the mind in which patterns of neural connections in the brain (shaped by the particular environment in which it developed) form a "map" of the world that corresponds to the mind.

That cultural evolution is not the result of human reason consciously building institutions, but of a process in which culture and reason developed concurrently is, perhaps, beginning to be more widely understood. *It is probably no more justified to claim that thinking man has created his culture than that culture created his reason.* [...] To repeat: *mind and culture developed concurrently and not successively.* (HAYEK, [1973] 1998, p. 155-6).

Given the importance Hayek attaches to the application of evolutionary analysis to social phenomena, he thinks it is necessary to clarify two common misconceptions. First, the concept of evolution is not something the social sciences have borrowed from the biological sciences. On the contrary, according to him, it was actually Darwin who inspired himself in social theorists²⁸ who were already applying the evolutionary reasoning in the discussion of spontaneous formations such as language, morals, law, and money. Unfortunately, some theorists who became known as Social Darwinists mistakenly transposed the particular formulation of evolution in biology to the social realm and thereby discredited the use of the idea of evolution in society. According to Hayek, these authors were wrong to focus on the selection of individuals rather than of institutions and social practices, and in the selection of innate characteristics of individuals rather than on those that are culturally transmitted (HAYEK, [1973] 1998, p. 22-3).

Given the suspicion that Social Darwinism generated about the use of the concept of evolution in the analysis of social phenomena, it is worth writing a little more on the differences between the biological and cultural processes. While the (neo-Darwinian) biological evolution precludes the transmission of acquired characteristics, cultural evolution is based entirely on the transmission of non-innate rules; in this sense, cultural evolution simulates Lamarckism. Moreover, in cultural evolution, parents are not the only transmitters of habits and practices. The individual has an unspecified number of "ancestors." Finally, cultural evolution operates mainly through a process of *group selection*, a kind of evolutionary process whose applicability in biology is still controversial²⁹ (HAYEK, 1988, p. 25).

The second misconception that Hayek sought to clarify was that the theory of evolution consisted in "laws of evolution" in the sense of a necessary sequence of stages or particular

²⁸ Hayek refers here to the thinkers of the Scottish Enlightenment and of the historical schools of law and language (HAYEK, [1973] 1998, p. 23).

²⁹ For a contemporary defense of the use of group selection in biology in the explanation of altruistic behavior, see Nowak, Tarnita and Wilson (2010). Once published, this article was harshly criticized by the advocates of kin selection, such as Strassmann et al. (2011).

phases through which evolution should go through and that, by extrapolation, would allow the prediction of the future course of evolution. The theory of evolution would be unable to provide laws of evolution in that sense, because it only describes a process whose specific outcome depends on a large number of particular facts to be known.

The theory of evolution, therefore, would not allow us to make predictions of particular events, but would be confined to what Hayek called explanations of the principle and pattern predictions. This belief in laws of evolution, according to Hayek, originates not in theory of evolution properly understood, but in authors such as Comte, Hegel and Marx, who, in his interpretation, claimed that evolution necessarily must take a predetermined particular course for mystical reasons (HAYEK, [1973] 1998 p.23-4).

To these two misconceptions, we can add a third one committed by some of Hayek's critics,³⁰ who interpreted his theory of cultural evolution as having incurred in a kind of Panglossian fallacy. They interpret Hayek as claiming that the evolutionary process ensures that any existing institution would be desirable or even optimal. Hayek, however, it is quite emphatic in denying that this would be the case:

I have no intention to commit what is often called the genetic or naturalistic fallacy. I do not claim that the results of group selection of traditions are necessarily 'good' - any more than I claim that other things that have long survived in the course of evolution, such as cockroaches, have moral value. (HAYEK, 1988, p. 27).

In Hayek's view, the products of cultural evolution should not be immune to criticism and change. Both moral norms and spontaneously originated laws can be improved, provided that such revision will be undertaken in the context of the general systems of morality and law, that is, by taking as given the other existing rules of conduct:

This givenness of the value framework implies that, although we must always strive to improve our institutions, we can never aim to remake them as a whole and that, in our efforts to improve them, we must take for granted much that we do not understand (HAYEK, [1960] 2011, p. 124).

Furthermore, Hayek states that cultural evolution does not necessarily lead to optimal results in terms of social welfare, claiming that “[t]here is no reason to suppose that the selection

³⁰ E.g., Gray (1989, p. 98) says, “Hayek frequently affirms that the sheer persistence of a tradition or a form of life suggests that it must possess some general utility” and De Vlieghe (1994, p. 293) interprets Hayek's theory of cultural evolution as implying that “only those cultural attainments can survive and spread that are beneficial. So, the very longevity of an institution proves its value.”

by evolution of such habitual practices as enabled men to nourish larger numbers had much if anything to do with the production of happiness” (HAYEK, 1988, p. 69). According to this author, cultural evolution operates through the survival and reproduction of groups, but he does not postulate the existence of optimality even in relation to this criterion:

It would however be wrong to conclude, strictly from such evolutionary premises, that whatever rules have evolved are always or necessarily conducive to the survival and increase of the populations following them. [...] Recognizing that rules generally tend to be selected, via competition, on the basis of their human survival-value certainly does not protect those rules from critical scrutiny (HAYEK, 1988, p. 20).

Finally, as correctly pointed out by Whitman (1998), the absence of necessarily optimal results is not a special feature of Hayekian cultural evolution, but it is something also present in biology. It is widely recognized, for example, that species can preserve "vestigial structures," i.e., non-adaptive or poorly adaptive structures in the context of present environmental conditions explained by the phylogenetic history of the organism (for instance, the human appendix).

It is also known that many traits often manifest themselves jointly³¹ so non-adaptive traits can be perpetuated because they are linked to traits of high adaptive value. There are also cases of evolutionary changes that occur for purely random reasons and others in which there are multiple adaptive peaks, allowing organisms to get stuck in "local maxima" fitness values, depending on the order by which changes occur. Therefore, in the same way that biological evolution is not inconsistent in recognizing the persistence of non- or maladaptive structures, neither is Hayek proposing a cultural evolution mechanism that features some dysfunctional institutions. Evolutionary processes need not result in optimal adaptations.

Hayek ([1979] 1998, p. 159-61) distinguishes among three main levels of rules of conduct in human societies. The first is the result of the biological evolution of *Homo sapiens*. At this level, genetic dispositions regarding social behavior were selected to the extent they were adapted to the environmental conditions. In this respect, the most relevant conditions were the ones that prevailed when men were organized in nomadic tribes of hunters and gatherers because this was the longer period of human biological evolution and also the one in which we went through the most strong selective pressure. Subsequently, such selective pressures were relaxed, but modern

³¹ This can happen either because one regulatory gene can control the activation of several genes, or due to the fact that the same gene (called pleiotropic gene) can cause multiple traits.

man largely still inherits the characteristics that were selected in this period. This level of rules explain, according to Hayek, the natural preference man has in favor of face-to-face concrete relationships suitable only to small groups, instead of abstract and impersonal relationships needed in order to maintain the Great Society (HAYEK, 1988, p. 17- 9).

The second level is the one of deliberately adopted and modified rules of conduct. As discussed previously, Hayek believes it is possible that certain spontaneous orders are maintained only thanks to deliberately created rules of conduct. Although he did not discard the desirability of such rules in all cases, Hayek argues that the proper role of them is limited.

The third level of rules is what Hayek most emphasizes and develops because it has been largely neglected by intellectuals. This is the level of traditions and morals; the level he characterized as being located between instinct and reason. It is at this level that operates what Hayek calls cultural evolution. According to him, these social rules of conduct emerge and change in an unintentional and uncontrolled way. As seen, these general rules of conduct can lead to the formation of spontaneous orders, and rules are selected according to the ability of these orders to preserve and multiply the group.³² Variation of the rules happens through historical accidents or by the creation of rules aiming at purposes other than obtaining the resulting order. Finally, the replication of rules of conduct is achieved by imitation.³³

The reflections on complexity that Hayek made throughout his life culminated in his mature works on the twin ideas of evolution and spontaneous order and the application of these concepts to the analysis of the process of cultural evolution. In some important respects, Hayek's works on evolution and spontaneous order are further developments of what he wrote on competition and equilibrium in the '30s and '40s. We have seen that the Hayekian concept of order is a generalization of Hayek's definition of equilibrium in *Economics and Knowledge*. Furthermore, in both periods, Hayek emphasizes the need of providing dynamic foundations for the explanation of the existing order in a given instant of time. In his earlier works, the process of

³² Witt (1994, p. 190) makes a pertinent criticism of the selection mechanism postulated by Hayek. According to him, the relationship between rules of conduct and group growth is virtually absent in modern societies, where the survival depends mainly on proper medical treatment and the consumption of a minimal amounts of calories.

³³ It is necessary to point out that this imitation occurs tacitly. Man does not need to be able to explain a rule he incorporated and follows in practice. For example, young children are able to communicate in their native language, committing relatively few grammatical errors, but are not able to explain the grammatical rules they use.

competition was responsible for the origin and transformation of the economic order. In the more recent ones, as discussed in this section, the same relationship is established between evolution and spontaneous order.

The importance of spontaneous institutions for social coordination, a topic Hayek had already touched in “The Use of Knowledge in Society,” (1945) is developed extensively in a complex perspective at the end of his career. Social orders, according to Hayek, are emergent properties that result from the interaction among individuals following certain rules of conduct and the environment in which they find themselves. Institutions evolve through the viability of the social order they generate, and this viability depends importantly on the fact that these institutions are adapted to the limited nature of rationality developed by man.

Finally, Hayek's project to understand the development of societies through cultural evolution is a good illustration of an application of the methodology of complex phenomena he developed in the '50s and '60s. What he seeks in this connection is not a specific prediction to serve the purposes of control or social engineering, but explanations of the principle, meaningful arrangements of events in light of certain principles.

3. Cybernetics and General System Theory

It is widely recognized in the literature³⁴ that the Austrian economist F. A. Hayek formed his views on complexity with great influence from the scientific movements of cybernetics³⁵ and general system theory (GST), the latter, in particular, through its creator, the Austrian biologist Ludwig von Bertalanffy.

This belief is justified for various reasons. First, there were explicit and positive references to the contributions of cybernetics and GST in Hayek's works from the 1950s onward. Moreover, Hayek maintained contact with some of the individuals associated with these two approaches, such as Ludwig von Bertalanffy, Heinrich Klüver,³⁶ Garrett Hardin and Ilya Prigogine.³⁷ Particularly close was his personal relationship with Bertalanffy, with whom he tried unsuccessfully to found an institute for advanced studies in Vienna in 1958.³⁸

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 makes references to authors associated with cybernetics and general system theory.

³⁴ See, for instance, Vaughn (1999b), Caldwell (2004) and Rosser (2010).

³⁵ In this work we will focus mainly on the so-called "old" or "first-order" cybernetics. The second-order cybernetics (the cybernetics of cybernetics) focuses on the subject-object problem and was associated with people such as Gregory Bateson, Margaret Mead, Heinz von Foerster, and Humberto Maturama. They see the investigation of cybernetic systems itself as a cybernetic system because there is feedback between the investigator and the system (the investigator at the same time affects and is affected by the system). There is no evidence of significant influence on Hayek from the second-order cybernetics.

