How to Make a Class

Hayek's Neoliberalism and the Origins of Connectionism

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> Mind thus becomes to me a continuous stream of impulses, the significance of each and every contribution of which is determined by the place in the pattern of channels through which they flow within the pattern of all available channels—with newly arriving afferent impulses, set up by external or internal stimuli, merely diverting this flow into whatever direction the whole flow is disposed to move. . . . I liked to compare this flow of "representative" neural impulses, largely reflecting the structure of the world in which the central nervous system lives, to a stock of capital being nourished by inputs and giving a continuous stream of outputs—only fortunately, the stock of this capital cannot be used up.
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> Friedrich Hayek, "*The Sensory Order* after Twenty-Five Years"

> Homo sapiens is about pattern recognition. . . . Both a gift and a trap.
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> William Gibson, *Pattern Recognition*

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Introducing the Classifier

It was not a cybernetician but a neoliberal economist who provided the most systematic treatise on connectionism or, as it would be later known, the paradigm of artificial neural networks.[1] In his 1952 book *The Sensory Order*, Friedrich Hayek advanced a connectionist theory of the mind already far more advanced than the theory of symbolic artificial intelligence (AI), whose birth is redundantly celebrated in 1956 with the exalted Dartmouth workshop.[2] In *The Sensory Order* Hayek provided a synthesis of Gestalt principles and Warren McCulloch and Walter Pitts's theory of neural networks to describe "the nervous system as an instrument of classification."[3] He went so far to speculate about the possibility of a device fulfilling a similar function, describing (in the jargon of today's machine learning) a classifier algorithm. In 1958 Frank Rosenblatt defined the Perceptron (the first operative artificial neural network for pattern recognition) as "connectionist" and acknowledged that the work of "Hebb and Hayek" was "the most suggestive" for his own.[4] While Donald Hebb was a neuropsychologist famous for the theory of brain cell assemblies, a doctrine of neuroplasticity that is encapsulated in the dictum "Neurons that fire together, wire together," Hayek was an economist who studied the self-organization of the mind in a similar way but to support a political belief, namely, the spontaneous order of markets. The thesis that Hayek invented connectionism, however, is a simplification that overlooks his debt to the neurology and cybernetics of the time. One might better say that Hayek stole pattern recognition and made it a neoliberal principle of market regulation.

Hayek began work on his theory of the mind in 1920, when he was an assistant in the laboratory of the neuropathologist Constantin von Monakow in Zurich, and continued developing it across a long list of publications throughout his career.[5] He provided an impressive synthesis of ideas from neurophysiology (Hermann von Helmholtz, Karl Lashley), holistic neurology (Constantin von Monakow, Kurt Goldstein), Gestalt psychology (Max Wertheimer, Wolfgang Köhler, Kurt Koffka), Gestalt sociology (Kurt Lewin), system theory (Ludwig von Bertalanffy), empirio-criticism (Ernst Mach),

and cybernetics (McCulloch and Pitts), but he mobilized the armamentarium of cognitive sciences to make neoliberal principles look natural and universal.[6] A striking example of this is that Hayek described the decentralization of knowledge across the market in the same way that Monakow and Goldstein's theories of neuroplasticity described the decentralization of cognitive functions across the brain.

Between the 1940s and the 1960s the theory of self-organization in markets contributed to the theories of self-organization in computing networks, and vice versa. It must be said, however, that Hayek's theory of the market's spontaneous order was part of an ideological coup d'état. Nothing looked less spontaneous than a market order within the sphere of influence of a nuclear superpower.[7] Historians of science and technology usually stress the influence of US military funding on the development of cybernetics and artificial intelligence, but another front of the Cold War has to be acknowledged to complete the picture: the making of neoliberal doctrines in response to the socialist calculation debate and Keynesian policies.[8] Just as much as the decentralized topology of the Arpanet military network (the precursor of the internet) was designed as a reaction to Soviet military threat, Hayek's connectionism was conceived, among other stimuli, as a response to socialist centralized planning and Keynesianism.[9] Reading Hayek through this lens helps illuminate the influence of economic rationality on the early paradigms of artificial intelligence, to trace the circulation of ideas through models of minds, markets, and machines in the post–World War II years but also to register the influence of political and social forces in the making of such models. It was a competitive market network that gave form to Hayek's neural networks, which were elevated to techniques for price calculation because, as Hayek confessed, they were implicitly envisioned as "a stock of capital being nourished by inputs and giving a continuous stream of outputs."[10] Hayek's theory of the mind was but a variant of *mercantile connectionism*.

