Hayekian Systems, the Economy, and Complex Phenomena

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Abstract: In an interesting and thoughtful monograph, Butos and McQuade aim to extend Hayek's theories of spontaneous market and complex cognitive orders to institutions and organizations with adaptive arrangements bearing the same name as the title of the book, *Hayekian Systems*. Even though analogies with markets have long appeared in the history of economics, the processes of science and government function quite differently than markets. Hayek had extended the theory of complex phenomena to the human mind in *The Sensory Order*. But Hayek apparently was less than successful in extending his theory to processes of government. This becomes the main thesis of *Hayekian Systems*, to extend the theory of spontaneous order from markets and the cognitive orders of the human brain to government, to science, and to the epistemological problems of central banking.

But questions can be raised about classifying the various conceptions of order found in this work. Are the various orders capable of being nested within one another, or existing in parallel, or perhaps both; and are they capable of infinite variation at least in principle? Moreover, do they make sense from an indeterministic view of natural, social, and economic phenomena. Hayek had extensive contact with Popper and both Hayek and Popper admired C. S. Peirce's contributions. Since Popper and Peirce were indeterminists, it is worthwhile to consider conceptions of spontaneous and cognitive orders from a context of indeterminism. Also, Hayek and Peirce thought that topology was the mathematics most relevant for representing and classifying entities in economic and scientific processes. Additionally, Peirce was a founder of semiotics, and he created a semiotic interpretation of mathematics and topology. The key theoretical metaphors of map and model from *The Sensory Order* and the array of theoretical diagrams portraying the key contributions in *Hayekian Systems* are both essentially semiotic in character and thus make sense from a Peircean perspective.

There seem to be social patterns in the economy and society which are not the intended result of any particular human mind in isolation or of multiple human minds aligned in concert in some collective deliberative process. Such patterns have become known as spontaneous orders. A corollary seems to be that knowledge of a spontaneous order precludes any individual or organization from altering those patterns in a predictable and predetermined way for unambiguous social or individual benefit. Attempts to do so inevitably imply unintended consequences. Although there is more to the history of the idea, the notion of a market economy as a spontaneous order is now associated with the ideas of Friedrich Hayek. Hayek also interpreted cognitive processes of the human mind as a complex order, one which is coordinated by a central nervous system.[1] These theories are elaborated in William Butos' and Thomas McQuade's *Hayekian Systems: Research into the Structure of Social Interaction* (2023). They aim to extend the theory of spontaneous and complex cognitive orders beyond market systems to institutions and organizations with adaptive arrangements which they call Hayekian Systems.

While there could be extensions of Hayekian systems to other patterns of social organization, Butos and McQuade turn most of their attention to science and government and to their epistemological constraints. Science and government are two of the more important institutions in society and their processes function quite differently than markets even though analogies with markets have appeared. In economics more broadly, science is often described as a marketplace of ideas and some larger corporations as having internal markets. These analogies with markets for science and for some internal processes of large organizations are most often quite misleading, directing attention away from the more important differences between markets and government or markets and science that are required to understand them as social processes. An important question is whether science and government exhibit important properties of spontaneous, complex orders or not. Science and government may provide venues for understanding how non-market processes function adaptively and solve problems in different ways than the price system.[2] Markets may be in the background of science and government but essential for providing the resources that both sectors employ. But their adaptive responses may be located in processes other than price or resource adjustment in markets. Scientists usually modify their theories and experiments using the scientific method and evidence with little active attention to economic constraints and input prices. Government officials fashion their administrative proposals by facing elections, legislative processes, and judicial review and leave the economic arrangements to their assistants and Treasury officials.

In their preface, Butos and McQuade describe how their work *Hayekian Systems* came to be. McQuade studied Hayekian and Austrian theories at Auburn University under several prominent Hayekian scholars such as Roger Garrison, Leland Yeager, and Mark Thornton likely in the 1990s. Butos participated in several graduate seminars organized by Walter Weimer at Penn State University in the 1970s. Weimer was a member of the faculty in the psychology department. Most important for *Hayekian Systems* is that in May of 1977 Weimer hosted the second Penn State conference on “Cognition and the Symbolic Processes,” which brought Hayek to campus to highlight his then largely ignored work, *The Sensory Order* (1952). Hayek (1982) gave a short overview and Weimer (1982) presented a long paper titled “Hayek's Approach to the Problems of Complex Phenomena: An Introduction to the Theoretical Psychology of *The Sensory Order*.” The next day there was considerable discussion of all of the presentations at the conference including those of Weimer and Hayek.[3] Not only did Butos attend the sessions of the conference, but so did this author. Weimer was on Butos' dissertation committee as well as mine. Butos wrote on Hayek's monetary theory while I authored a critique of the then very new idea of rational expectations from the perspective of cognitive psychology and philosophy of science. Weimer taught several graduate seminars. He offered Penn State's graduate course in the philosophy of science which was cross listed with both psychology and philosophy for students from both departments. In psychology, he offered a two-term sequence on the history of psychology and a third graduate class on cognitive psychology. I had the good fortune of taking each of these seminars, enrolling five times in graduate courses offered by Weimer.[4]

The thesis of a market system as a spontaneous order would be difficult to refute. As trade and commerce evolved several centuries ago, no less a figure than Adam Smith called attention to markets functioning with the metaphor of an invisible hand. Producers fabricate and create goods and services even though they do not yet know the identity of those who will actually come to purchase what they display for sale or trade. Similarly, households plan to purchase entities from the market when they do not often have specific prior information about what, how, and when products will be produced and distributed to the marketplace. Market processes appear to be coordinated but in fact no human or human organization organizes everything. Individual habits, behaviors, contracts, perceptions, and interpretations of market exchange lead to reliance on those processes as long as past contingencies behind both sides of market patterns adjust adaptively. Price is an important indicator, but product attributes are relevant as well. One hopes to acquire fresh vegetables at the market price. Nearly spoiled produce at the same price in the same market situation would be a bad transaction. Thus, quality and reputation matter as well. Individuals in market situations develop a sharp but fallible capability of distinguishing good from bad transactions.

A market system leads to thousands if not millions of transactors responding to price-quality signals within distinct markets. If one ignores most of the distinctive circumstantial differences of individual markets, then one can present the simple logic of market supply and demand with price adjusting in positive or negative directions as needed to move toward an equilibrium outcome as displayed on the classroom board. Now many students do not have an organized notion of market processes, so this is an essential starting point. The logic of equilibrium in one market can be extended to others. Many of these markets may be in equilibrium simultaneously. If all markets are hypothesized to be in simultaneous equilibria at a single intersection point for each market, then we have the simplest notion of general equilibrium. Pedagogical experience reveals that students have a difficult time imagining an economy where every market is at a single-point equilibrium simultaneously. Economists are a different matter. Walras inspired by Cournot seems to have been the first to raise such an idea in the 19th century and to imagine that counterfactually an auctioneer would call out prices for every market until the general equilibrium array of prices was found. Then exchange was permitted after all excess demands and supplies had been eliminated. Joseph Schumpeter (1954, p. 1026) recognized general equilibrium as the "basis of practically all the best work of our own time." As Butos and McQuade (p.1 and note 2, p. 4) point out, general equilibrium is the theoretical concept behind the latest version of macro known as dynamic stochastic general equilibrium (DSGE) macroeconomics. Hayek (1967b, pp. 35-36) made use of a conception of general equilibrium in his economic work as a pattern that could be best represented mathematically but not quantified since it was the outcome of an ongoing evolutionary spontaneous order.[5]