³⁶ Klüver was professor at University of Chicago during the 1950s, when Hayek worked on the Chicago Committee of Social Thought (NAHM and PRIBRAM, 1998). 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).

³⁷ Ilya Prigogine was a physicist of the Free University of Brussels and associated with the cybernetics approach. Rosser (2009, p. 5) states that he learned of Hayek's approach to the "Brussels School" of cybernetics from Peter M. Allen, a student of Prigogine's

³⁸ Pouvreau (2014, p. 182), based on letters of The Bertalanffy Archive (Bertalanffy Center for the Study of Systems Science), writes that, in 1958, "Hayek wanted to found in Vienna an 'institute for advanced studies' similar to those of Princeton, Dublin and Stanford; Bertalanffy proposed that the two collaborate. But they received no support and ultimately had to give up this idea." A draft of the proposal for the creation of the institute is found on the Hayek Collection (Box 62, Folders 8-9). Besides Bertalanffy, among the other names mentioned in the proposal are the ones of Karl Popper, Gottfried Haberler, Heinz von Foerster, K. Lorenz, F. Machlup, Karl Menger, Paul Weiss and Kurt Gödel.

Second, Hayek thanked Bertalanffy for having commented on the book's draft in the preface of this book. The book's introduction was also 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 and general system theory do not appear in a peripheral way, but constitute a central part of the argument of the book. This fact surprisingly has not previously been noted by commentators.

In the next section (3.1), we will review some elements of the theories and histories of cybernetics and GST relevant to our discussion. Later, in sections 3.2 and 3.3, we will explore, respectively, how the ideas of cybernetics and GST appear in TSO and in Hayek's later works on social theory.

3.1. Cybernetics and GST: basic concepts

3.1.1. Cybernetics

Cybernetics (a neo-Greek expression that means "steersman") was defined by Norbert Wiener (1948, 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,³⁹ it doesn't 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 to represent automatic pilots, radio sets and cerebellums and draw useful parallelisms between machine, brain and society (ASHBY, 1956, p. 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:

³⁹ Cybernetics was explicitly inspired by the design of servo-mechanisms (or feedback-control systems) and by statistical mechanics (as we will see, information is defined as negative entropy).

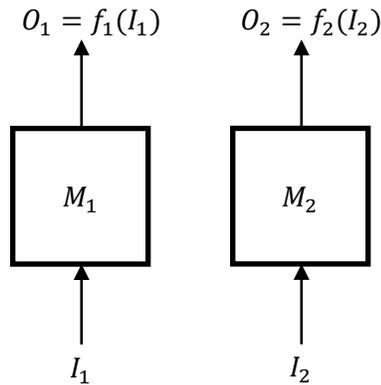


Figure 1: Isolated parts

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.

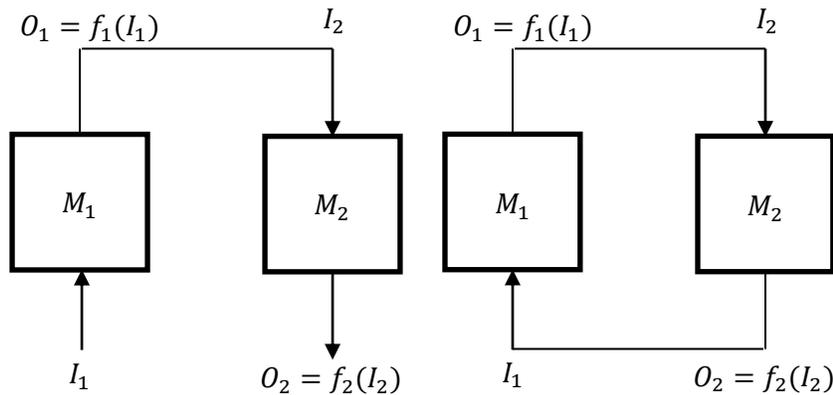
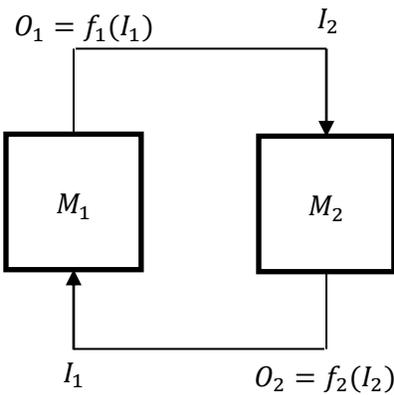
Figure 2: M_1 dominates M_2 

Figure 3: Feedback system

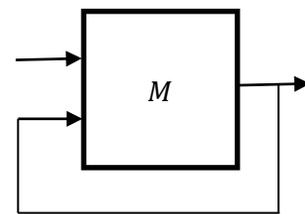


Figure 4: Feedback system seen as a whole.

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 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 by taking measures to ensure 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.⁴⁰

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.

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; TAPLIN, 1951, p. 5).

⁴⁰ In general, a system that regulates variables in order to maintain internal conditions stable is said to display the property of *homeostasis*. 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.

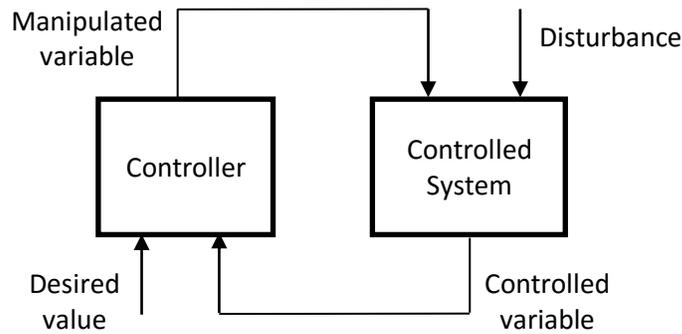


Figure 5: The components of a feedback control system. Adapted from Ahrendt and Taplin (1951, p. 5).

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:

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

In his paper, Shannon proved this was the only equation that satisfied a set of desired properties.⁴¹ Because this formula is the same as the expression for entropy in statistical mechanics, he used the terms information and entropy interchangeably.⁴² The unit of measurement of information is determined by the choice of the base of the logarithm. If 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.

At the same time, Wiener was working on similar lines as Shannon's and reached almost the same conclusions (WIENER, 1948, p. 60-94). There were, though, two significant 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, 1948, p. 11). Order – in the mechanical, living, and social worlds – could only be maintained if a sufficient quantity of information was produced so as to oppose the tendency of increasing entropy.

⁴¹ 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 $\lim_{p_i \rightarrow 0^+} p_i \log(p_i) = 0$, we can redefine $0 \log(0) = 0$ and preserve the property of continuity (KAPUR and KEVASAN, 1992, p. 28).

⁴² According to Kapur and Kevasan (1992, p. 8), it was John von Neumann who supposedly advised Shannon to use the term entropy by saying, "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 (1971) report similar but different quotes from von Neumann.

Defined in this way, information fit neatly into Wiener's general cybernetic framework. Negative feedback control systems are regulated by information that "is fed back to the control center [and] tends to oppose the departure of the controlled from the controlling quantity" (WIENER, 1948, 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,⁴³ when the allies were seeking more effective methods to defend themselves against air attacks. Invited by Vannevar Bush, Norbert Wiener 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 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 (MIROWSKI, 2002, p. 17-8).

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; SIEGELMAN, 2005, p. 88).

The end of Wiener's period in the military was immediately followed by the beginning of his work to take the analogy between servomechanisms and human behavior to the next level. 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.

⁴³ Wiener, in turn, based his work on the pre-war literature on control engineering and communication engineering and, in particular, on servomechanisms.

Rosenblueth, Wiener and Bigelow (1943) interpreted all goal-directed action as being governed by 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 interesting conclusions. First, there is no contradiction in systems being simultaneously deterministic and teleological 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, p. 62) 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.”

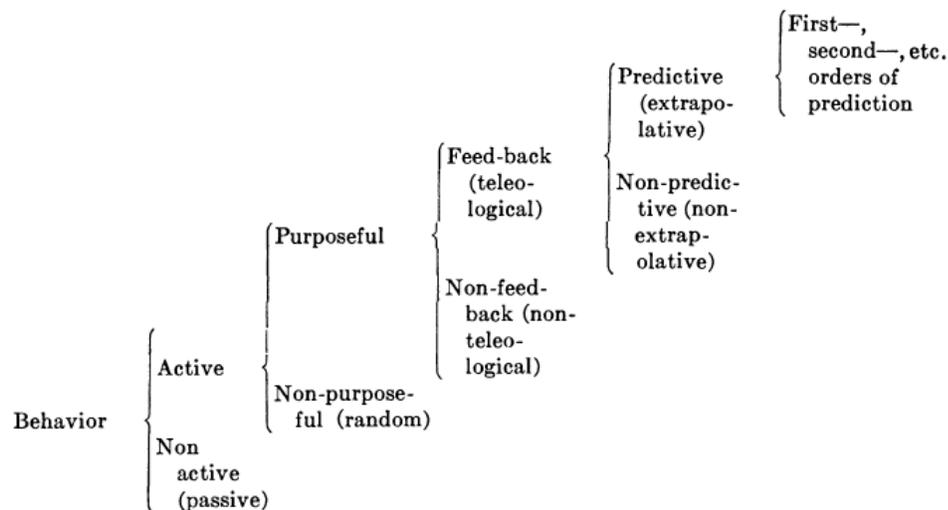


Figure 6. The classification of behavior (ROSENBLUETH; WIENER; BIGELOW, 1948, p. 11).

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.⁴⁴ Rosenblueth’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.⁴⁵

McCulloch would soon become a leading figure of the cybernetics movement. At that time, he was working with his younger colleague Walter Pitts on a project that aimed at understanding the brain as an electrical machine which 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 year after. 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; 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, named 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 of mathematics (Norbert Wiener, John von Neumann, Walter Pitts), engineering (Julian Bigelow, Claude Shannon, Heinz von Forster), philosophy (Filmer Northrop), neurophysiology

⁴⁴ The Macy Foundation was established in 1930 by a family of merchants with the mission of promoting “health and the ministry of healing.” The foundation mainly funded medical research and medical schools (TUDICO and THIBAULT, 2012). Frank Fremont-Smith, medical director of the foundation, had been a friend of Rosenblueth since their days at Harvard Medical School (CONWAY and SIEGELMAN, 2005, p. 108).

⁴⁵ 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).

(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, p. 255-6).

To our purpose, it would not be worthwhile to go through a more detailed inspection of the history of the cybernetics movement.⁴⁶ 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.

3.1.2. Bertalanffy's General System Theory

Cybernetics was not alone in its quest for interdisciplinarity based on common sets of concepts and frameworks. Another intellectual movement – general system theory – attempted to extend 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*.

The origins of cybernetics and general system theory were also quite different. Contrary to cybernetics, which was inspired by physics and engineering, general system theory's origins were initially connected to developments in the field of biology.