The following pages aim to put Hayek's epistemological project "on its feet," so to speak, showing how his connectionist theory of the mind was used to shore up a specific (ideological) view of the market. This will require a schematic reconstruction of Hayek's argument from his economic paradigm backward to his theory of

cognition. Hayek tried to forward the following lines of argumentation: (1) The economic problem is about the limited knowledge of free individuals that establish the optimal price of commodities on the basis of incomplete information. (2) Knowledge is acquired through the act of classification or pattern recognition, that is, the universal faculty to make categories out of perceptions that appear different and incomplete. (3) Classification happens via the self-organization of connections in the brain, or neural networks: knowledge is not made of propositions and representations but is performed by a topology of connections to take decisions (to classify something within a class or not). (4) The mind is a dynamic mental order of connections that is related but not identical to the external order: knowledge is not a rigid representation but an approximate model of the world constantly rearranging itself. Eventually, in Hayek's political intention, connectionism and neural networks provide a relativist paradigm to justify the "methodological individualism" of neoliberalism.[11]

The Decentralized and Tacit Rationality of the Market

In 1945 Hayek intervened in the famous socialist calculation debate with the essay "The Use of Knowledge in Society." Ludwig von Mises of the Austrian school of economics had initiated the debate, arguing that the optimal calculation of commodity prices would be impossible under the centralized bureaucracy of socialist economies. On the other side of the debate, it happened that Marxist economists such as Oskar Lange were questioning the importance of units of calculation such as money and labor time in the formation of prices. Hayek agreed with his mentor Mises but framed the antisocialist argument differently: the economic order was, he claimed, an issue of spontaneous knowledge rather than of mathematical exactitude. Hayek saw the pricing of commodities as a spontaneous order emerging from tacit knowledge, that is, as "a problem of the utilization of knowledge not given to anyone in its totality."[12] For this reason, neither centralized institutions nor technical apparatuses of calculation could grasp and embody such knowledge efficiently. Hayek's perhaps most famous passage on the decentralized rationality of the market reads:

> The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society is thus not merely a problem of how to allocate "given" resources—if "given" is taken to mean given to a single mind which deliberately solves the problem set by these "data." It is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. Or, to put it briefly, it is a problem of the utilization of knowledge not given to anyone in its totality.[12]

Philip Mirowski and Edward Nik-Khah believe themselves to have found here "the First Commandment of neoliberalism. Markets don't exist to allocate given physical resources, so much as they serve to integrate and disseminate something called knowledge."[14] Curiously, the idea that knowledge is distributed across a system and not possessed by any single component in its totality is not an original one by Hayek but is derived from the nonlocalization theory of brain functions of Monakow, with whom, as mentioned above, Hayek worked as assistant in 1920. Monakow advanced the hypothesis that cognitive functions (including memory) are not localized in one specific part but are distributed across the whole brain. He coined the term *diaschisis* (Greek for "shocked throughout") to describe how an injured brain can recover cognitive functions through neural reorganization.[15] Monakow's holistic model of the brain (what nowadays would be termed "neuroplasticity") was further systematized by another author Hayek read and often quoted, the Gestalt neurologist Kurt Goldstein.[16] Hayek's idea that the market is a place of distributed knowledge did not proceed from the study of economic phenomena but was first extrapolated from holistic neurology and early theories of neuroplasticity. In *The Sensory Order* Hayek also referred to the neurophysiologist Karl Lashley's idea of the brain's equipotentiality, which is similar to Monakow and Goldstein's:

> Certain mental processes which are normally based on impulses proceeding in certain fibres may, after these fibres have been destroyed, be relearned by the use of some other fibres. Certain associations may be effectively brought about through several alternative bundles of connexions, so that, if any one of these paths is severed, the remaining ones will still be able to bring about the result. Such effects have been observed and described under the names of "vicarious functioning" and "equipotentiality."[17]

Holistic neurology influenced not only Hayek's idea of distributed knowledge across the market but also the architecture of distributed memory in computing machines, as the cybernetician John von Neumann, among others, has suggested.[18] In his 1961 book *Neurodynamics*, Rosenblatt also acknowledged Lashley's and von Neumann's remarks on the distributed architecture of the brain as one of the main inspirations for the Perceptron neural network.[19]

Alongside the decentralization of knowledge, in his economic paradigm Hayek performed another important operation of decentering: the mobilization of tacit knowledge.[20] Hayek took great inspiration from Gilbert Ryle's 1945 paper "Knowing How and Knowing That," which famously defended the status of know-how and skills against the alleged "higher" forms of conscious and procedural knowledge:[21]

> The "know how" consists in the capacity to act according to rules which we may be able to discover but which we need not be able to state in order to obey them. . . . Rules which we cannot state thus do not govern only our actions. They also govern our perceptions, and particularly our perceptions of other people's actions. The child who speaks grammatically without knowing the rules of grammar not only understands all the shades of meaning expressed by others through following the rules of grammar, but may also be able to correct a grammatical mistake in the speech of others.[22] . . . What we recognize as purposive conduct is conduct following a rule with which we are acquainted but which we need not explicitly know. Similarly, that an approach of another person is friendly or hostile, that he is playing a game or willing to sell us some commodity or intends to make love, we recognize without knowing what we recognise it from.[23]

A similar position was also shared by holistic neurology of the time. For Goldstein, for instance, the unconscious is the locus not of primordial instincts that drive the conscious mind, as was the case with its Freudian predecessor, but of abstract behaviors as important as the conscious ones. By this account, the unconscious is a space of rules in the making, of embryonic abstractions to be perfected.[24] Thanks to these studies, Hayek could declare that unconscious behaviors also possess the power to make habits, norms, and abstractions. Mirowski and Nik-Khah comment that "for Hayek, it was rationality that was largely unconscious. . . . Knowledge here was no longer like entropy or pixie dust; now it resembled a great submerged iceberg, nine-tenths of it invisible."[25] Although captivating, the analogy of submerged rationality is not an accurate picture of Hayek's position. Reversing the Freudian topology of the mind, Hayek suggested that tacit knowledge is not subconscious but "supra-conscious" or "meta-conscious." Hayek stressed the existence of meta-conscious rules that are as abstract as conscious ones:

> While we are clearly often not aware of mental processes because they have not yet risen to the level of consciousness but proceed on what are (both physiologically and psychologically) lower levels, there is no reason why the conscious level should be the highest level, and many grounds which make it probable that, to be conscious, processes must be guided by a supra-conscious order which cannot be the object of its own representations. Mental events may thus be unconscious and uncommunicable because they proceed on too high a level as well as because they proceed on too low a level.[26]

What escapes Hayek's assessment is that this decentralized and unconscious rationality is not only of markets but can be found in other forms of human organization and cooperation. Karl Marx, for example, recognized the division of labor in workshops and manufactories as a form of spontaneous and unconscious rationality.[27] Capital, according to Marx, does not just exploit workers individually but does so through the social cooperation that is augmented by the division of labor and machinery. Marx famously assigned the power of the division of labor to the figure of the

collective worker (*Gesamtarbeiter*), which is distinct from the sum of individual tasks; similarly, Hayek saw the market as a spontaneous form of self-organization that is more than the mere sum of its individual exchanges. The difference between the two is that Marx, following Charles Babbage's lead, was aware that the spontaneous rationality of labor could be captured by the factory system and technological innovation, while Hayek assumed that the capture of the rationality of the market by a technical or institutional apparatus would be impossible and, if ever possible, illiberal. Hayek could not forecast that, at the turn of the coming century, digital networks and large data centers, employing the very artificial neural networks discussed by cyberneticians, would be able to trace and compute social behaviors and collective rationality in real time, inaugurating a highly effective regime of knowledge extractivism on a global scale.