The application of the theory of spontaneous order to markets seems intrinsically appealing. Prices in concert with other economic variables such as income, wealth, and resource stocks and flows help largely anonymous participants coordinate their consumption and production activities without the intervention of any planner. Patterns of market activity emerge which were never planned by any individual. Market processes incorporate the particular and limited knowledge of each participant which in total represents more information than a single individual could have, interpret, or calculate. But markets are not the only institutions of human society and the question becomes whether the theory of spontaneous order can be adapted to other institutions. As mentioned, Hayek had extended the theory of complex phenomena to the human mind in *The Sensory Order*. But Hayek was apparently less than successful in extending his theory to processes of government. This becomes the main thesis of *Hayekian Systems* (chapter 3, p. 23). to extend the theory of spontaneous order from markets and the cognitive orders of the human brain to government, to science, and to the epistemological problems of central banking. After providing the background and introduction to Hayek's work, chapters three and four look to *The Sensory Order* and to biological systems theory for inspiration in how to extend the Hayekian framework. Then chapters five and six deal with the adaptive systems in market economies and science. Chapters seven, eight, and nine are concerned with the systems of government, with systems of interaction between government and central banking, and with the problems stemming from state-sponsored science.

At this point, consider some of the finer points from *The Sensory Order* as presented in chapter four.[6] There Hayek presents a theory of how the human mind functions in its environment. The mind receives external inputs through the senses and internally from neural connections to other processes in the body. Similarly, other more complex external events are sources of neural impulses that are transmitted to the brain. The brain is a complicated and distributed network of neurons and neural connections that transmit impulses electrically from their source to the brain. Information, whatever its source, becomes embedded in extraordinarily complex multi-dimensional, distributed, patterned, and networked brain-wave firings. The brain has both short and long-term, networked and distributed representations of neural activities. The long-term representations, if often repeated, effectively function as a "map" of the external environment according to Hayek. Shorter term variations of stimuli stemming from current events and sources function as a "model" of the present environment and are generated within the map.[7] The neural model is also forward looking and provides the basis for an expectation of what might happen in the immediate future. Maps and models have classificatory functions. Stimuli are recognized as similar or dissimilar and classified as such by the brain. Basic stimuli can be recognized as parts of patterns leading to higher levels of classification. The map is a vehicle of long-term memory while the model is a more recent classification pattern. Since there is no single locus of control, the classificatory activities of a human brain function something like a spontaneous order and eventually the characteristics of a particular complex cognitive order emerge.

The next step towards a Hayekian systems theory is to extend the theory of the brain as a spontaneous order to social systems. Butos and McQuade note that social systems have many of the same but not all of the pattern features of the human brain:

> We are proposing that these basic processes of classification described by Hayek as operating in the brain, including particularly the formation of a mutable map of the brain's environment as experienced in the past and the ability of that map to support a model driven by current experience, have their counterparts in adaptive social orders, implemented differently, of course, but very similarly in principle. We are certainly not proposing that social orders are brains but that they are brain-like in certain very specific and circumscribed respects (p. 33).

Butos and McQuade then go on to identify eight brain-like aspects of social systems such as structural persistence and complexity, an increase in social system pathways, mutability of social systems, some anticipatory features, inertially lagged adjustment effects, primacy of relational connections, bounded responses within the social system, and the dependence of the reaction of the system on the stimuli and current state of the system.

A second source of inspiration for *Hayekian Systems* theory is biological systems theory as found in chapter five. The idea that biological entities and processes have orders beyond their physical and chemical processes can be traced as far back as Aristotle and especially to Kant. Among the contributions from Kant were the ideas that biological organisms are purposeful and have a unity of the whole, that they are self-organizing and self-maintaining, and that parts of biological systems are formed and maintained by those systems. Also noted are the contributions of Bertalanffy on biological systems and Piaget on the concept of closure as an operation of the system. The main biological systems theorist of interest to Butos and McQuade is mathematical biologist Rosen (p. 39). Rosen provided a systematic treatment of anticipatory behavior observed in many ways in biological systems. He reformulated the phenomena of thermodynamic openness and process closure in terms of the Aristotelian notions of material and efficient causality. He pointed to the adaptive response capabilities of biological systems, and he seems to have connected anticipatory behaviors with adaptability.

The core features of Hayekian systems for the remaining chapters (5-9) are organized around a series of adaptive systems diagrams. They provide a theoretical picture of the key features of an adaptive anticipatory system. The first diagram provides a simple but effective representation of Rosen's adaptive, anticipatory biological systems theory (Figure 5.1, p. 41). The boundary between the system and its environment is represented with a rectangular figure. Inside the figure are the processes of learning, anticipation, and action interacting with a model of the biological system itself and its environment. Inputs that cross the boundary from the outside are resources and reactions represented by arrows pointing inward. The biological system produces output which is represented by an arrow pointing outward. The processes and model inside the boundary form a closed loop. The anticipatory biological systems diagram is sparse and paired down to the essentials relevant for anticipatory performance.

The authors recognize that the processes, inputs and outputs of social systems would be very different for other systems. The next step is to modify the theory of biological systems as represented in that first figure with the most important contributions from Hayek's *The Sensory Order*. A second diagram (Figure 5.2, p. 42) illustrating the key relational features of the process structure of anticipatory social systems is nearly twice as complex as the first one. Instead of four key features inside of the boundary rectangle there are eight. Interpreted for social systems, the process structure of an anticipatory social system can be characterized as an epistemic system and more specifically as a Popperian learning and knowing system (p. 42). The system can create conjectures and eliminate mistakes so that what is considered as being known can be updated. Biological analogies in social theory have been created previously. Rosen apparently recognizes that his biological theory could be applied to social systems. Economists such as Marshall, Boulding, and Alchian have employed biological analogies for economic activity and the firm as well.

In chapter six, attention is directed to the economy. Three versions of the Popperian anticipatory adaptive systems theory are developed for economic systems. Anticipatory social systems diagrams are constructed one each for the market, the firm, and a free banking system (Figures 6.1, 6.2, and 6.3; pp. 52, 55, 61). The anticipatory diagram and theory of a market system shows the importance of economic processes usually ignored in mainstream economics such as: the entrepreneur, dramatically rising standards of living over the past 200 years, the role of prices in enabling economic calculations essential for production, and Hayek's knowledge problem which is how to best use resources when only individuals in special decentralized circumstances of time and place have such knowledge in limited form. The last anticipatory diagram is for a free banking system where the four processes are judgment, banking, clearing, and anticipation. Its purpose is to provide a benchmark for discussing the epistemological problems of central banks later in the book.