Bertalanffy's early contributions were on the field he called theoretical biology. He distinguished between two senses in which theoretical biology may be understood. In the first and philosophical one, theoretical biology is the logic and methodology of the science of organisms. In the second sense, theoretical biology denotes “a branch of natural science which is related to descriptive and experimental biology in just the same way in which theoretical physics is related to experimental physics” (BERTALANFFY, 1933, p. 5). Bertalanffy thought theoretical biology,

⁴⁶ 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.

in both senses, was needed as “the crown of the whole structure of the science of life” (BERTALANFFY, 1933, p. 21).

The task of theoretical biology was to establish what had already been discovered in biological research by means of a firm general knowledge, aiming to construct a unitary system. In order to accomplish this, a critical analysis was needed of the various theories that have been put forward in connection to the phenomena of life. Bertalanffy, then, proceeded with a lengthy discussion about the 1920s controversy between the biological theories of mechanism and vitalism.

The defenders of mechanism argued that biological phenomena were completely reducible to physical and chemical processes. According to these authors, once this reduction is made (and certainly it would eventually be made), there would be no more biological phenomena distinct from physicochemical ones. On the other side, the so-called vitalists denied the possibility of such reduction, based on the claim that some special non-physicochemical principle existed in living beings that could not be found in the inanimate world. This principle – which different authors called “entelechy,” “diaphysical forces,” “élan vital” or “soul,” – would be responsible for guiding and organizing the vital processes of the most diverse organisms (BERTALANFFY, 1933, p. 28).

While Bertalanffy, contrary to the mechanists, thought that biological explanation could not be completely translated strictly into physicochemical ones, he argued that to postulate a distinct and mystical “substance” of life was not an acceptable scientific solution to the problem in hand. He also pointed out that mechanism vs. vitalism was a false dichotomy because these two visions differed both in their methodological and metaphysical positions. Whilst “methodological” mechanists thought that physical laws sufficed to explain biological phenomena, “metaphysical” mechanists argued that the ultimate reality of both organic and inorganic matter was the blind interplay of atoms. Therefore, vitalism, by postulating a distinct vital substance, is the antithesis of metaphysical mechanism, but not necessarily of methodological mechanism:

From the methodological standpoint, however, we see that 'mechanism' and 'vitalism' by no means form the mutually exclusive disjunction they have been supposed to do. If a 'non-mechanist' wishes to deny the assumption of methodological mechanism that biological explanations must also be physico-chemical ones, it is obviously by no means intended that the required explanation must be 'vitalistic' (BERTALANFFY, 1933, p. 29).

That would be the position advocated by Bertalanffy. He argued that the traditional mechanist modes of explanation were, in principle, inadequate for dealing with certain essential characteristics of organisms.⁴⁷ This was because they employed the additive (or reductionist) point of view by trying to reduce biological process into physicochemical ones. In this way, they ignored the central fact that organisms display organization above the chemical level that could not possibly be grasped by chemical analysis alone. To be sure, the chemical compounds inside the organisms are analyzable in the same way as they are outside it. But there is more in the organism. The organism is its physicochemical compounds plus the way they are organized:

This is shown by the well-known experiment of rubbing lightly in a mortar the plasmodium of a slime-fungus which is about to form the sporangium. Although the substance remains quantitatively unchanged, the organization is irrevocably destroyed by this ill-treatment. And whilst under normal circumstances the plasmodium becomes converted into sporangia forming innumerable spores, after the injury it changes, in dry air, into a horny structureless mass. If drying is prevented, it decomposes under the influence of bacteria, a change which does not occur in the 'living protoplasm'. Thus *the basis of life rests on something quite different from the chemical properties of the compounds found in the plasma. This simple experiment shows that destruction of the organization means at the same time destruction of life* (BERTALANFFY, 1933, p. 47, italics added).

Therefore, Bertalanffy rejects both mechanism, because it provides us with no grasp of the organization of organic processes among one another, and vitalism, for it means “nothing less than a renunciation of a scientific explanation of biological data” (BERTALANFFY, 1933, p. 45). The vision he advocated was the system theory of the organism (or organismic biology), which recognized that the vital properties of organisms are emergent properties (or system properties) that arise out of the organization of the materials and processes inside living beings (BERTALANFFY, 1933, p. 48).

The system theory of the organism, therefore, maintains that “the whole is more than the sum of its parts.” By this, it is meant that the whole cannot be understood by the simple summation of the properties of its parts studied in isolation. Organic wholes are not mere aggregates; they are *Gestalten* or “configurations,” i.e., a totality of elements portraying strong

⁴⁷ As we will see, Bertalanffy's criticisms were directed to the “additive” mechanists, which could not provide an explanation for the organizational character of organisms. He did not maintain that *every* form of mechanism was doomed to fail. He thought it was possible, though highly improbable, that some form of “Gestalt theory” of physics (such as quantum mechanics) would allow the reduction of biology to physics. Thus, the “demand for a final reducibility to physics would be justified, although by a far more difficult path than ‘additive’ mechanism supposed.” (BERTALANFFY, 1933, p. 55).

interactions. They could, in principle (but not yet in practice), be reduced only to the combination of all its parts *and* internal relations, but not solely to its parts (BERTALANFFY, 1933, p. 54).⁴⁸ The implication Bertalanffy draws from this is that all levels of organization of the organism should be studied. He approvingly quotes Woodger:

If the organism is a hierarchical system with an organization above the chemical level, then it is clear that it requires investigation at all levels, and the investigation of one level (e.g. the chemical) cannot replace that of higher levels. This remains true quite apart from the remote future possibility of expressing the properties of all higher levels in terms of the relations between the parts of the lowest level (WOODGER, 1929, p. 273).

Bertalanffy points out that there were recent developments in other fields of knowledge that also emphasized the role played by “wholes” and “organization.” In psychology, Gestalt Theory was originated in opposition of the atomism of associationist theories. In the natural sciences, fields such as quantum mechanics, structural chemistry, crystallography and atomic physics focused on the organization of the respective parts. There were, of course, also social theories and philosophies that treated society and the world as dynamic wholes (BERTALANFFY, 1950a, p. 134-6). In the 1930s, Bertalanffy reacted to these tendencies by working on a generalization of his ideas on organismic biology to systems in general. Thus general system theory was born.

Bertalanffy identifies more than general similarities between the viewpoints of diverse areas of knowledge. He sees that there are formally identical or isomorphic laws in different fields. The exponential law, for example, is employed in the study of the decay of radium, the mono-molecular reaction, population growth, compound interest rates, etc. Though the mathematical law describing these phenomena is the same, the entities involved are different (BERTALANFFY, 1950a, p. 136-7).

The same considerations could be made about other widely used equations or systems of equations. In these cases, we have laws characterized by the fact that “they hold generally for certain classes of complexes or systems, irrespective of the special kind of entities involved” (BERTALANFFY, 1950a, 138). They are general system laws that apply to any system of a certain type, regardless of the different nature of the elements involved. The basic scientific

⁴⁸ For Bertalanffy, then, there is no emergence in the ontological sense of the term. On this, see Pouvreau and Drack (2007, p. 28-30).

theory of the exploration of formal correspondences between different theories would be called general system theory.

These formal correspondences or homologies studied by general systems theory are neither mere analogies (superficial similarities of phenomena that correspond neither to their causal factors nor in their relevant laws) nor necessarily involve identical specific explanations (in the sense of substituting specific functional forms for general ones) (BERTALANFFY, 1968, p. 84-5). The example given by Bertalanffy is of a system of n differential equations with n variables:

$$\begin{cases} \frac{dQ_1}{dt} = f_1(Q_1, Q_2, \dots, Q_n) \\ \frac{dQ_2}{dt} = f_2(Q_1, Q_2, \dots, Q_n) \\ \vdots \\ \frac{dQ_n}{dt} = f_n(Q_1, Q_2, \dots, Q_n) \end{cases}$$

Even in this general form, the conditions for properties like stability or instability can be stated. As soon as we specify the functions, other properties, such as wholeness, progressive segregation, progressive centralization, competition, hierarchy, openness, and finality, may be deduced. All these concepts, usually considered muddled or mystical, can be precisely defined and discussed by the use of the mathematical language. Even more importantly, general system theory could facilitate communication among distinct fields, enabling an easier transfer of models, but, at the same time, safeguarding against vague analogies (BERTALANFFY, 1968, p. 34).

The project of general system theory, therefore, forms an ideal of unification of the various sciences based not on the remote possibility of reduction of every field into physics, but on the claim that the world displays structural uniformities in its different levels: physical, chemical, biological and sociological. In short, the “unifying principle is that we find organization at all levels” (BERTALANFFY, 1968, p. 49).

When Bertalanffy became aware of cybernetics in 1950-1951, he started to recognize there were some different approaches similar to what he had previously called general system theory (POUVREAU, 2014, p. 183). Compartment theory, set theory, graph theory, net theory, cybernetics, information theory, theory of automata, game theory, decision theory, and queuing

theory can all be said to deal with whole general classes of systems. He, then, proceeded to distinguish between “classical” general system theory (or general system theory in the strict sense) and general system theory in the broad sense. While classical general system theory dealt only with systems of differential equations, general system theory in the broad sense included classical general system theory and the other disciplines that studied classes of systems (BERTALANFFY, 1968, p. 20-3). In the broad sense, then, general system theory is composed of scientific and philosophical perspectives on the transdisciplinary study of systems.

This vision of general system theory was not held exclusively by Bertalanffy. By the mid-1950s, he co-founded – with the economist Kenneth Boulding, the biologist Anatol Rapaport and the neurophysiologist Ralph Gerard – the Society for the Advancement of General Systems Theory (SAGST) with the aim of stimulating the integration and communication of systems research. The plural in the word systems expressed the above-mentioned awareness that there was a multiplicity of valid approaches for studying systems⁴⁹ (POUVREAU, 2014, p. 183-5). The society lasted until 1987, and among its members there were figures who also had important roles in the Macy Conferences on cybernetics, such as W. Ross Ashby, Margaret Mead, and Heinz von Foerster.

Among the contributions made by Bertalanffy himself, it is important to mention his theory of open systems and its relationship to finality. According to the second law of thermodynamics, closed systems display a general tendency toward maximum entropy or disorder. In contrast, in the living world, there seems to be present 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 products to the environment” (BERTALANFFY, 1950b, p. 26), the organism feeds from negative

⁴⁹ Later, the society was renamed the Society for General Systems Research (SGSR) in order to make more explicit the group was not committed to a single theory, but accepted and aimed at integrating a diverse range of approaches.

entropy. More rigorously, we have the following equation for the total change of entropy in an open system (PRIGOGINE, 1955, p. 16):

$$dS = d_eS + d_iS,$$

where dS stands for the total change of entropy of the system, d_eS for the change of entropy due to import and d_iS for the change due to processes inside the system. According to the second law, d_iS must be non-negative, but d_eS may be negative, in this way opening the possibility that dS may also be negative. Therefore, although the system plus the environment taken together must display an increase in entropy, the same is not true for the open system itself, which can decrease its entropy to the detriment of the environment.

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 doesn't 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's discussion on the emergence of equifinality in an (open) system that feeds from negative entropy resembles closely the cybernetics' view of goal-seeking behavior as the result of information and negative feedback mechanisms. Bertalanffy was aware of the emerging cybernetics literature, but maintained that his concept of equifinality was the more general one. According to him, implicit in the explanation of purposive behavior by means of a feedback mechanism was the assumption of a *fixed* structure that guaranteed the desired result (BERTALANFFY, 1950, p. 159). This perspective, contrary to the open system's view, would not be adequate for dealing with cases where the structure itself evolves. Thus, feedback could explain 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).