The Faculty of Classification; or, What Is a Pattern?

Throughout his career Hayek defined classification as the main faculty of the mind in its interactions with the world and making of new ideas (including those "ideas" most crucial to economists: commodity prices). In a fairly technical paper published in 1947, McCulloch and Pitts already theorized artificial neural networks for "the perception of auditory and visual forms," but Hayek's 1952 book, *The Sensory Order*, was the first systematic treatment of connectionism and classification as a general faculty of the mind. Hayek's account of classification remains even today a valid introduction to the definition of classifier algorithm in machine learning:

> The phenomena with which we are here concerned are commonly discussed in psychology under the heading of "discrimination." This term is somewhat misleading because it suggests a sort of "recognition" of physical differences between the events which it discriminates, while we are concerned with a process which *creates* the distinctions in question. The same is true of most of the other available words which might be used, such as "to sort out," "to differentiate," or "to classify." The only appropriate term

> which is tolerably free from misleading connotations would appear to be "grouping." For the purposes of the following discussion it will nevertheless be convenient to adopt the term "to classify" with its corresponding nouns "classes" and "classification" in a special technical meaning. . . . By "classification" we shall mean a process in which on each occasion on which a certain recurring event happens it produces the same specific effect. . . . All the different events which whenever they occur produce the same effect will be said to be events of the same class, and the fact that every one of them produces the same effect will be the sole criterion which makes them members of the same class.[28]

The above passage is followed in *The Sensory Order* by Hayek's speculations about the possibility of machines embodying the principle of classification. Hayek provided examples of analog machines that in their simplicity can help illustrate the basic statistical logic of early artificial neural networks such as Rosenblatt's Perceptron:

> We may conceive of a machine constructed for the purpose of performing simple processes of classification of this kind. We can, for instance, imagine a machine which "sorts out" balls of various size which are placed into it by distributing them between different receptacles. . . . Another kind of machine performing this simplest kind of classification might be conceived as in a similar fashion sorting out individual signals arriving through any one of a large number of wires or tubes. We shall regard here any signal arriving through one particular wire or tube as the same recurring event which will always lead to the same action of the machine. The machine would respond similarly also to signals arriving through some different tubes or wires, and any such group to which the machine responded in the same manner would be regarded as events of the same class. Such a machine would act like a simplified telephone exchange in which each of a number of incoming wires was permanently connected with, say a particular bell, so that any signal coming in on any one of these wires would ring that bell. All the wires connected with any one bell would then carry signals belonging to the same class. An actual instance of a machine of this kind is provided by certain statistical machines for sorting cards on which punched holes represent statistical data.[29]

What this mechanical analogy helps illuminate is that for Hayek, the mind's construction of classes (concepts, categories, patterns, prices, etc.) is not the mere grouping of perceptions and mental events that appear similar. Hayek claimed that the human mind defines classes not only by recognizing similarities but often by *establishing* such similarities (also among arbitrary elements). This means that for Hayek (as for the cyberneticians), the establishment of a class is a pragmatic gesture rather than an abstract one, much like the acquisition of an individual habit or social convention by repetition. For Hayek, different perceptual events are recognized as part of the same class whenever they trigger, in all their instances, the same effect in the nervous system or as motor response: that is, the same perceptual pattern has to produce the same conscious idea and/or the same motor pattern.