In chapter seven, the authors turn from the economy to science. The authors note some similarities and analogies between markets and science. The greatest similarity is that science is often described as a marketplace of ideas. Other similarities are that scientists and individuals in the economy are both self-interested, both face scarce resources, they both face limits and constraints of different varieties, and communication is often with others who are hardly known. Also, specialization, competition, entrepreneurial innovativeness, and risk-taking activities are common to scientific and economic processes. However, there are sharp differences between the economy and science. As most widely understood, the interactions and processes within science are not primarily economic. Scientific theories and hypotheses are not evaluated by relative prices. Scientific entities such as research attributes and results are not bought and sold on markets. Property arrangements are sharply limited in science. The unknown properties and enduring features of natural patterns or social arrangements which are the subject of scientific investigation and experimentation are not private property since they could never be owned privately. Once some discovery is made about those natural or social patterns and that outcome is conveyed publicly, the result is available to everyone who thinks it is important at a low or zero cost. Also, competition within science is very different than the Cournot-like textbook perfect competition of many identical or similar firms driving price down to cost in the marketplace. In science, usually there are one to a few scientists or research teams. The competition is rivalrous more like what occurs in sports as Hayek (1968b) held in his, "Competition as a Discovery Procedure." In such processes the emphasis is more on producing knowledge rather than efficiently and perfectly competitively produced goods and services. Epistemic scarcity is as prevalent as material and chronological scarcity.

Chapter seven is the second longest chapter in *Hayekian Systems*. A science sector version of the anticipatory process diagram is created (Figure 7.1, p. 77). Near the end of the chapter, the authors take up analyzing science as a Hayekian process. The distinguishing feature is that knowledge generation can be characterized with "reputation-driven arrangements" (p. 82). After discussing various contributions and issues in recent philosophy of science which are too extensive to include here, they summarize their analysis of science as a Hayekian anticipatory system:

> Scientific knowledge is not just a selection from the best offerings of individual scientists.; it is the outcome of an extended, institutionalized, social process of publication, criticism, interpretation, citation, argumentation, promotion, rejection, reinterpretation, assimilation, and even (from some participants' points of view) misinterpretation of individual contributions. It is not inherently propositional ……Knowledge generation cannot be separated from the procedures through which scientists interact and through which individual efforts are transmitted to become accepted as scientific knowledge.… (Butos and McQuade, 2022, p. 88).

The last three chapters of *Hayekian Systems* present a theory of government as a multiplicity of anticipatory social systems which interact with other social systems. In chapter eight on government systems, separate attention is given to legislatures and bureaucratic agencies. Government in general is one of the most successful institutions in human history in terms of influence and growth but is constantly prone to failure. This presents something of a paradox. Legislators and other government actors promise many things that they cannot deliver and some that are quite harmful. How is that government as an institution persists? Butos and McQuade point to the arguments of several prominent economists that there must be some net benefit from government, or it would cease to exist. Alternatively, they point to the adaptive nature of government so that changes are made which effectively prevent a general rebellion.

Analysis of legislative processes comes with an anticipatory systems diagram that is visually similar to those from previous chapters (Figure 8.1, p. 100). Legislatures have significant epistemological problems compared to other anticipatory systems. Mainstream economists have extended the rational choice approach to legislatures and other political processes. This approach is characterized as naïve. Instead, the Hayekian anticipatory systems approach is developed as a superior conception of what legislatures do and why they grow and persist. A legislative system contains a working model of its environment, and that system reacts with its environment and the working ideologies of the electorate. Legislatures are most successful when they are responding to a crisis of survival such as war, depression, or a pandemic. But the epistemological problems of legislatures are profound as noted by Scheall. Policymakers are relatively ignorant of society, and they do not know which legislation might solve real problems. Thus, many varieties of government failure persist. How then does the government survive? The inference seems to be that legislatures must have some adaptive capabilities relative to the external pressures of ideologies which allow them to grow, adapt, and survive.

From legislatures, Butos and McQuade turn to bureaucracies. Bureaucracies implement legislation that will be created and tested by the political system. Legislatures create the legislation, but an executive branch housing bureaucracies implements new laws, and the judiciary may review and modify those new laws. Another Hayekian anticipatory system is constructed for a government agency, but this one comes with a major change (Figure 8.2, p. 105). The lower two-thirds of the diagram is an anticipatory systems diagram for an agency. Its four main processes are learning, innovation, judgment, and action and these processes are connected by consequences, knowledge, initiatives, and plans. The major change is that above the Hayekian anticipatory systems process appear three agency clients of government bureaucracies: the executive, the legislature, and the judiciary. Also, bureaucracies face constraints which are different than the discipline of markets and profit in the private sector; their internal operations are subject to more invasive influences than firms; and those influences may be more unpredictable than those faced in the private sector. They conclude: "Given such differences, any exhortation that agencies would be more efficient if run like a business are naïve" (p. 107).

In chapter nine, interactions between government and the market and between government and science are developed. The diagram of process organization from chapter five is provided again in revised form as background for an analysis of how government interacts with science and markets (Figure 9.1). There are three major effects of governmental processes: they may alter the flow of resources to other social actors; they may destabilize those actors; and they may distort the adaptive processes of markets and science. The authors briefly point to the fact that the private sector will develop work around procedures which lead to cycles of increasing intervention by government. Some of the government interventions create large bureaucracies which take on the role of a "Big Player" relative to the entities in the private sector. One of the best examples of a Big Player is the central bank (p. 119). Butos and McQuade argue that the information available to the central bank is flawed and too aggregated or centralized and it is unable to respond accurately to micro level imbalances between various financial markets and financial institutions. They argue that a free banking system or a monetary system without a central bank is better able to respond to the knowledge problems of banking and financial markets (pp. 119-124).

A similar analysis is made for government and science. Government creates funding agencies which function like "Big Players" (p. 151). The science funding agencies are too centralized relative to the domains of actual scientific research which leads to excess funding in some areas of scientific research. This excess funding distorts the direction of research creating a boom in favored areas of funding. When scientists encounter experimental failures, funding may eventually be diminished or ended completely. This creates a "boom and bust" cycle in scientific activity and it may also distort the path of future research. Chapter ten provides a history of government science funding, a summary of rationales for government funding of scientific research, and examples of destabilizing and distorting effects of such spending. The authors argue that central planning in science is not possible, and they illustrate with two examples, nutrition science and climate research.

So, what can be said of the contributions of *Hayekian Systems*? Overall, the effort to extend the mindset of Hayek's works to science and government is truly interesting, perhaps even pathbreaking. Consider the conceptualization of government as a governance process. Even while in graduate school taking mainstream economics courses and then Weimer's classes, this author had the sense that the Austrian economics of spontaneous orders was incomplete. Now the obvious thought which arises is that *Hayekian Systems,* as developed in that work, could fill some of the larger holes in the theoretical landscape of Austrian and perhaps even mainstream economics. Decades ago, I came to believe that science and even government could have aspects of spontaneous orders or complex phenomena since society and nature separately appear to exhibit phenomena with properties indicative of spontaneous orders. Also, a deeper understanding of government and especially science might provide nonmarket models of social-institutional adjustment processes with the primacy of adjustment located in something other than changing relative prices. *Hayekian Systems* clearly aims to take us beyond the limits of Hayek's works creating a theoretical path for extending the idea of spontaneous orders or subsystems of such orders to government and science.[8]