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).

Bertalanffy, though, didn't maintain that all types of finality were explainable by means of equifinality. There was also *true finality* or *true purposiveness*, in which the behavior is actually determined by the foresight of a particular goal, i.e., in which the future goal is already present in thought and is used to direct the current action. According to him, true purposiveness was a distinct characteristic of human behavior and has its origins connected with the evolution of the symbolism of language and concepts (BERTALANFFY, 1950a, p. 160).

3.2. Cybernetics and GST in *The Sensory Order*

In 1918, after a year serving in the Austrian army in World War I, the young Hayek returned to Vienna, his hometown, where he would graduate from high school (Gymnasium) and begin his higher studies at the University of Vienna. Officially, he studied law. In practice, however, he obtained a much broader training by attending classes taught by good professors from various fields of knowledge.⁵⁰ This allowed Hayek to dedicate himself to the study of psychology in his early college years. In a period in which he spent in Zurich, Hayek worked for a few weeks in the laboratory of the brain anatomist Constantin von Monakow, tracing fiber bundles of the brain (CALDWELL, 2004, p. 151-2).

⁵⁰ At that time, the University of Vienna allowed a high degree of freedom of choice among courses. Class attendance was not compulsory and students were evaluated only at the end of their formal education through oral examinations (CALDWELL, 2004, p. 149-50).

By 1920, Hayek began to write a work on psychology motivated to criticize the ideas of the positivist thinker Ernst Mach. The psychologist Adolf Stöhr and the philosopher Alois Riehl read the draft of Hayek's piece and encouraged him to continue. In September of the same year, however, he was forced to put aside this project in order to prepare for some law exams. Hayek would only return to his psychology manuscript twenty-five years later, in 1945, using it as the basis for his book *The Sensory Order* (1952) (CALDWELL, 2004, p. 137).

Regarding the state of psychology in the period between the first manuscript in 1920 and the book's publication in 1952, the dominance of the behaviorist school deserves to be highlighted. Behaviorism conceived psychology as the science of behavior, which should be described without ultimate references to mental events or internal psychological processes. According to this current of thought, the sources of behavior would be found in the external environment and not inside the head of the individual. Thus, in the scientific explanation of behavior, terms that made reference to mental states should be eliminated or reduced into solid behavioral concepts (GRAHAM, 2015).

It is hard to find two more contrasting positions than behaviorism and the subjectivism advocated by the Austrian School. Indeed, behaviorism was strongly attacked by Hayek as a form of "scientism," i.e., mechanical and uncritical transposition of the methods of the natural sciences to the social sciences. He particularly attacked behaviorism for its "objectivist" character, as opposed to the subjectivism he defended as the only legitimate and truly scientific approach to the social sciences (HAYEK, [1943] 2010). According to Hayek, 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 belief that individuals formed about the objects of their environment.

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).

Economics had not been entirely unaffected by the dominance of behaviorism in the field of psychology. The American economist Wesley Clair Mitchell, for example, argued that economic theory had to undergo a radical reformulation by the incorporation of more solid

psychological foundations which, he said, would be provided by behaviorism (MITCHELL, 1930).⁵¹ For an economist so averse to behaviorism as Hayek, it was a propitious time for the return and completion of his manuscript on psychology, and that is what he started to do in 1945, only completing the project in 1952.

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 the biologist and creator of general systems theory, Ludwig von Bertalanffy, and those by Wiener, Rosenblueth, McCulloch, Pitts, and Ashby, pioneer researchers in the field that would become known as Cybernetics.

3.2.1. TSO and the quest for 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. Objects classified as the same kind in the sensory order may be classified as different kinds in the physical order and vice-versa (HAYEK, 1952, p. 1-3).

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 that 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).

⁵¹ Hayek had direct contact with Mitchell's ideas. Between 1923 and 1924, he had the opportunity to work in New York as an assistant in empirical research on business cycles. During this period, Hayek attended Mitchell's course on the history of economic thought at Columbia University (CALDWELL, 2004, p. 150).

This is a particular way of formulating what in philosophy is known as the mind-body problem.⁵² 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 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. The philosopher Edward Feser characterizes the problems posed by qualia and intentionality in the following way:

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, p. 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, p. 299) 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.” Therefore, in Hayek’s thought, the existence of qualia presupposes the existence of intentionality, which we will now discuss.

⁵² Hayek (1952, p. 1) himself used the expression “mind-body problem” to describe his objective in TSO.

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 express 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.

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, among the effects of alternative courses, the desirable ones. Then, the effective course of action is chosen among these pre-selected ones that takes the "path of least resistance" (i.e., the course whose representation is associated with more attractive and less repellent qualities). 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, p. 124-6).

The human brain, though, is not unique in its capacity of generating purposive behavior. Much simpler organisms and machines exist and can be built by acting according to (i) and (ii)

and therefore 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 anti-aircraft guns, or the automatic pilots for aircraft, have actually been produced) which show all the characteristics of purposive behaviour (HAYEK, 1952, p. 126).

Such machines are 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. However, regarding purposiveness, Hayek sees them as differing from the human brain in degree, but not in kind.

Though he discusses in more detail the explanation of purposive behavior given by cybernetics, Hayek praised the work of Bertalanffy on equifinality in open systems as the more promising and helpful contribution to the elucidation of the problem of how purposiveness is generated by the working of the human brain (HAYEK, 1952, p. 83). Curiously, he makes no mention of Bertalanffy's notion of true finality,⁵³ which Bertalanffy himself thought to be characteristic of the higher purposive behavior of human beings. But Hayek seems to have in mind something similar to Bertalanffy's true finality as the ultimate phenomena to be explained when he 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 concepts of negative feedback and equifinality. He nevertheless endorsed both as providing good, albeit not fully satisfactory, explanations 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

⁵³ It must be said that Bertalanffy defines true finality in his 1950 article, which is cited in TSO.

cybernetics and general system theory. In fact, it seems that his views were already formed before he had any contact with the ideas of both of them.⁵⁴ What I do contend is that Hayek made an important use of equifinality and, specially, of negative feedback as scientific evidence in favor of his theory of the existence of multiple degrees of purposiveness in machines, lower organisms, and men.

3.2.2. Theoretical psychology and non-reductionism

We have seen how Hayek tried to explain the emergence of mental phenomena from physical forces with the help of cybernetics and GST. In order to meet the behaviorist challenge to subjectivist economics, however, he would need more than that. To justify the use of mentalist categories, Hayek would have to make a case for why mental phenomena could not be reduced to the physical constituents from which they emerge.

Hayek's task had close parallels with Bertalanffy's early contributions to theoretical biology. It is interesting to note that Hayek claims that *The Sensory Order* is – as its subtitle indicates – “an inquiry into the foundations of theoretical psychology.” TSO, though, as Birner (2015, p. 169) correctly emphasized, is “not primarily a book on psychology but on the theory of the mind.” Theoretical psychology here must be understood in the same sense of Bertalanffy's theoretical biology, which, as we have seen, included philosophical aspects. Hayek's theoretical psychology was about the nature of the relationship between the mental order and its physical constituents in the same way that Bertalanffy's theoretical biology explored the relationship between the biological whole and its physicochemical components.

It is not surprising, then, when Hayek writes that all that “theoretical biology has in this respect to say on the significance of structural properties as distinct from the properties of the elements, and about the significance of 'organization' is directly applicable to our problem”

⁵⁴ Already in the first manuscript of “What is Mind?” dated in 1945, in which no sign of influence from either cybernetics or general system theory 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).

(HAYEK, 1952, p. 47), referring to the works of Bertalanffy and Woodger in a footnote. He also asserts that what he attempted in the book was “a sketch of a 'theoretical psychology' in the same sense in which we speak of theoretical physics or theoretical biology” (HAYEK, 1952, p. 184). As Caldwell (2004, p. 278) has already pointed out, Hayek seems to owe to Bertalanffy all the references he makes to the findings of theoretical biology.⁵⁵

Hayek, in his theory of the mind, made a similar characterization as the one made by Bertalanffy regarding emergent or structural properties as arising out of the organization or relations between the parts of a whole. As we have seen, Bertalanffy had argued that the elements of an organism had physicochemical properties that could be discovered by studying these elements in isolation, but that they also had properties obtained from the way the parts were related or organized. Similarly, Hayek writes on how “irrespective of the properties which those [neural] events will possess by themselves, they will possess others solely as a result of their position in the order of inter-connected neural events” (HAYEK, 1952, p. 46). For Hayek, then, as for Bertalanffy, the whole is greater than the mere sum of its parts because an “order involves elements plus certain relations between them” (HAYEK 1952, p. 47) and an arrangement of relations may generate emergent properties that would not be found in the elements in isolation.

In the “philosophical consequences” chapter of his book, Hayek discusses the possibility of the reduction of mental phenomena to physical ones. As we have seen, Bertalanffy had a similar discussion relative to the reducibility of biology into physics. In the end, Bertalanffy left open the question of whether biology would ultimately be reduced to physics, concentrating his criticisms on the existing types of reduction of “additive mechanism” that did not take into account that organization was a central characteristic of organisms. Until the issue of reducibility was resolved, though, he urged the search for scientific laws at all levels of reality. It was completely legitimate, then, to postulate biological laws that were non-deducible from present physical theory.

⁵⁵ Further evidence that Hayek’s usage of “theoretical psychology” was influenced by Bertalanffy’s theoretical biology is provided by the reading of the two manuscripts of “What is Mind?” from 1945 and 1947, that would later become *The Sensory Order*. In 1945, Hayek makes reference to neither theoretical psychology nor theoretical biology. By the end of 1947, the year in which correspondences indicate Hayek had read the German version of Bertalanffy’s *Problems of Life* (Hayek Collection, Box 12, Folder 4) the subtitle of the work became “An Essay in Theoretical Psychology” (Hayek Collection, Box 128, Folders 34-35).

Hayek took a similar position to Bertalanffy's, but went beyond him by asserting an absolute irreducibility of mental phenomena. According to Hayek, it is not the case that a dualistic description of the world is necessary only until a remote reduction of the mental to the physical is done by scientists. For him, that reduction could not possibly be done.⁵⁶ At the same time, Hayek's theory was materialist and physicalist: ultimately, mind was "determined by the same kind of forces that rule in that [physical] world" (HAYEK, 1952, p. 178)

He maintained such a seemingly contradictory position by pointing to the fact that, when men tried to reduce mental phenomena into physical ones, the human brain was both the object to be explained and the explanatory apparatus. According to his theory, however, an explanation of detail was only possible if the explanatory apparatus had a higher degree of complexity than the object to be explained. Therefore, the "whole idea of the mind explaining itself is a logical contradiction" (HAYEK, 1952, p. 192).

Lewis characterizes Hayek's position on the mind-body problem as an example of non-reductive materialism or property dualism:

It is materialist in the sense that it portrays the brain as consisting, ultimately, of nothing more than physical matter; but it is non-reductive nevertheless because it suggests that the structured interaction between those physical particles gives rise to distinctive, ontologically irreducible mental properties (hence, property dualism) (LEWIS, 2015, p. 11-2).