Within the notion of class, Hayek included perceptual and aesthetical categories such as Gestalt and pattern but also ethical and political ones such as habit and norm. Gestalt theory had a profound influence on Hayek, to the extent that his theoretical framework can be considered the translation of Gestalt principles in the economic and social field.[30] In German literature and science, the notion of Gestalt (or perceptual configuration) had played a central role since the eighteenth century, from Goethe to Mach, before being canonized in the Gestalt school's psychology of perception. At the 1948 Hixon symposium in particular, cyberneticians confronted Gestalt perception as a unique faculty of the human and advocated its mechanization under techniques such as McCulloch and Pitts's artificial neural networks for pattern recognition. In fact, the more technical English term *pattern* gradually replaced the German word *Gestalt*, which was imported to the United States by the diaspora of scholars fleeing Nazism.[31]

However, it was thanks to Gestalt theory and not cybernetics that Hayek could extend the definitions of class and pattern to the economic field. Already in *Sensory Order* he expanded the understanding of pattern beyond the visual sphere and in so doing covered, respectively, "patterns within the brain," "topological patterns," "patterns of movements," "temporal patterns," "patterns of behavior," "patterns of motor responses," "patterns of attitude or dispositions," "patterns of nervous impulses," and so on. He developed

a large repertoire of the notion of pattern that included form, template, mold, schemata, abstraction, norm, habit, disposition, arrangement, rule, and inference. However, it was first with "The Theory of Complex Phenomena" (1961) that Hayek began to use the prescient moniker *pattern recognition* to define classification.[32] Probably Hayek's most visionary passages are those in which mathematical equations describe multidimensional patterns (which is in fact what the equations of artificial neural networks compute with differential calculus).[33] For example:

> Many of the patterns of nature we can discover only *after* they have been constructed by our mind. The systematic construction of such new patterns is the business of mathematics. The role which geometry plays in this respect with regard to some visual patterns is merely the most familiar instance of this. The great strength of mathematics is that it enables us to describe abstract patterns which cannot be perceived by our senses, and to state the common properties of hierarchies or classes of patterns of a highly abstract character. Every algebraic equation or set of such equations defines in this sense a class of patterns, with the individual manifestation of this kind of pattern being particularized as we substitute definite values for the variables.[34]

Like other modern philosophers, Hayek made no distinction between the ability to invent a class and to change behavior: the constitution of habits and norms follows the same logic as the constitution of ideas. Hayek extended the faculty in this way to construct classes and patterns to praxis and social behaviors: "People do behave in the same manner towards things, not because these things are identical in a physical sense, but because they have learnt to classify them as belonging to the same group, because they can put them to the same use or expect from them what to the people concerned is an equivalent effect."[35]

Nevertheless, what is crucial to any epistemology is not the definition of knowledge per se but its invention. How does a mind invent new ideas? Hayek not only had to offer a definition of classification or pattern recognition but also had to clarify how new classes and patterns are made. For Hayek, human beings continuously make

and unmake classes and patterns in their everyday activities. Specifically, the disruption of traditional and familiar classes through which reality is perceived and the reconstitution of new ones within unexpected constellations should be considered the modus operandi of science (against scientism and the "engineering type of mind"):[36]

> The idea that science breaks up and replaces the system of classification which our sense qualities represent is less familiar, yet this is precisely what Science does.[37] . . . This process of re-classifying "objects" which our senses have already classified in one way, of substituting for the "secondary" qualities in which our senses arrange external stimuli a new classification based on consciously established relations between classes of events is, perhaps, the most characteristic aspect of the procedure of the natural sciences. The whole history of modern Science proves to be a process of progressive emancipation from the innate classification of the external stimuli till in the end they completely disappear.[38]

Given the synthesis of psychology, mathematics, cybernetics, sociology, and philosophy of science in his theory of connectionism, Hayek can be truly defined as the economist of pattern recognition, or better, the economist that turned pattern recognition into a market principle of neoliberalism.