There are issues which lurk behind spontaneous orders and Hayekian systems. In attempting to understand the main claims of Butos and McQuade, one issue which led to a detailed search throughout their work is the definition of a system and to what extent it is co-extensive with the conception of spontaneous order. The authors are careful to define and elaborate what is meant by a spontaneous order. Then there is almost an imperceptible shift to the term "system" and there is no specific definition of a system or systems. The term "market system" seems at times to be used as an equivalent substitute for the market as a spontaneous order. Also, the aim of the work is to extend Hayek's theory of spontaneous order to the social orders of complex societies and those extensions are "Hayekian systems." So are Hayekian systems spontaneous orders within the overall spontaneous order of society or are they organizations with prominent features patterned mostly by human design but nested within or between various other spontaneous orders or complex phenomena? Hayek (1967b, p. 76) at one-point talks of simpler complex phenomena within the broader pattern of the spontaneous order or society. Another question is whether the order of Hayekian systems may be more highly ordered than the broader order of the spontaneous order within which they operate. But this is never clearly discussed, and the term spontaneous order seems to fall into the background as the theory of *Hayekian Systems* is further developed. Also, there are criticisms of mainstream economics as being too mechanistic. Mechanical processes are extremely rigid, and this rigidity lends itself to data collection, mathematical theories, and predictive ability. So, an indirect implication is that mechanically ordered processes are not spontaneous orders, but they do exhibit the properties of tightly ordered systems up to a certain limit.

Another question is whether any organization or process of human design can be completely determined by such design. If not, this suggests that some limitations of human organizations could be understood as stemming from the properties of a spontaneous order or a complex phenomenon in which it is nested. If mechanical ordering is incomplete at the physical level which is recognized in the philosophical theory of indeterminism, then human organizations would appear to be less powerful in bringing order to the human domain than the laws of nature are to the physical domain. Indeterminism is consistent with an evolutionary perspective and spontaneous orders and especially at the social level. The leads to the obvious question of whether there are different genres of systems and spontaneous orders.

Yet another question or concern is that there appears to be no sharp distinction between the individual and social processes in which individual humans function. The anticipatory systems diagram portrayed for *The Sensory Order* (Figure 5.2) represents cognitive processes that clearly function at the level of a single human individual according to Hayek. Then the authors discuss biological analogies in social theory and how biological systems are different than social systems. Perhaps for the purposes of this work the anticipatory processes of individuals and social organizations are quite similar. But that does not mean that they are similar in every respect. There is a recognition that human individuals have brains and social organizations do not, but their differences are left underdeveloped. Some of the features in the Hayekian anticipatory systems diagrams could clearly be fulfilled by individuals and others by some organization, committee, or group. One wonders whether these differences are significant or not. Actually, Butos and McQuade do have a very nice descriptive table of levels and types of order including those at the level of individuals which would have been quite useful to include in this work. That table is in one of their articles on *The Sensory Order*. Readers would be well-served to consult McQuade and Butos (2005, pp. 353-354).

To address important aspects of the preceding questions, here the focus will shift to another intellectual figure of great prominence lurking in the background of both Hayek's and Popper's works. Here I have in mind the ideas of C. S. Peirce and some of his contributions which have received little attention from economists or Austrians. Besides his place in the history of American pragmatism, Peirce was also considered a founder of a rather new field of inquiry now within linguistics—semiotics. Hayek's use of concepts like map and model in the *Sensory Order* and his understanding of prices as symbols are clearly semiotic in character. Both Hayek and Popper knew of Peirce. Hayek quotes one of Peirce's most famous passages about not blocking the path to inquiry and Popper considers Peirce to be the first modern indeterminist.

Consider what Hayek had to say about Peirce. On a separate page at the beginning of Part Two of his *Studies in Philosophy Politics and Economics* (p. 134) Hayek quotes without further comment a very well-known rule of conduct for learning processes from Peirce's writings. Given the prominence of its placement in the work, Hayek seems to imply that he thinks highly of the position Peirce offers:[9] In 1898, Peirce was presenting a set of lectures in Cambridge, Massachusetts in close proximity to Harvard's campus. Earlier in one of his lectures, Peirce spoke of the need of a "Will to Learn" which would have been seen as a reply to James' well known conception of the "Will to Believe." Then later, Peirce qualified his conception of the "Will to Learn" with remarks that often have been widely cited by many interpreters of Peirce:

> Upon this first, and in one sense this sole, rule of reason, that in order to learn, and in so desiring not to be satisfied with what you already incline to think, there follows one corollary which deserves to be inscribed upon every wall of the city of philosophy:
>
> Do not block the way of inquiry.
>
> — C. S. Peirce as quoted by Hayek (1967, p. 134).[10]

One would imagine that what Hayek had in mind was not blocking learning about spontaneous and cognitive orders of the economy, the principles of a liberal society, and perhaps Hayekian systems.

Turning to Popper, Popper offered high praise recognizing Peirce's indeterminism. Popper's (1973a) laudatory comments come from one of his most interesting essays, "Of Clouds and Clocks: An Approach to the Problem of Rationality and the Freedom of Man." Clouds are meant quite generally to represent physical systems like gasses which are highly irregular, disorderly, and mostly unpredictable. In contrast physical systems which are quite regular, orderly, and highly predictable are termed clocks. The phenomena of our world exhibiting mixes of order and disorder could be placed on a line between clouds and clocks with clouds on the far left and clocks on the far right. Determinism would be the idea that all cloud-like systems are clocks where we should be able to find models, principles, and forces which would explain cloud-like phenomena as resulting from clock-like processes. For Popper this is Newtonian determinism. The alternative is that all phenomena are clouds—even the most clockwork like of phenomena. This brings us to Popper's comments about Peirce:

> Among the few dissenters [to physical determinism] was Charles Sanders Peirce, the great American mathematician and physicist and, I believe, one of the greatest philosophers of all time (Popper, 1973a, p. 212).

Popper goes on to quote one of Peirce's more interesting comments about indeterminism. From his considerable experience as an experimental physicist, Peirce held that the most accurate measurements of the physical sciences "fall behind the accuracy of bank accounts" and "are about on par with an upholsterer's measurements of carpets and curtains" (Peirce 1892, CP 6.44, p. 35). That would include pendulum clocks since Peirce was one of the world's leading gravity researchers which required swinging a pendulum instrument in intervals for hours over several days. No one tried to measure a deterministic physical property more minutely and with mechanical precision than Peirce. Popper even claims that the pendulum clock is the most exemplary example of clockwork-like phenomena (Popper 1973a, p. 207). For Peirce, observations which are interpreted as favoring determinism and mechanism "simply prove that there is an element of regularity in nature, and have no bearing whatever upon the question of whether such regularity is exact and universal or not" (Peirce 1892, CP 6.46, p. 36). Popper's analysis of indeterminism goes on to present four functions of language where higher levels of language control lower levels. His theory is especially sharp at the individual level: "Each organism can be regarded as a hierarchical system of *plastic controls*—as a system of clouds controlled by clouds." The controlled subsystems make trial-and-error movements which are partly suppressed and partly restrained by the controlling systems" (Popper 1973a, p. 245). Popper does not mention Hayek's theories of complex phenomena, spontaneous orders, and the cognitive orders of *The Sensory Order* even though Popper's analysis of indeterminism would seem to encompass such phenomena. One can only wonder why not.