However, Lewis' description is not precise in two ways. First, while it is true that, for Hayek, the properties of the sensory order were not reducible solely to the physical properties of the individual neurons, it is also true that they can be reduced to these properties *and* the relations among them. The answer to the question of whether Hayek believes in "ontologically irreducible mental properties" depends on what one considers to be the ontological elements of reality. If one considers not just properties but also relations as ontological elements, then there can be no doubt that emergent properties are seen by Hayek as ontologically reducible.

⁵⁶ At this point, Hayek was even more radical than Ludwig von Mises, the other champion of Austrian subjectivism. Mises did not claim that a future reduction of mental into physical events was impossible, but just that science had not succeeded yet in doing so and that, until this is done, a methodological dualistic approach was needed: "Man—up to now, at least—has always gone lamentably amiss in his attempts to bridge the gulf that he sees yawning between mind and matter [...]. All that we can infer from it is that science—at least for the time being—must adopt a dualistic approach" (MISES, 1957, p. 1).

Second, the reason why Hayek considered men could not reduce mental phenomena into physical ones has no direct relation with the sole presence of emergent properties in the brain. Hayek never denies the possibility of reduction of wholes showing emergent properties into their elements and their relations if these wholes display a low degree of complexity. His claim that mental phenomena are irreducible is grounded not on the assertion that emergent properties are inherently irreducible, but on his contention that there are limits to the explanatory capacity of the human brain which forbid human detailed explanation of phenomena with high degree of complexity.⁵⁷

According to Lewis, Hayek's "emergence-based perspective" describes the human mind as having the "ability to imbue events with subjective meaning and to initiate novel courses of action" (LEWIS, 2015, p. 12), contrary to Birner's (1999, p. 75) claim that "Hayek's physicalist reductionism turns out to be a straightjacket that leaves no room for any active and creative role of man." The two authors, though, seem to define "creativity" in different ways: for Lewis it means emergence of ontologically irreducible properties, whereas for Birner it seem to denote non-determinism. If this is so, their claims are not incompatible. As we have argued, Hayek's position may be described as portraying "new" ontologically non-reducible emergent properties, depending on one's vision of what counts as ontological elements. At the same time, Hayek's theory is completely deterministic, in the sense that "all human action is causally determined by physical processes" (HAYEK, 1952, p. 193).

Hayek's intention in TSO, though, was not to defend the existence of human creativity in Birner's sense. His goal was to argue that the subjectivist approach to social sciences was not only legitimate, but was the only truly scientific one. Borrowing the concepts of negative feedback and equifinality from cybernetics and general system theory, Hayek was able to argue that purposive behavior and determinism were not incompatible. Purpose thus should not be seen as a meaningless metaphysical concept, but a scientific one grounded on solid physical and

⁵⁷ Of course, the concepts of emergence and of the degree of complexity are closely related in Hayek's thought. But they should not be confounded. While, in his view, each emergence of a "new" property increases the degree of complexity of a phenomenon, the mere presence of emergent properties does not necessarily imply that we are dealing with complex phenomena. Emergent patterns can be characterized as complex only if the "minimum number of elements of which an instance of the pattern must consist in order to exhibit all the characteristic attributes of the class of patterns in question" is high (HAYEK, [1964] 2014).

biological knowledge. By further claiming that the brain could not fully explain itself, Hayek concludes that mental events could not possibly be reduced to physical ones.

Our conclusion, therefore, must be that to us mind must remain forever a realm of its own which we can know only through directly experiencing it, but which we shall never be able fully to explain or to 'reduce' to something else. Even though we may know that mental events of the kind which we experience can be produced by the same forces which operate in the rest of nature, we shall never be able to say which are the particular physical events which 'correspond' to a particular mental event (HAYEK, 1952, p. 194).

Therefore, human purposive behavior, which we know to be explainable in principle by physical phenomena (and is wholly compatible with physical determinism), cannot in practice be explained in detail. Unable to recur to physics, the sciences of human action could only be based on “our direct knowledge of the different kinds of mental events, which to us must remain irreducible entities” (HAYEK, 1952, p. 191). Thus Hayek’s “scientific subjectivism” (CALDWELL, 1994) was formulated in which “a physicalistic theory of mind serves him to save the autonomous position of intentional phenomena and their consequences, including subjectivism in the methodological sense” (BIRNER, 2015, p. 173).

In the beginning of the twentieth century, behaviorism was influential in psychology and claimed that mentalist descriptions of events – like those of subjectivist economists – had no place in rigorous scientific analysis. Hayek’s task in TSO was to show that the other way around was true: not only was it entirely legitimate to make a subjectivist description of human behavior, but this was also the only truly scientific procedure. In order to support this strong claim, Hayek would tackle the mind-body problem, using both philosophical arguments and *scientific* ones he borrowed from cybernetics and general system theory.

As we have seen, the mind-body problem involves the explanation of qualia and intentionality. Hayek’s explanation of qualia involves the intentional concept of “classification” and, therefore, presupposes the solution of the problem of intentionality. To the phenomena of intentionality, in turn, he gives the following explanation of the principle of its working: “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” (HAYEK, 1952, p. 26).

From Wiener’s anti-aircraft machine to the human brain, all purposive behavior would be explainable by this principle. The basic difference between such distinct purposive systems lay not on their nature, but in their different degrees of complexity. A difference solely in the degree

of complexity can generate a difference in the nature of the explanation allowed to the phenomena. Both the anti-aircraft machine and the human brain are, at the same time, purposive and *in principle* entirely reducible to physics. However, as the human brain is itself the apparatus of explanation to be used, we could only explain in detail phenomena having a lower degree of complexity than that displayed by the brain itself. Therefore, in practice, men cannot reduce to physics the human brain, but can only do so (and have done so) to other simpler purposive systems like the anti-aircraft machine.

By identifying human purposive behavior as having the same nature as the behavior of negative feedback systems and equifinal open systems, Hayek was able to claim that the existence of subjective qualities and purpose was grounded in the rigorous findings of the natural sciences. By further arguing that the brain fully explaining itself was a logical contradiction, he maintained that human subjectivity, though explainable in principle by the natural sciences, could not be so in detail, thus rendering its reduction to physical events impossible in practice. Consequently, the social sciences must start with mental phenomena, which are to be taken as irreducible data. Subjectivism is their only truly scientific approach.

3.2.3. 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 lay 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:

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)

As Birner (2009, p. 188-90) has shown, 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 causal 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 argues 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 Bühler, Popper says it is 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 “[a]ny 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 explanations of the principle of these phenomena. It seems that it was this that motivated him to write his unfinished manuscript named “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 “having”[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 systems⁵⁸ (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 language 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 that 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 gives of a cybernetic system that regulates its stock of fuel through negative feedback. When the stock of fuel is low, the system's response would be to act in a manner 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 doesn't mention the argumentative function, leaving unexplained two of Popper's four functions of language.

⁵⁸"The term system will thus be used here roughly in the sense in which it is used in von Bertalanffy's 'General System Theory'" (ibid, p. 4).

Hayek, therefore, “had failed to explain one or more higher functions of language within his theory – *as Popper had predicted!*” (BIRNER, 2009, p. 189, italics in the original).

Hayek ultimately did not succeed in explaining in principle the highly purposive behavior displayed by human beings as illustrated by their uses of language. It seems like neither negative feedback nor equifinality were enough to give an account of the workings of human purpose, leaving a not so well technically trained Hayek helpless in front of this huge challenge. Hayek’s use of cybernetics and general system theory, however, does not end here. When Hayek, after learning about these intellectual movements, turned his attention from the sensory order back to the social order, he saw that he could restate and further elaborate his ideas using the same concepts. Self-regulating machines and organisms, from analogs to the human brain, would be used by Hayek as analogs to human society.

3.3. Cybernetics and GST in the social order

3.3.1. 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. We must avoid, however, the temptation of describing TSO as laying some kind of foundation to 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] 1998, 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.⁵⁹ Our aim is the more humble one of analyzing this issue solely from the point of view of the ideas and concepts of cybernetics and general system theory. Restricting the scope of analysis in this way, and recalling that Hayek makes no reference to these theories before he started working on TSO,⁶⁰ it becomes evident that the use of these ideas proceeded chronologically from TSO to his other works. Our task, therefore, will be to describe how the ideas of cybernetics and general system theory, 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 make a presentation on “*The Sensory Order After 25 Years*” in a conference organized by psychologists who were rediscovering his long neglected book on theoretical psychology.⁶¹ 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:

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, p. 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] 1998, 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

⁵⁹ 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* titled *The Social Science of Hayek's 'The Sensory Order.'* Also relevant to this theme are Butos and Koppl (2007) and Gick and Gick (2001).

⁶⁰ Interestingly, references to cybernetics and general system theory are also not to be found 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.

⁶¹ 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, p. 2-4).

the knowledge of the whole. In both systems, the mutual coordination of the parts (neuron or individual) 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).

This leads us back to Hayek's seminal article, "Economics and Knowledge," in which he explicitly introduced the broad and interdisciplinary research program of coordination he would pursue until the end of his life. It is worth quoting the following passage once again:

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 of the spontaneous order of which liberal economists have so long been talking (HAYEK, [1965] 2014, p. 49-50).

In this article, Hayek considers the challenges posed by the subjectivity and dispersion of knowledge to the use of the notion of equilibrium. 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. The question asked by Hayek is how this state of things is obtained. 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), 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" (HAYEK, [1945] 2014, 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.

Prices, thus, implicitly convey important information to the individuals of which they could not be directly aware.

Cybernetics, with its emphasis on the relationship between information and organization, seemed to provide to Hayek 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 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, 1948, p. 159).

In spite of this, Wiener's discussion of the cybernetics of society hints at some 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, 1948, 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, 1948, p. 157).

The implications Wiener drew from this, however, were quite different from Hayek's. According to Wiener, the means of communication of a society too large for direct contact among its members 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 given by 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, 1948, p. 161).

Contrasting Wiener's perspective with Hayek's, what draws one's attention is not only their ideological differences, but mainly what each of them thought as being the main communication mechanisms that could allow order in society. 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 the different goods of 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 were the whole thing.

3.3.2. 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.⁶² We will show that Hayek and Hardin knew each other personally, and that Hayek made positive references to Hardin in some of his works.

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, "[i]n 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

⁶² Garrett Hardin is widely known in the economics circles as the formulator of the problem of "The Tragedy of the Commons." However, Chiappin and Leister (in press) claim that the true original formulation of this problem should actually be credited to Thomas Hobbes.

tendency of gravitation toward the norm. In short, Smith's "invisible hand" was actually a "cybernetic hand," which had a close analog in the Darwinian adaptation process.