The Connectionist Machine as Model of the Mind

How is a set of different stimuli associated with the same class, that is, recognized as a recurrent pattern? What is the cerebral process that makes classification possible? Hayek's connectionism provided an empirical explanation for the relation between perception and cognition. Influenced by McCulloch and Pitts's idea of neural networks, Hayek simplified cognition as a simple act of decision (rather than intuition, or *Einsicht*, as in the Gestalt school).[39] In McCulloch and Pitts's model, a structure of progressive layers of nodes (made of multiple neurons or switches) filters a large input into a single binary output (a single neuron or switch) that decides if the group of input stimuli belongs to a given class or not. The solution is quite elegant: one node computes a large input into a simple binary output to signify yes or no. As in the modality of supervised machine learning, the

end node is assigned to a given class by a convention (for instance, to the label "apple"). It is said that the model is not isomorphic, meaning that it does not resemble the knowledge it interprets, that there is no localized area of the network that memorizes, for instance, the general form of the apple.[40] The correct classification of stimuli depends on the overall behavior of the computing structure.

Hayek's connectionism, however, did not advocate for a computational theory of the mind. It would be no mistake to call his version *Gestalt connectionism* to distinguish it from McCulloch and Pitts's *logical connectionism* and Rosenblatt's *statistical connectionism*. Hayek argued that the mind (which in his view was a mental order, a self-organized network of entities such as neurons) can only provide a *model* rather than a representation of the world (a sensory order, made of relations among qualia). Hayek wrote that "what we call mind is thus a particular order of a set of events taking place in some organism and in some manner related to but not identical with, the physical order of events in the environment."[41] Model-making was framed in 1945 by the cyberneticians Arturo Rosenblueth and Norbert Wiener in similar terms: "Partial models, imperfect as they may be, are the only means developed by science for understanding the universe. This statement does not imply an attitude of defeatism but the recognition that the main tool of science is the human mind and that the human mind is finite."[42] The construction of a model is the implementation of a given environment within the internal parameters and constraints of another environment, yet in the process of translation some elements are dispersed, approximated and distorted. Hayek, as well, acknowledged that a mental order is a partial, often false, interpretation of reality:

> We have seen that the classification of the stimuli performed by our senses will be based on a system of acquired connexions which reproduce, in a partial and imperfect manner, relations existing between the corresponding physical stimuli. The "model" of the physical world which is thus formed will give only a very distorted reproduction of the relationships existing in that world; and the classification of these events by our senses will often prove to be false, that is, give rise to expectations which will not be borne out by events.[43]

It is telling that, after Babbage, yet another political economist is to be found at a watershed in the history of computing: Babbage proposed computation as the automation of mental labor in the industrial process, while Hayek maintained that computation of market transactions would be impossible and, in any case, detrimental to the market autonomy itself. The theoretical difference and historical gap between Babbage and Hayek mirror the difference between symbolic and connectionist AI, between an idea of cognition based on representation and one based on modeling. Babbage's project to automate mental labor as hand calculation unfolded into the Turing machine and the deductive algorithms of symbolic AI: numerical manipulation became symbol manipulation, leaving no space for interpretation of meaning and capacity of adaptation. Whereas Babbage's computation was born following a drive to exactitude to fix errors in logarithmic tables, a flexible and adaptive epistemology is found in connectionism (including in Hayek's variant). After Hayek and von Neumann, Rosenblatt stressed that his neural network Perceptron was a simplification and exaggeration of specific traits of the human minds without claiming to be the ultimate paradigm of intelligence.[44]

The Market as a Neural Network

In addition to the theory of pattern recognition, Hayek is acknowledged for having employed *avant la lettre* a technical definition of information. His 1945 essay "The Use of Knowledge in Society" anticipated Claude Shannon's 1948 mathematical theory of communication, providing an operative definition of information as units of communication, more precisely, in this case, as "price signal." Hayek is recognized also for describing *avant la lettre* the market as a computer or, in the language of the time, as a sort of distributed telegraph network, "a kind of machinery for registering change, or a system of telecommunications" (it must be noted that at the time the numerical computer was not yet a common technology, and no design solution, such as the von Neumann architecture, existed to be taken for granted):

> We must look at the price system as such a mechanism for communicating information if we want to understand its real function, a function which, of course, it fulfils less perfectly as prices grow more rigid. . . . The most significant fact about this system is the economy of knowledge with which it operates, or how little the individual participants need to know in order to be able to take the right action. In abbreviated form, by a kind of symbol, only the most essential information is passed on and passed on only to those concerned. It is more than a metaphor to describe the price system as a kind of machinery for registering change, or a system of telecommunications which enables individual producers to watch merely the movement of a few pointers, as an engineer might watch the hands of a few dials, in order to adjust their activities to changes of which they may never know more than is reflected in the price movement.[45]