Indeterminism is especially relevant to conceiving of spontaneous orders and systems within those orders. Butos and McQuade recognize that Hayek took an evolutionary view of natural and biological processes which would lead to an evolutionary epistemology for human beings as individuals and how they function within whatever social processes they may create. The clear implication is that economic processes are knowledge creating processes which actually function in an evolutionary way. Individuals and social organizations have a mix of narrower to broader knowledge creating processes depending on the scope of their streams of information and the processes and abilities which they bring to understanding their situations. Those knowing processes which economic agents have in the course of conventional economic activities are termed "epistemic" processes and the term "epistemology" is reserved for the more formal knowledge creating processes of the sciences and philosophy. In either case, those in the economy and scientists of all varieties find ways to navigate the indeterminism of the subject matter of complex economic or scientific phenomenal processes.

All of this is relevant to a consideration of what could be meant by the term "spontaneous order." In Hayek's writings, a term is encountered which seems to be absent from Butos and McQuade's treatment of spontaneous orders. Hayek (1967b, p. 74) repeatedly speaks of "regularities" that result from natural or social interactions that are not the product of human design. At one point, he likens studying economic activity to investigating the patterns of galaxies and solar systems (Hayek 1967b, p. 76). An implication not directly stated is that galaxies and solar systems are examples of spontaneous orders in the natural world. If so, this would seem to require a conception of indeterminism. Popper is much more directly in favor of indeterminism. In the "Clouds and Clocks" essay where he notes Peirce's views on indeterminism, he clearly declares that he is for indeterminism with Peirce and others, and he rejects Einstein's effort to retain some form of determinism (Popper 1973a, p. 213).

Indeterminism is helpful because it provides a useful starting point for thinking about patterns of regularities in nature and society. The very term spontaneous order suggests a pattern of order which has emerged from a more encompassing background of disorder or unordered phenomena. This is the simplest conception of indeterminism. Disorderliness or randomness comes first and recognizable patterns later. It is possible that one could try and define a spontaneous order as embodying a weak form of determinism or as being toward the clock end of Poppers clouds-and-clocks spectrum line. Determinism asserts the reverse of indeterminism, that order is primary, and disorder is secondary in the background and is due to the incompleteness or imperfection of whatever order exists. Decades ago, economist Arthur Okun (1981) described this view as a sand-in-the-machinery view of economic proesses. Hayek seems to recognize somewhat indirectly what Popper, Peirce, and modern cosmologists assert, that indeterminism is prior to and logically a stronger and more fundamental position than determinism. Such an indeterminism would take the contributions across the sciences, like modern physics, astronomy, and the life and social sciences, into account. Indeterminism seems to be the stronger position for interpreting our world than determinism.

If indeterminism is the stronger position for interpreting the events and phenomena of our world and universe, then that conception needs to be adopted explicitly for spontaneous orders. Spontaneous orders are patterns of regularities which emerge in nature, life, and society and are not the direct result of human cognition or activities. Such orders are incomplete and imply a remaining background of disorder as a first approximation. As time passes, a multiplicity of other spontaneous orders might emerge. Some of those orders might be replications leading to ordering processes in parallel. Or the scale of a spontaneous order may allow for smaller scale orderings within the larger pattern. So, we could have spontaneous orders within spontaneous orders and those orders may further evolve in parallel, by replication, within other spontaneous orders, or allow another layer of orders within those which have emerged. Within all of these possible layers and orderings of spontaneous orders, very rigid orderings of phenomena may result as well. One can use the term mechanical to refer to such rigid orderings.

The extraordinarily rigid orderings of planets circling a star for billions of years constitute some of the most rigid repetitions imaginable to humans. Even so, for any stellar system, a stage of disorder apparently preceded the highly rigid but later stage of that star system. At another level, once humans have discovered rigid natural properties and the enduring qualities of the natural elements, then that knowledge can be used to create clocks. Clocks are machines of extraordinary rigidity that have been constructed to indicate the tightly ordered passage of time. As noted previously and as Popper argued in his essay, "Of Clouds and Clocks," pendulum clocks have been the most iconic example of mechanical processes in our world (Popper 1973a, p. 207). There are others such as well-engineered buildings, bridges, and cars. The most important idea for machines in light of spontaneous orders and indeterminism is that the highly rigid order of machines is both constructed and limited, and it exists against and within a background of disorder and an array of a complex spontaneous orders. What emerges from the preceding considerations is the idea that there may be multiple types or kinds of spontaneous orders and complex phenomena and that a nomenclature of types and a system of classification might be helpful. Such sentiments could be extended to include the cognitive orders of individuals functioning within spontaneous orders and Hayekian systems. Butos and McQuade provide comments in some of their chapter notes heading in this direction and they also describe knowledge as a process of classification.

At this point, it is time to turn to another conception of an abstract pattern which at first might seem to be unrelated to spontaneous orders and complex phenomena. However, that concept might provide parallels to some problems stemming from conceptions of spontaneous orders and complex phenomena. Here a concept will be raised which might strike some as odd. The concept which might be helpful in thinking about spontaneous orders is the concept of infinity. Infinity is an unobservable but logical property of an extremely large quantity of entities and a process of classification seems to have led to some progress in reasoning about infinity. Also, the concept of infinity could be relevant to some of the aspects of a conception of spontaneous order. For instance, is any particular spontaneous order a singularity only or could it stem from generating processes that could yield an infinite number of different spontaneous orders not just one? Does this matter? For centuries before the late 19th century, mathematicians and philosophers did not know what sense could be made of the concept of infinity. Infinity was imagined as a quantity that goes on indefinitely and is larger than any large but finite quantity. However, infinity seemingly defied a logic of rationalizing with simple rules such as addition, subtraction, multiplication, and division. For example, before newer thinking about orders of infinity, not much could be said about infinity and reasoning seemed to be somewhat circular as exemplified by the following rules: infinity plus infinity equals infinity, infinity times infinity is still infinity, and any number divided by zero equals infinity. Beyond mathematics and number theory, philosophers wondered if there was such an entity as an infinite being and scientists whether space was finite or infinite. It took a mathematician such as Cantor to theorize that there could be orders of infinity.

A theory of orders of infinity provides a process of classification. For example, to any non-negative integer *n*, plus one could be added to form *n+1* and this could continue indefinitely towards infinity.[11] Thus, the non-negative integers most familiar to every rational human being and child can be meaningfully classified as being infinite. This is often recognized as the lowest order or zeroth level of infinity. To this lowest order of infinity, one could form the next order simply by adding one-tenth or 0.1 to every non-negative integer. This series would have the non-negative integers *n* of the first infinite series interspersed in sequence with another series of numbers taking the form of *n.1*. Then they could be placed in sequential order of magnitude from smallest to largest: 0, 0.1, 1, 1.1, 2, 2.1, …., *n+1, n+1.1*. This is an example based on the mathematical writings of Peirce.[12] Such a series of numbers would have twice as many numbers as the non-negative integers, both series would be infinite, but the second series would have twice as many members as the first. The process could continue to yet a another or third order of infinity. One could add .01 to every second member of the immediately preceding second series to form a third term so that now there are an infinity times three of terms in the third series: *n, n.1, and n.11* or using specific integers and starting with zero we have: *0, 0.1, 0.11; 1, 1.1, 1.11; 2, 2.1, 2.11,* etc.