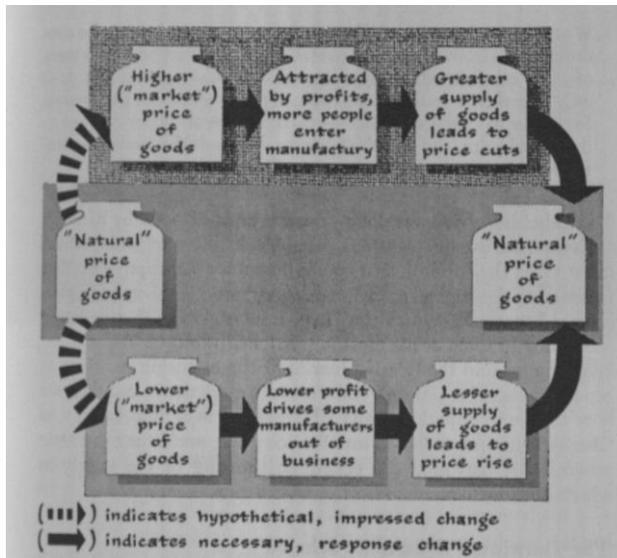


Figure 7. The cybernetic system of price regulation in classical economics (HARDIN, 1959, p 53)

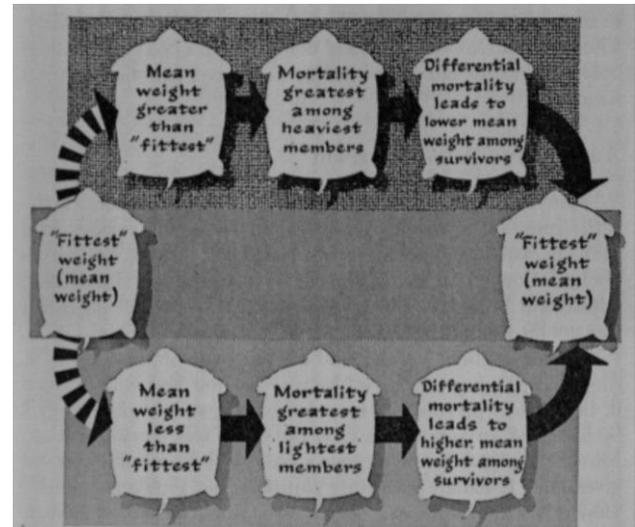


Figure 8. The cybernetic system of trait regulation in Darwinian evolution (HARDIN, 1959, p. 55)

These adjustment processes are not costless. They incur "waste" in the form of, say, 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 eighteenth 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, p. 326-7).⁶³

⁶³ 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 “[i]n 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, p. 301-2). But why is this waste not quickly eliminated by the selection process? The first reason 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’s⁶⁴ book and made 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).⁶⁵ Besides, as some “intelligent biologists” like Hardin had recognized, “the idea of the formation of spontaneous or self-determining orders, like the connected idea of evolution, has

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, p. 304-5).

⁶⁴ Hardin was also familiar with Hayek’s works. In the Hayek Archives of the Hoover Institute, there is a couple of letters from Hardin to Hayek. 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).

⁶⁵ 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, 345) and “in the language of modern cybernetics, the feedback mechanism secures the maintenance of a self-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).

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 enough technical training,⁶⁶ Hayek would never develop a formal cybernetic model of the price system. The work in which he would best develop the understanding of prices changes as conveying negative feedback is *Law, Legislation and Liberty* (LLL):

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] 1998, p. 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 the conditions for a tendency to equilibrium.⁶⁷ 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 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).

⁶⁶ As Caldwell (2016, p. 176) puts it: “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.”

⁶⁷ Except that in LLL he substitutes the concept of order for the one of equilibrium. As we have seen in section 2.3, the difference between the two is that while equilibrium requires a perfect compatibility of plans, order requires only partial compatibility. For a great discussion about Hayek’s concept of order and its implications for economics, see Vaughn (1999a).

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, is 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-communicating ability of the price system because they restrict the amount of knowledge used in the determination of prices from the knowledge of particular circumstances of millions of individuals to the one 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] 1998, 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, we often see undeserving people being highly rewarded and deserving ones receiving 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 (FLEETWOOD, 1996, p.744).

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 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.

3.3.3. Bertalanffy and the structural dynamic foundations of social order

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 cybernetic models can only account for orders generated through the secondary regulations of a given fixed structure (in the case of Hayek’s 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.

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 similar remarks about the limitations of homeostasis as a means of attaining and preserving order. Changes in the environment, says Hayek, sometimes requires 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, p. 282-3, italics added)

Hayek’s theory of cultural evolution, however, cannot be said to be a particularly “Bertalanffyian” one.⁶⁸ To the contrary, Hayek’s disagreements with Bertalanffy on evolution should not be understated. For example, in a paper called “Chance or Law” presented in the 1968 Alpbach Symposium,⁶⁹ Bertalanffy criticized the neo-Darwinian orthodoxy, claiming that adaptation and random mutations did not constitute a satisfactory account of the evolution of species because it left largely unexplained the observed tendency of the progression of evolution toward higher organization. Hayek was present at this symposium and commented that he was not convinced of Bertalanffy’s claims (BERTALANFFY, 1969, p. 56-82). In fact, the central role of chance is one of the few substantive parts of biological evolution that Hayek retains in his theory of cultural evolution. According to Hayek, new beneficial rules of conduct were usually adopted not because their outcomes were anticipated, but were either adopted for other reasons than the (unintended) outcomes, or were the result of accidental developments (HAYEK, [1973] 1988, p. 9).

The relevance of Bertalanffy’s ideas to understanding Hayek, therefore, should not be sought in the latter’s particular formulation of the theory of cultural evolution. Following Lewis (2015), what is contended here is that Bertalanffy provided the *abstract conceptual framework* that Hayek would use to articulate his views on the nature and evolution of self-organizing

⁶⁸ His actual inspirations are to be found in the thinkers of the Scottish Enlightenment, in Carl Menger, and in the few biologists that advocated the relevance of group selection mechanisms in the theory of evolution.

⁶⁹ The 1968 Alpbach Symposium, with the title of “Beyond reductionism: New perspectives in the life sciences,” gathered around scientists discontent with “the insufficient emancipation of the life sciences from the mechanistic concepts of nineteenth-century physics, and the resulting crudely reductionist philosophy” (KOESTLER, 1969, p. 2). Hayek presented “The Primacy of the Abstract” at this conference.

systems.⁷⁰ Significantly, Hayek borrowed Bertalanffy's view of stratified character of reality, which displayed regularities on its multiple levels, from the "lower-level" regularities of physics and chemistry to the "higher-level" ones of biology and social sciences.

Writing to Popper in the year of 1960, Hayek said he was trying to apply the Bertalanffyian notion of higher-order regularities in his economic theory.

[I] began ... an attempt to restate my views of the nature of economic theory and the conception of higher level regularities which I then formed continues to occupy me and seems fruitful far beyond the field of economics. I suspect it is really what Bertalanffy with his General Systems Theory was after and the conception itself was of course already implied in my 'Degrees of Explanation.' I continues to become clearer, though I have not yet got an altogether satisfactory formulation of what I am after (Hayek Collection, Box 44, Folder 2).⁷¹

In his 1967 article "Notes on the Evolution of Systems of Rules of Conduct," Hayek distinguished between the separate actions of the individuals of a group and the overall order or system of actions. Hayek argues that this overall order of actions is more than the mere sum of the separate actions not only because there are relations among the actions, but also because the whole and its parts interact with a world external to the system. The regularities of the system of actions are thus higher-order regularities in the sense that they could not be reduced to the regularities observed in the behavior of its individual elements (HAYEK, [1967a] 2014, p. 282-3).

In "The Results of Human Action but not of Human Design," Hayek further developed his views on the relationship between evolution and spontaneous orders. There, Hayek argued 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 he meant the

⁷⁰ Cybernetics was also an inspiration for a terminological shift Hayek undertook in his later works. As he puts it in his book *Law, Legislation and Liberty*: "It was largely the growth of cybernetics and the related subjects of information and system theory which persuaded me that expression other than those which I habitually used may be more readily comprehensible to the contemporary reader. Though I still like and occasionally use the term 'spontaneous order', I agree that 'self-generating order' or 'self-organizing structures' are sometimes more precise and unambiguous and therefore frequently use them instead of the former term. Similarly, instead of 'order', in conformity with today's predominant usage, I occasionally now use 'system'. Also 'information' is clearly often preferable to where I usually spoke of 'knowledge', since the former clearly refers to the knowledge of particular facts rather than theoretical knowledge to which plain 'knowledge' might be thought to refer" (HAYEK, 1973, p. xviii-xix).

⁷¹ In this letter, Hayek was referring to a book he planned to write (without success) and a lecture he gave in 1961 at the University of Virginia with the title of "A New Look at Economic Theory." This lecture has been published recently (HAYEK, 2014). For more information on the failed book project, see Caldwell (2016).

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.

Hayek then notes the similarities between his conception and the one found in the biological field:

The theory of evolution of traditions and habits which made the formation of spontaneous orders possible stands therefore in a close relation to the theory of evolution of the particular kinds of spontaneous orders which we call organisms, and has in fact provided the essential concepts on which the latter was built (HAYEK, [1967b] 2014, p. 298).

In a footnote added to this passage, Hayek asks the reader to compare his discussion with the one made by Bertalanffy in the context of the study of biological organisms. In the chapter from which Hayek quotes in *Problems of Life*, Bertalanffy argues that the usual biological distinction between morphology (the study of organic *structures*) and physiology (the study of the organic processes or *functions*) is an artificial one. It is interesting to quote him at length:

The antithesis between *structure* and *function*, *morphology* or *physiology*, is based upon a static conception of the organism. In a machine there is a fixed arrangement that can be set in motion but also can be at rest. In a similar way the pre-established structure of, say, the heart is distinguished from its function, namely, rhythmical contraction. Actually, this separation between a pre-established structure and processes occurring in this structure does not apply to the living organism. For the organism is the expression of an everlasting, orderly process, though, on the other hand, this process is sustained by underlying structures and organized forms. What is described in morphology as organic forms and structures, is in reality a momentary cross-chapter through a spatio-temporal pattern. What are called structures are slow processes of long duration, functions are quick processes of short duration (BERTALANFFY, 1952, p. 134).

We are now able to clarify the significance of Bertalanffy to understand Hayek's ideas on spontaneous orders and evolution. First, drawing in part from Bertalanffy's ideas, especially his concept of higher-order regularities, Hayek was able to restate his views on the relationship among the individual parts of a system, the system as a structured whole, and the resulting order generated by the interaction between the system and its environment. Second, and more importantly, although Hayek attributes the original insight of the close relationship between evolution and spontaneous order to the thinkers of the Scottish Enlightenment and to the later Carl

Menger,⁷² it was from Bertalanffy that he got the conceptual framework that enabled him to articulate and justify this alleged intimate relationship.⁷³

As we have seen, Bertalanffy's influence on Hayek should not be sought in the particulars of Hayek's theory of cultural evolution but is found instead in the way Hayek links the "dynamics" of evolution to the "statics" of spontaneous orders. This also helps us better understand the role played by cybernetics in this connection. 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 of the price system that, provided it is embedded in a larger background of suitable social institutions, can maintain a good degree of individual plan coordination. These social institutions, in turn, are formed and change over time through a larger dynamic process of cultural evolution.

⁷² 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 at 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.

⁷³ As Lewis (2015, p. 22) puts it: "... 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 [...] What we can see here, then, is that 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."