Peirce's examples of infinities take the mathematics towards the issue of continuity. The non-negative integer line has gaps that need to be filled. In fact the integer line has an infinite number of gaps and each gap can be filled with an infinite number of decimals, some which repeat without end. One can imagine filling the gaps as Peirce's example suggests with the logic of infinitesimals or with a theory of limits. The point is that we do not want a number line with holes or gaps as a matter of the fundamentals of mathematical logic. Numbering is actually a process of classification. Think of the various applications in everyday life, science, and the economy. The number line combined with various units of measure can yield scales of measure for many basic magnitudes in human activity and of course for science and commerce. Such scales need to be free from gaps and without limit otherwise the numbers used in science and in economic processes such as basic accounting, national income accounting, index numbers, interest rates, etc. could have gaps, discontinuities, and perhaps finite limitations. It also needs to be noted that the basic concepts of calculus used in economic theory and probability theory require or incorporate the concepts of continuity and infinity.

If there are broader patterns of spontaneous orders containing other spontaneous orders with some in parallel or nested arrangements and others containing pockets of more rigidly ordered phenomena, then Hayek's (1955, 1964) theory of complex phenomena comes to mind. Complex phenomena are those with abstract and perhaps potentially unlimited patterns or features of order, or levels of order within other patterns of order, and of orders in parallel with other orders which might be nested within larger scale orders. A human being is a complex phenomenon even though each one of us is limited and finite. But our capacities are capable of infinite variation. Think of a human being as nested arrays of orders with some orders within other orders and with others in parallel. All of the orders present within a human being are connected by a central nervous system including the brain. Humans in society essentially function arranged as arrays of parallel orders within other orders which are all contained in the overall structures and orders constraining and governing individual activity and social interaction. If Hayek is right, then the central nervous system is a spontaneous or complex cognitive order housed within the various nested, parallel, and replicating orders that structure the physical, biological, and neurological systems characteristic of an individual. In turn, after the number of individuals has multiplied greatly, patterns among and across individuals result in large populations of human beings living in civilized arrangements conducted in isolation and/or with moral principles and laws and within organizations and institutions. If Peirce is right, then a central nervous system equipped with the simplest logic of mathematics could symbolize and imagine the various orders of infinity. A human mind which has the capacity to understand infinity and its logical orders likely could understand and classify the most important abstract features of spontaneous orders, cognitive orders, and Hayekian systems operating within the institutions and social processes of society, government, and science.

Perhaps there is a hierarchy of spontaneous orders like that in the mathematics of infinities or in Popper's hierarchy of plastic controls. If one reads *Hayekian Systems* closely, Butos and McQuade seem to recognize that the phenomena of spontaneous orders may also exhibit order and pattern.[13] In the economy, human minds would seem to be functioning within the spontaneous order of market processes, the evolutionary knowledge orders of Hayekian systems, and the orders of other social processes. It seems logical that human minds functioning as individual level cognitive orders as Hayek portrays them in *The Sensory Order* would function in parallel first within small groups such as families and then is in some hierarchical way in larger social processes and organizations including Hayekian systems. Above the level of human individuals and specific social organizations with each level having properties of spontaneous orders, individuals and social organizations may be part of larger patterns of spontaneous orders and complex phenomena.

Similar considerations could be made for science. It seems logical that scientists would function in parallel as a first approximation and then in hierarchical order if one or several scientists are rank-ordered relative to others taking roles such as principal investigators, research scientists, post docs, lab assistants and so on. If science is a spontaneous social order containing many cognitively capable scientists, then we have another spontaneous order of the overall process containing human individuals who also function in parallel with each other and within the overall order of their research niches. In those niches, scientists are also organized into one, two, or perhaps several research teams in each field of research often with low numbers of participants compared to the large numbers involved with commercial markets. In an economic sense, science is a densely concentrated and concatenated succession of activities which make them susceptible to the problems and inefficiencies of monopoly-like power.[14] Likewise, the outcomes of the research processes in science would seem to be at the low end of numerical possibilities. Scientific research which does not narrow the range of hypotheses is not very valuable to science.

Next consider the discipline of economics. If Hayek, other Austrian economists, and Butos and McQuade are right, then the subject matter studied by economists, economic activity itself, takes the form of arrays of patterned, nested, and replicating spontaneous orders, complex phenomena, and the organizational orders and mechanical processes within those orders including Hayekian systems. If economists study all of these differing orders of complexity and if science is another process of complex spontaneous orders, then economic science itself must be a complex phenomenon. If so, the orders of various complex economic processes are quite extensive and capable of generating an infinite variety of outcomes, then some type of specialization might occur in the economics profession according to the type of ordering processes. In simpler terms, if economics is about complex economic phenomena, then the discipline itself must be a complex phenomenon addressing different aspects of the complex phenomena in the economy.

The various layers and arrays of complex economic orderings suggest the possibility of pluralistic economic profession where different approaches or schools of scientific thought and practice specialize in types of economic phenomena within a limited range of complexity. What is being suggested is that if the economy is a complex array of spontaneous orders and Hayekian systems, then different approaches to economics could take up specific ranges or types of phenomenal order abstracting from others. Thus, various approaches to economics, to the extent they confront a real domain of ordered economic processes, encounter something fundamental in the economy. Mainstream economists seem to prefer instruments, tools, and economic phenomena that are highly rigid and that give rise to large data sets. They seem to think of the economy as a grand machine containing a multiplicity of mechanical economic sub-processes which are generated by human beings with the humans themselves conceived as optimizers acting and behaving in the most logically consistent and rigidly patterned economic activities in machine-like ways. The rigid order and pattern of economic processes, which is the subject matter of mainstream economics, is a constructed order and how that order came to be is mostly left unexplained.

Non-mainstream economists like Austrians alternatively focus on the non-mechanical aspects of individual and social processes which in turn might be interpreted as enabling the mechanically repetitive social and economic processes that are the subject matter of mainstream economics. Non-mainstream economists focus on the broader social processes in which the more rigid processes are conceived and constructed. In a very real sense, mainstream economists ignore what could be categorized as background orders and processes which are so much the focus of Hayek, Austrian economics, and other social science disciplines. If the patterns of spontaneous orders persist for a time, then they may not be readily apparent or essentially function in a constant way relative to the dynamic patterns of economic phenomena which mainstream empirical researchers take as their subject matter and for which they collect data. One can ask how the patterns embedded in economic equations came to be and how is it possible that the patterns identified in such equations could endure for a time. But those questions are not of great importance in mainstream applied economic research. The theory of *Hayekian Systems* attempts to explain the evolving qualitative orders of institutional processes in which market systems function. These sentiments take us toward an intellectual position that Hayekian systems and mainstream economics could be intellectual complements to some degree even if economists of each approach tend to be dismissive of the methods and scientific practice of the other. It is unfortunate that the enduring evolutionary orderliness of economic and governance processes is essentially relegated to the error terms of the many stochastic equations of mainstream economic analysis.

Besides spontaneous orders and complex phenomena including those of the human brain, Hayek also had some interesting things to say about the uses of mathematics in economics. Anyone who is aware of the impact of modern macroeconomics on policy analysis at central banks is aware of how highly mathematical some models of economic activity have become. Nearly every national or central bank in most nations of the world construct and interpret economic activity with DSGE macro models. Unfortunately, very little is said about mathematics in *Hayekian Systems* although it is implied that DSGE models are misdirected.[15] However, Hayek does give us some significant remarks on mathematics that could be redirected towards DSGE macroeconomics. At the Penn State Conference on Cognition and the Symbolic Process in 1977, Hayek was asked what he thought about increased mathematization of economics:

> This is a rather complex issue. Mathematical economists do not understand that the great advantage of mathematics is that it permits us to describe patterns without requiring that we know their quantitative mechanisms. But most economists are bad mathematicians who imagine that mathe-

> matics consists of quantitative or numerical statements like statistics. Instead of statistics, we need powerful and abstract mathematics, because that is still the only method for describing complex patterns. But that is not a numerical or quantitative mathematics. The most accurate illustration is topology (Hayek in Weimer-Hayek Discussion, 1982, p. 326).

Similarly, in *The Sensory Order* itself, Hayek claims that the patterns within the brain need to be understood with topology. The resemblance between the elements of sensation and external physical elements is relational and not to be borrowed from gestalt psychology. The sensory qualities that we experience in our mental experience need to be "topologically equivalent" to the order of physical elements in the external world (1952, pp. 37-39). The relational resemblance between sensory and physical elements can be stretched, twisted, or crumbled using topological operations as metaphors as long as these operations do not change the isomorphism between sensations and physical elements stimulating those sensations.

Hayek's remarks on mathematical topology as being appropriate occur again in "The Theory of Complex Phenomena" (1964, pp. 23-25). There Hayek maintains that pattern prediction is possible even if the prediction of a detailed instance within the pattern is not predictable. Until DSGE models, general equilibrium models were mathematical pattern models illustrating in principle how many markets interacting together might come to an overall general equilibrium. But no one had figured out a method for infusing empirical content into the theory except with analogical anecdotes. Indeed, one of the criticisms of general equilibrium theory before the 1990s was that it was a mathematical model that could not find an applied form and thus was not testable. Similarly, Weintraub's (1975, 1984, 1991) work on general equilibrium theory informed by Lakatos' (1976) *Proofs and Refutations*, suggested that general equilibrium theory should not be rejected merely because, to that point in time, there was no empirical version of the model. Instead, the appropriate standard for mathematical progress is proof and other forms of mathematical demonstration, not falsification or some form of empirical or econometric validation. Peirce did take up many of the same issues as Lakatos essentially holding that mathematical discovery could be understood as a semiotic and reasoned process of diagrams and demonstrations.[16] However, DSGE methodology and practice have changed the landscape of general equilibrium theory and macroeconomics.

DSGE theorists have asserted a strong form of general equilibrium with an elaborate multiple equation system which can be solved yielding a dynamic intertemporal solution. Then they created a sophisticated simulation method for conducting empirical research which became known as calibrating the model. Calibration involves taking given empirical values for some accepted macro parameters and then running the model forward to estimate other macro variables such as GDP, interest rates, unemployment, etc. The method uses most of the data to determine how closely the model tracks the more recent quarters of economic activity for the most important macro variables. DSGE models have become one of the more important versions of macro models used by central banks.[17] Every central bank seems to have one. The New Keynesian DSGE models typically contain an equation for monetary policy known as the Taylor rule. The simplest versions of the Taylor rule can be described as a Fisher equation plus additional mathematical terms reflecting U.S. federal way which mandates something like equal attention to inflation and unemployment.

While an argument cannot be developed in detail here, no DSGE theorist has provided a deep argument that the actual data streams used in macro modeling must come from equilibrium processes. In reality, the data is a consequence of whatever natural, social, and economic processes that actually generate the numbers. Spontaneous orders endure and have complex patterns and suborders and patterns within which market processes and individual level economic decisions take place. All equilibria, including economic ones, occur with spontaneous orders in the background. One might argue that macroeconomic data are as much a product of evolutionary complex phenomena as they are of equilibrium phenomena. Institutions and Hayekian systems may stabilize economic activity enough so that the indeterminacy of spontaneous orders and Hayekian systems falls into the background. But that does not last forever as the system changes in evolutionary fashion, sometimes at slower rates and other times at faster ones. If this is so, then there are obvious implications for monetary policy. Fine-tuning short-term nominal interest rates to nudge the economy to counter inflation or recession with six, eight, or ten successive policy steps in a row is likely mistaken except in times of systemic crisis. Similarly holding and compressing nominal interest rates near zero like what happened for more than a decade from 2009 to 2020 is extremely distorting both for risk appraisal and household net worth and the epistemological processes embedded in private sector decisions relying on accurate absolute and relative interest rates and accurate estimates of household the worth, financial assets, and capital valuations.

The idea that mathematics could be used to model the complexity of the patterns of phenomena in the natural and social worlds and that it has a topological character can be found in the writings of C. S. Peirce. Also, mathematical abstractions and methods for their discovery and demonstration form a large part of Peirce's theory of cognition.[18] Instead of focusing on science or entrepreneurship as types of complex cognitive activity, Peirce chose two closely related domains, mathematics and semiotics. Mathematics is the most abstract of all human abstractions for Peirce, then logic, followed by philosophy, theoretical science, applied science, and eventually common-sense knowing processes. In taking these positions, William James and his contributions are almost always directly or indirectly in the background of Peirce's mind. Peirce did not follow the positivists of his time into behaviorism, and he turned away from James' somewhat anthropological research methods for observing human cognitive activity. As noted, James did write some very interesting articles on higher mental processes. However, after leaving his psychological laboratory and moving to philosophy from psychology, James pioneered a process of solicited personal accounts to illustrate how humans changed their minds. His *Varieties of Religious Experience* (1902) may be the best illustration of James' survey method. Instead of behaviorism and personal accounts, Peirce thought that attention to mathematics and mathematical properties related to phenomena could reveal how complex human minds could innovate and discover new mathematics, novel applications, and how they could convey those innovations with other minds through diagrams and demonstrations. This led Peirce to create a new way for conceiving how humans with complex evolutionary cognition might communicate with signs or symbols—the theory of semiotics.[19] Peirce, like Hayek, was deeply influenced by Kant. Peirce took the important idea from Kant that all thought is in signs and developed it to such an extent that he is now recognized as a founder of this relatively new field. Mathematics and science were two of Peirce's most important domains for illustrating the possibilities of semiotics and the nature of human understandings and meaning.