4. Concluding Remarks

As seen in our introduction, Colander, Holt and Rosser (2004) claim that a new complex orthodoxy is gradually emerging inside the mainstream of the economics profession. Given this context and the affinity between the ideas of complexity theory and of the Austrian school, Koppl (2006) argues that a lot of mutually beneficial exchange could occur between Austrians and cutting-edge economics researchers. This is even truer in the case of Austrians that take as their main inspiration the works of Hayek, the Austrian author closest to the complexity approach.

A mutually beneficial intellectual interaction, however, requires some degree of mutual comprehension. Unfortunately, we are still far from a satisfactory understanding of Hayek's own conception of complexity and its relationship with the complexity theories of both his time and of today. In this work, I tried to contribute a little bit to fill this gap in the present literature. More specifically, I explored the fundamental ideas on complexity Hayek developed in different moments of his career and analyzed his relationship with the intellectual movements of cybernetics and general system theory.

As we have seen in chapter 2, Hayek had already laid the foundations for his complex social and economic theories in his papers on the nature of knowledge and competition in the '30s and '40s. Later, in the '50s and '60s, he developed his own concept of complexity and proposed a methodology for the study of complex phenomena. Finally, from the late '60s onward, Hayek worked on the application of the twin ideas of evolution and spontaneous order to the interpretation of the complex development of human culture and institutions.

In chapter 3, we have seen how Hayek used the concepts and ideas drawn from cybernetics and GST from his book *The Sensory Order* to his later works on the nature and origins of social order. I argued that Hayek's initial interest in these theories lay in their potential in explaining purposive behavior and thus providing a scientific justification for the subjectivist approach to the social sciences. This project, however, would ultimately fail, as Hayek was unable to provide a satisfactory answer to Popper's challenge to his theory.

Later, Hayek would use the frameworks of cybernetics and GST to restate and further develop his ideas on the spontaneous formation of orders. One of the central institutions allowing 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 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 work, Hayek said he thought he was almost alone when he was beginning to work on complexity, but that this was no longer true by the end of his career. Were Hayek alive today, he would have even fewer reasons to feel lonely. It is simply amazing how little complexity economics and complexity social science have learned from such an important pioneer as Hayek, and how little most of the self-proclaimed "Hayekians" have contributed to the complexity literature. With this small contribution to the historiography of economic thought, I hope to drag a bit more attention from complexity researchers and Hayekians to the possibilities of gains from trade.

References

- AHRENDT, W. R.; TAPLIN, J. F. **Automatic Feedback Control**. New York: McGraw-Hill Book Company, 1951.
- ARTHUR, W. B.; DURLAUF, S.; LANE, D. **The Economy as an Evolving Complex System II**. MA: Addison-Wesley, 1997.
- ASHBY, W. R. Principles of self-organizing dynamic systems. **J. Gen. Psychol.**, v. 37, p. 125-8, 1947a.
- _____. Dynamics of the cerebral cortex. Automatic development of equilibrium in self-organizing systems. **Psychometrika**, v. 12, p. 135-40, 1947b.
- _____. Design for a Brain. **Electronic Engineering**, v. 20, 1948.
- _____. Review of N. Wiener, Cybernetics. **J. Mental Sc.**, v. 95, p. 716-24, 1949.
- _____. **An Introduction to Cybernetics**. New York: John Wiley & Sons Inc., 1956.
- _____. **Design for a Brain**. 2. ed. New York: John Wiley & Sons Inc, 1960.
- _____. Principles of the Self-Organizing System. In: FOERSTER, H. V.; ZOPF JR., G. W. **Principles of Self-Organization**. New York: Pergamon Press, 1962. p. 255-278.
- AVERY, J. **Information Theory and Evolution**. River Edge: World Scientific Publishing Co. Pte. Ltd., 2003.
- BARBIERI, F. Complexity and the Austrians. **Filosofía de la Economía**, Julho 2013. 47-69.
- BERTALANFFY, L. V. **Modern Theories of Development: An Introduction to Theoretical Biology**. London: Oxford University Press, 1933.
- _____. An Outline of General System Theory. **The British Journal of Philosophy of Science**, London, p. 134-65, August 1950a.
- _____. The Theory of Open Systems in Physics and Biology. **Science**, 13 January 1950b. 23-9.
- _____. **Problems of Life**. London: Richard Clay and Co., 1952.
- _____. **General System Theory: Foundations, Development, Applications**. New York: George Brazillier, 1968.
- _____. Chance or Law. In: KOESTLER, A.; SMYTHIES, J. R. **The Alpbach Symposium 1968 - Beyond Reductionism: New perspectives in the life sciences**. London: Hutchinson & Co, 1969. p. 56-84.
- BIRNER, J. Hayek's Grand Research Programme. In: BIRNER, J.; ZIJP, R. V. **Hayek, Coordination and Evolution**. London: Routledge, 1994. Cap. Introduction.
- _____. The Surprising Place of Cognitive Psychology in the Work of F.A. Hayek. **History of Economic Ideas**, v. 7, p. 43-83, 1999.

_____. From group selection to ecological niches. Popper's rethinking of evolutionary theory in the light of Hayek's theory of culture. In: COHEN, R. S.; PARUSNIKOVÁ, Z. **Rethinking Popper, Boston Studies in the Philosophy of Science**. Dordrecht: Springer, 2009. p. 185-202.

_____. F. A. Hayek's The Sensory Order: An Evolutionary Perspective? **Biological Theory**, v. 10, n. 2, p. 167-75, June 2015.

BIRNER, J.; ZIJP, R. V. (Eds.). **Hayek, Coordination and Evolution**. London: Routledge, 1994.

BLAUG, M. Competition as an end-state and competition as a process. In: BLAUG, M. **Not Only an Economist: Recent Essays by Mark Blaug**. [S.l.]: Edward Elgar, 1997.

BUTOS, W. N.; KOPPL, R. G. Does The Sensory Order Have a Useful Economic Future? In: KRECKÉ, E.; KRECKÉ, C.; KOPPL, R. **Cognition and Economics**. Oxford: Elsevier Ltd., v. 9 of Advances in Austrian Economics, 2007. p. 19-51.

_____. (Ed.). **The Social Science of Hayek's 'The Sensory Order'**. [S.l.]: [s.n.], v. 13 of Advances in Austrian Economics, 2010a.

_____. The Unexpected Fertility of Hayek's Cognitive Theory: An Introduction to The Social Science of Hayek's The Sensory Order. In: BUTOS, W. N. **The Social Science of Hayek's 'The Sensory Order'**. [S.l.]: Emerald Group Publishing Limited, v. 13 of Advances in Austrian Economics, 2010b. p. 1-20.

CALDWELL, B. Hayek's Transformation. **History of Political Economy**, 1988. 513-41.

_____. Hayek's Scientific Subjectivism. **Economics and Philosophy**, v. 10, n. 2, p. 305-313, Oct. 1994.

_____. **Hayek's Challenge: An Intellectual Biography of F. A. Hayek**. Chicago, US: The University of Chicago Press, 2004.

_____. Popper and Hayek: Who Influenced Whom? In: JARVIE, I.; MILFORD, K.; MILLER, D. **Karl Popper: A Centenary Assessment**. [S.l.]: Aldershot, 2006. p. 111-24.

_____. F. A. Hayek and the Economic Calculus. **History of Political Economy**, v. 48, n. 1, p. 151-180, Mar. 2016.

CHAMBERLIN, E. **The Theory of Monopolistic Competition**: : A Re-orientation of the Theory of Value. Cambridge: Harvard University Press, 1933.

CHIAPPIN, J.; LEISTER, A. Experimento Mental I.O problema da Emergência da Cooperação e o Modelo da Tragédia dos Comuns: Hobbes, os fundamentos do Estado e a emergência do indivíduo como pessoa. **Economic Analysis of Law Review**, In press.

COLANDER, D. Complexity and the history of economic thought. In: ROSSER, B. **Handbook of Research on Complexity**. Cheltenham: Edward Elgar, 2009. Cap. 16, p. 409-26.

COLANDER, D.; HOLT, R. P. F.; ROSSER, J. B. **The Changing Face of Mainstream Economics**. [S.l.]: University of Michigan Press, 2004.

CONWAY, F.; SIEGELMAN, J. **Dark Hero of the Information Age: In Search of Norbert Wiener, The Father of Cybernetics.** Cambridge: Basic Books, 2005.

DE VliegHERE, M. A Reappraisal of Friedrich A. Hayek's Cultural Evolutionism. **Economics and Philosophy**, 1994. 285-304.

DEBREU, G. **A Theory of Value: An Axiomatic Analysis of Economic Equilibrium.** New Haven and London: Yale University Press, 1959.

FESER, E. Hayek the cognitive scientist and philosopher. In: FESER, E. **The Cambridge Companion to Hayek.** Cambridge: Cambridge University Press, 2006. p. 287-314.

FLEETWOOD, S. Order without equilibrium: a critical realist interpretation of Hayek's notion of spontaneous order. **Cambridge Journal of Economics**, Cambridge, v. 20, p. 729-747, 1996.

GAUS, G. The Evolution of Society and Mind: Hayek's System of Ideas. In: FESER, E. **The Cambridge Companion to Hayek.** Cambridge, UK: Cambridge University Press, 2006. p. 232-58.

GEROVITCH, S. **From Newspeak to Cyberspeak: A History of Soviet Cybernetics.** Cambridge: MIT Press, 2002.

GICK, E.; GICK, W. F. A. Hayek's theory of mind and the theory of cultural evolution revisited: toward an integrative perspective. **Mind and Society**, p. 149-162, 2001.

GRAHAM, G. Behaviorism. **Stanford Encyclopedia of Philosophy**, 2015. Available in: <<http://plato.stanford.edu/entries/behaviorism/>>. Accessed on: 9 Jun 2015.

GRAY, J. **Liberalism.** London: Routledge, 1989.

HARDIN, G. **Nature and Man's Fate.** New York: Rinehart & Company, Inc., 1959.

_____. Review of The Fatal Conceit: The Errors of Socialism, by F. A. Hayek. **Population and Development Review**, p. 551-561, 1989.

HAYEK, F. A. Economics and Knowledge. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, v. 4, [1937] 2014. p. 57-77.

_____. **The Pure Theory of Capital.** [S.l.]: Jarrold and Sons Limited, 1941.

_____. The Objectivism of the Scientistic Approach. In: HAYEK, F. A. **Studies on the Abuse and Decline of Reason.** Chicago: University of Chicago Press, [1943] 2010. p. 108-116.

_____. The Facts of the Social Sciences. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1943] 2014. p. 78-92.

_____. The Use of Knowledge in Society. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, v. 35, [1945] 2014. p. 93-104.

_____. The Meaning of Competition. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, v. 4, [1948] 2014. p. 105-118.

_____. **The Counter-Revolution of Science.** Indianapolis: Liberty Press, [1952] 1979.

_____. **The Sensory Order: An Inquiry into the Foundations of Theoretical Psychology.** Chicago: The University of Chicago Press, 1952.

_____. Degrees of Explanation. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1955] 2014. p. 195-212.

_____. **The Constitution of Liberty.** The Definitive Edition. ed. Chicago: The University of Chicago Press, [1960] 2011.

_____. A New Look at Economic Theory. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1961] 2014. p. 373-414.

_____. The Theory of Complex Phenomena. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1964] 2014. p. 257-277.

_____. Kinds of Rationalism. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1965] 2014. p. 39-56.

_____. Dr Bernard Mandeville. In: HAYEK, F. A. **New Studies in Philosophy, Politics, Economics and the History of Ideas.** [S.l.]: [s.n.], [1967] 1978. p. 249-66.

_____. Notes on the Evolution of Systems of Rules of Conduct. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1967a] 2014. p. 278-292.

_____. The Results of Human Action but not of Human Design. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1967b] 2014. p. 293-303.

_____. The Confusion of Language in Political Thought. In: HAYEK, F. A. **New Studies in Philosophy, Politics, Economics and the History of Ideas.** London: Routledge & Kegan Paul, [1968] 1978. p. 71-97.

_____. Competition as a Discovery Procedure. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1968] 2014. p. 304-313.

_____. The Errors of Construtivism. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1970] 2014. p. 338-356.

_____. **Rules and Order.** London: Routledge, v. 1 of Law, Legislation and Liberty, [1973] 1998.

_____. The Pretence of Knowledge. In: HAYEK, F. A. **The Market and Other Orders.** Chicago: University of Chicago Press, [1975] 2014. p. 362-372.

_____. **The Mirage of Social Justice.** London: Routledge, v. 2 of Law, Legislation and Liberty, [1976] 1998.

_____. The Atavism of Social Justice. In: HAYEK, F. A. **New Studies in Philosophy, Politics, Economics and the History of Ideas.** London: Routledge & Kegan Paul, 1978. p. 50-56.

_____. **The Political Order of a Free People.** London: Routledge, v. 3 of Law, Legislation and Liberty, [1979] 1998.

_____. Weimar-Hayek Discussion. In: WEIMER, W. B.; PALERMO, D. S. **Cognition and the Symbolic Processes, v. 2.** Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1982. p. 321-9.

_____. **Nobel prize-winning economist oral history transcript.** Los Angeles: University of California, 1983.

_____. **The Fatal Conceit: The Errors of Socialism.** [S.l.]: Routledge, 1988.

_____. The Overrated Reason. **Journal of the History of Economic Thought**, 35, 2013. 239-56.

_____. **The Market and Other Orders.** Chicago: University of Chicago Press, 2014.

HEIMS, S. J. **Constructing a Social Science for Postwar America: The Cybernetics Group, 1946-1953.** Massachusetts: The MIT Press, 1993.

HORGAN, J. **The End of Science: Facing the Limits of Knowledge in the Twilight of Scientific Age.** [S.l.]: Broadway Books, 1997.

HUTCHISON, T. W. **The politics and philosophy of economics: Marxians, Keynesians and Austrians.** [S.l.]: Oxford University Press, 1981.

KAPUR, J. N.; KEVASAN, H. K. **Entropy Optimization Principles with Applications.** San Diego: Academic Press, 1992.

KOESTLER, A. Opening Remarks. In: KOESTLER, A.; SMYTHIES, J. R. **The Alpbach Symposium 1968 - Beyond Reductionism: New perspectives in the life sciences.** London: Hutchison & Co, 1969. p. 1-2.

KOHLER, R. E. The management of science: The experience of Warren Weaver and the Rockefeller Foundation programme in molecular biology. **Minerva**, p. 279-306, 1976.

KOPPL, R. Austrian economics at the cutting edge. **Review of Austrian Economics**, 2006. 231-241.

_____. Complexity and Austrian Economics. In: ROSSER, J. B.; CRAMER, K. R. **Handbook of Research on Complexity.** London: Edward Elgar, 2009. p. 393-408.

_____. Some epistemological implications of economic complexity. **Journal of Economic Behavior & Organization**, Madison, US, 2010. 859-872.

LAVOIE, D. Economic Chaos or Spontaneous Order?: Implications for Political Economy of The New View of Science. **Cato Journal**, 1989. 613-640.

LAWSON, T. Developments in Hayek's Social Theorising. In: FROWEN, S. **Hayek the Economist and Social Philosopher: A Critical Retrospect.** London: Macmillan Press Ltd., 1997. p. 125-147.

LEWIS, P. Emergent properties in the work of Friedrich Hayek. **Journal of Economic Behavior & Organization**, 2012. 368-78.

_____. Systems, Structural Properties and Levels of Organisation: The influence of Ludwig von Bertalanffy on the work of F. A. Hayek. **Working Paper**, 2015.

MACHOVEC, F. M. **Perfect Competition and the Transformation of Economics.** [S.l.]: Routledge, 1995.

- MCCULLOCH, W. S. A recapitulation of the theory with a forecast of several extensions. In: FRANK, L. K. **Teleological Mechanisms**. New York: Annals of the New York Academy of Sciences, v. 50, 1948. p. 259-77.
- MCCULLOCH, W. S.; PITTS, W. A logical calculus of the ideas immanent in nervous activity. **Bulletin of Mathematical Biophysics**, v. 5, p. 115-133, 1943.
- MCNULTY. A note in the history of perfect competition. **The Journal of Political Economy**, Aug. 1967.
- MILLER, J. H.; PAGE, S. E. **Complex Adaptive Systems: An Introduction to Computational Models of Social Life**. Princeton, US: Princeton University Press, 2007.
- MIROWSKI, P. **Machine Dreams: Economics Becomes a Cyborg Science**. Cambridge: Cambridge University Press, 2002.
- MISES, L. V. **Theory and History: An Interpretation of Social and Economic Evolution**. New Haven: Yale University Press, 1957.
- _____. **Ação Humana: Um Tratado de Economia**. São Paulo: Instituto Ludwig von Mises Brasil, 2010.
- MITCHELL, M. **Complexity: a guided tour**. New York: Oxford University Press, 2009.
- MITCHELL, W. C. The Prosepects of Economics. In: TUGWELL, R. G. **The Trend of Economics**. New York: Crofts, 1930. p. 3-34.
- NAHM, F.; PRIBRAM, K. **Heinrich Klüver: 1897-1979**. Washington, D.C.: National Academy Press, 1998.
- NOWAK, M. A.; TARNITA, C. E.; WILSON, E. O. The evolution of eusociality. **Nature**, 26 August 2010. 1057-62.
- OLIVA, G. The Road to Servomechanisms: The Influence of Cybernetics on Hayek from The Sensory Order to the Social Order. **Research in the History of Economic Thought and Methodology**, v. 34, In press.
- PAQUÉ, K.-H. Pattern predictions in economics: Hayek's methodology of the social sciences revisited. **History of Political Economy**, p. 281-94, 1990.
- PARETO, V. **Manuel d'économie politique**. 2. ed. Paris: [s.n.], 1927.
- POPPER, K. **Language and the body-mind problem: A restatement of interactionism**. Proceedings of the 11th International Congress of Philosophy. Brussels: North-Holland Publishing Company. 1953. p. 101-7.
- POUVREAU, D. On the history of Ludwig von Bertalanffy's "general systemology", and on its relationship to cybernetics - Part II: Contexts and developments of the systemological hermeneutics instigated by von Bertalanffy. **International Journal of General Systems**, v. 43, n. 2, p. 172-245, 2014.
- POUVREAU, D.; DRACK, M. On the history of Ludwig von Bertalanffy's "General Systemology", and on its relationship to cybernetics. **International Journal of General Systems**, v. 36, n. 3, p. 281-337, June 2007.
- PRIGOGINE, I. **Introduction to Thermodynamics of Irreversible Processes**. 3rd. ed. New York: Interscience Publishers, 1955.

ROSENBLUETH, A.; WIENER, N.; BIGELOW, J. Behavior, Purpose and Teleology. **Philosophy of Science**, Chicago, v. 10, p. 18-24, Jan. 1943.

ROSSER, J. B. On the Complexities of Complex Economic Dynamics. **Journal of Economic Perspectives**, 1999. 169-192.

_____. Introduction. In: ROSSER, J. B. **Handbook of Complexity Research**. Cheltenham: Edward Elgar, 2009. p. 3-11.

_____. How Complex are the Austrians? In: KOPPL, R.; HORWITZ, S.; DESROCHERS, P. **What is so Austrian About Austrian Economics? (Advances in Austrian Economics Series)**. Howard House, UK: Emerald Group Publishing Limited, v. 14, 2010. p. 165-179.

Santa Fe Institute. Frequently Asked Questions, 201-?. Available in:
<<http://plato.stanford.edu/entries/behaviorism/>>. Access on: Mar. 17, 2016.

SCHEALL, S. A brief note concerning Hayek's non-standard conception of knowledge. **Review of Austrian Economics**, p. 1-6, 2015.

SCHELLING, T. Dynamic Models of Segregation. **Journal of Mathematical Sociology**, 1971. 143-86.

SHANNON, C. A Mathematical Theory of Communication. **The Bell System Technical Journal**, v. 27, p. 379-423, July 1948.

SOROMENHO, J. E. D. C. **Um estudo sobre as origens da crítica de Hayek ao conceito de equilíbrio**. Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo (FEA-USP). São Paulo. 1994.

STRASSMANN, J. et al. Kin selection and eusociality. **Nature**, v. 471, Mar. 2011.

TRIBUS, M. Energy and Information. **Scientific American**, n. 224, Sept. 1971.

TUCKER, W. Complex Questions: the new science of spontaneous order. **Reason**, p. 34-8, 1996.

TUDICO, C.; THIBAUT, G. **The History of the Josiah Macy Jr. Foundation**. New York: Josiah Macy Jr. Foundation, 2012.

VAUGHN, K. Hayek's Implicit Economics: Rules and the Problem of Order. **Review of Austrian Economics**, p. 129-144, 1999a.

_____. Hayek's Theory of the Market Order as an Instance of the Theory of Complex, Adaptive Systems. **Journal des Economistes et des Etudes Humaines**, v. 9, n. 2/3, p. 241-256, June/Sept. 1999b.

VRIEND, N. J. Was Hayek an Ace? **Southern Economic Journal**, Apr. 2002. 811-40.

WEAVER, W. Science and Complexity. **American Scientist**, v. 36, n. 4, p. 536-44, Oct. 1948.

_____. A Quarter Century in the Natural Sciences. In: FOUNDATION, R. **Annual Report**. New York: [s.n.], 1958. Cap. 1, p. 1-91.

_____. Recent Contributions to the Mathematical Theory of Communication. In: SHANNON, C.; WEAVER, W. **A Mathematical Theory of Communication**. Urbana: The University of Illinois, 1964. p. 1-28.

WHITMAN, D. G. Hayek contra Pangloss on Evolutionary Systems. **Constitutional Political Economy**, Boston, 1998. 45-66.

WIENER, N. **Cybernetics**. [S.l.]: MIT Press, 1948a.

_____. Time, Communication, and the Nervous System. In: FRANK, L. K. **Teleological Mechanisms**. New York: Annals of the New York Academy of Sciences, v. 50, 1948b. p. 197-278.

WITT, U. The Theory of Societal Evolution: Hayek's Unfinished Legacy. In: BIRNER, J.; ZIJP, R. V. **Hayek, Coordination and Evolution**. London: Routledge, 1994. p. 184-195.

WOODGER, J. H. **Biological Principles**. London: Kegan Paul, 1929.