Providing even a simple elaboration of Peirce's semiotics and how he illustrated cognitive complexity and the ability to perceive and reinterpret the orders of signs, symbols, and systems of representation available to particular individuals in specific forms of human inquiry and science would be beyond the scope of this essay. What we can recognize is that Hayek, Popper, and even Weimer have taken positions that are essentially semiotic or have significant semiotic features. As already noted, Hayek's *Sensory Order*, which asserts ideas of cognition occurring with neural maps and models that are understood topologically are inherently semiotic and can be further elaborated in semiotic terms. Hayek (1952, p. 181) also diagrammatically displayed an example of the logic of a classifying order that might occur internally in a human mind. That diagram is semiotic as well. Also, Popper offers theories of mind, scientific inference, and the functions of language with significant semiotic aspects. Popper asserts that humans function within three domains or worlds of phenomena: matter, mind, and a third world of logical entities resulting from mental activity (Popper 1973b, pp. 153-162). Popper's third world can be manifest in the first world of physical existence when it is manifest in semiotically facilitated material entities such as books, libraries, mathematics, science, designed physical structures, machines, schedules, plans, and written or spoken accounts of events, interpretations and criticisms of interpretations. The partitioning of what we experience into three worlds is semiotic in character as well. What Popper does not do is explicitly extend his discussion of the entities of his three worlds to semiotics. However, this is what Peirce has done.[20]

Peirce's most general term for indicating the nature of a sign as employed in mathematics and science was "diagram." A diagram could serve as a model of major relational arrangements of the patterns of any phenomena.[21] Across human inquiry diagrams could take a multitude of forms. Anything which stands in place or represents another thing, entity, or process is a sign and the special symbols and representations of mathematics are all considered diagrams in Peirce's thought. Sketches on the wall of caves and geometric figures clearly could be recognized as diagrams and so were dots, lines, letters, numbers, variables, equations, musical notes and scores, artistic creations, words written and spoken, articles, books, sounds, utterances, etc.

Moving these comments toward a close, a final comment or two is in order. There is a perspective from which *Hayekian Systems* has a significant Peircean quality. For Peirce the relational fundamentals embedded in any particular type of mathematics or science or in any type of intersubjective human understanding can be illustrated with a diagram. For Peirce, such diagrams are both mathematical and semiotic in character. They indicate the relational patterns that may be the most important and they should be constructed as thought experiments when inaugurating a new line of research or inquiry. Essentially diagrams constitute a preliminary stage of conceptualization and facilitate theorizing about the nature of natural, social, or economic phenomena. Such diagrams should be developed before any specific mathematical or scientific research is conducted. Thus, the diagrams representing core aspects of Butos and McQuade's *Hayekian Systems* convey the key theoretical ideas and relational patterns elaborated in that work and they facilitate focusing on fundamental patterns of economic, governance, and scientific processes. Thus, in an important way, the analytical diagrams of *Hayekian Systems* are very Peircean. The Rosen biological systems diagram does have equation-like process designations for symbolism. Also, the system diagrams for the *Sensory Order* and for the Hayekian systems of government, science, and central banks indicate the main relational patterns essential for the successful theorizing of those processes. One can even imagine combining the diagrams of *Hayekian Systems* and *The Sensory Order* with a modified general equilibrium pattern diagram. There processes of individual optimization would be nested within processes of semiotically facilitated inquiry, discovery, and entrepreneurship which would be further nested within spontaneous orders, arrays of Hayekian systems, and other complex phenomena. Thus, Butos and McQuade's *Hayekian Systems* points toward many new understandings of economic and institutional processes, and they should be commended for the accomplishments found in their work.

NOTES

1 In rereading Hayek's (1955, 1964, 1969, 1976, p. 76) essays and other writings on these matters, I am continually asking the question whether the cognitive orders emerging in any particular individual and human brain could also be called a spontaneous order. Hayek does not seem to have as sharp a theory of the individual as Popper in my view.

2 This was a point made about science in my *Economics of Science* and a passage titled, "Hayek's Theory of Science as a Noncommercial, Rule-Governed Order," (Wible 1998, pp. 144-150).

3 Details for the conference volume can be found in Weimer (1982).

4 Weimer (2022a, 2022b) has authored a two-volume account of his work on science and cognitive psychology as it relates to the classical liberalism of the Hayekian variety. Those volumes are worthy of consideration in their own right.

5 For an analysis of Hayek and general equilibrium see Butos (1985).

6 For an introduction, see Hayek (1953, chapters 1 and 2).

7 See Hayek (1952, pp. 107-118) for his discussion of map and model relating to mental order.

8 Government and many of its processes and organizations may function as Hayekian systems. If government agencies function in proximity to spontaneous order, any government economic agency concerned with an advanced, market economy such as the continental-scale American economy would encounter significant limitations from the patterns and processes of various arrays of spontaneous orders of such a large-scale democracy and society. Yet another implication would be that a government regime of central planning for a spontaneous

social order would be particularly ill-conceived. Central planning would inhibit decentralized arrangements essential for a dynamic economy in the short run and would curtail economic growth especially in the long run. From those implications it is quite obvious to infer that economic freedom and economic growth are essential for political freedom and vice versa.

9 Hayek lauded Peirce's view of cognitive processes: "From H. von Helmholz's still insufficiently appreciated conception of 'unconscious inference' and the similar ideas of C. S. Peirce ...... they all stress in one way or another that our perception of the world is made possible by the mind possessing an organizing capacity; and that what used to be called elementary qualities are its product rather than its material." (F. A. Hayek, "Primacy of the Abstract," 1978/1969, p. 38).

10 Hayek likely read this passage from a fragment of a lecture published as a note in Peirce's *Collected Papers* (1898a, CP 1, par. 135, p. 56) since the first six volumes appeared in the 1930s. A complete version of the 1898 lectures was published in 1992. The "Will to Learn" and its corollary can be found in that 1992 publication or Peirce (1898b, pp. 170-171, 178).

11 Peirce ([1976a], NEM IV, and [1976b], NEM IV) calls this sequence Fermat's inference. There are many mentions in Peirce's *Collected Papers*.

12 Peirce (1895, NEM III/1, pp. 53-58; 1897, NEM III/1pp. 87ff; 1903, NEM III/1, p. 341 ff.).

13 See Butos and McQuade (2023, pp. 24-25, notes 2, 3, 8, 12).

14 No one has discussed monopoly power in science as much as Bartley (1990).

15 Butos and McQuade 2023, p. 1 assert that modern macro models "represent the market economy as a mathematical machine." Also see notes 2, 3, 4 on p. 4.

16 Peirce's (1976) mathematical contributions were belatedly published in a massive collection of mathematical textbooks, mathematical notes, writings on the philosophy of mathematics, and correspondence titled *New Elements of Mathematics*.

17 The chairman of the Federal Reserve, Powell (2023) seems to criticize DSGE models as interpreted by Torres (2023).

18 For an overview of Peirce's views on mathematics and cognition, see Pietarinen (2022).

19 For a more detailed discussion of Peirce's semiotics see Everett (2024) and Pelkey (2019) and for semiotics and economics, see Wible (2022).

20 Similarly, especially in his latest two-volume work, Weimer (2022a, b) has one of the richest discussions and treatments of human cognition that one can encounter, and it extends to Hayek, Popper, market and other human activities. But Weimer does not take up Peirce's work on semiotics and mathematics as an important domain for studying the complexities of human cognition at their highest levels of abstraction. Weimer often recognized that Peirce anticipated some of Popper's most important ideas, but not the semiotic, mathematical, and cognitive side of Peirce's views.

21 Marshall (1879, p. 5), the great British economist, takes a similar view of diagrams and mathematics: "Diagrams present simultaneously to the eye the chief forces which are at work, laid out, as it were, in a map; and thereby suggest results to which attention has not been directed by the use of the methods of mathematical analysis. The method of diagrams can be freely used by every one who is capable of exact reasoning, even though he have no knowledge of Mathematics."

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