Contrary to the hubris of cyberneticians for full automation, Hayek asserted that the magnitude of the market complexity would exceed the hardware limits of any apparatus of calculation and manageable equations. In 1967, from the other side of the socialist calculation debate, the economist Oskar Lange countered that innovation had overcome these limitations and advocated for the use of powerful new computers in solving the math problems of economy: "So what's the trouble?" Lange replied to Hayek. "Let us put the simultaneous equations on an electronic computer and we shall obtain the solution in less than a second."[46] Lange understood the computer as a new instrument of knowledge that inaugurates a different perspective on the economy, as "the computer fulfils a function which the market never was able to perform."[47] Implicitly, Lange suggested the use of the computer as technical mediator between the troubles of market spontaneity and (the troubles of) centralized planning. This particular insight of Lange has been quoted by left-accelerationist rhetoric to generically foster a public use of algorithmic planning in the age of big data against the private use of said planning by corporations; Fredric Jameson, for example, advocated for the nationalization of the computing power of global logistics giants such as Walmart and Amazon.[48] But what sort of computing technique was Lange

specifically referring to? The way he continued the argument is often neglected: Lange referred not to deterministic computing but to something that resembles the process of training in artificial neural networks:

> The market mechanism and trial and error procedure proposed in my essay really played the role of a computing device for solving a system of simultaneous equations. The solution was found by a process of iteration which was assumed to be convergent. The iterations were based on a feedback principle operating so as to gradually eliminate deviations from equilibrium. It was envisaged that the process would operate like a servo-mechanism, which, through feedback action, automatically eliminates disturbances. . . . The same process can be implemented by an electronic analogue machine which simulates the iteration process implied in the *tâtonnements* [incremental approximations] of the market mechanism. Such an electronic analogue (servo-mechanism) simulates the working of the market. This statement, however, may be reversed: the market simulates the electronic analogue computer. In other words, the market may be considered as a computer sui generis which serves to solve a system of simultaneous equations. It operates like an analogue machine: a servo-mechanism based on the feedback principle. The market may be considered as one of the oldest historical devices for solving simultaneous equations. The interesting thing is that the solving mechanism operates not via a physical but via a social process. It turns out that the social processes as well may serve as a basis for the operation of feedback devices leading to the solution of equations by iteration.[49]

Along the tradition of Hayek's connectionism, Lange described the market as a machine solving simultaneous equations by incremental approximations, that is, as a learning algorithm that changes its parameters with trial-and-error adjustments, basically an artificial neural network. Lange's example of approximation techniques (trial and error, linear programming) to solve market equations surely does not remind us of centralized socialist economies but instead, nowadays, interestingly echoes training algorithms that are used in deep neural networks, such as back-propagation and gradient descent. As

the two passages by Hayek and Lange have shown, in twentieth-century economic debates, models of market and computation sometimes exchanged positions, but the real issue at stake remained the autonomy of social processes.

Toward a Political Epistemology of Neural Networks

Hayek's confession that he envisioned the connectionist mind as a stock capital in a continuous exchange with the market seems to confirm, in the age of AI, the seductive theory of real abstraction by the Marxist scholar Alfred Sohn-Rethel. In his 1977 book, *Intellectual and Manual Labour*, Sohn-Rethel sketched a "critique of epistemology" that posited the commodity form as the origin of abstract thinking itself. Sohn-Rethel argued that the exchange of goods in antiquity mediated by money would have been the first instance of abstract thought such as philosophy, since money, like philosophy, instituted a principle of abstract equivalence between material things. A commodity that is exchanged with another is for Sohn-Rethel a paradigmatic example of "real abstraction," that is, an abstraction expressed by the means of a thing. This happens even when the act of exchange is unconscious (here both Marx and Hayek would agree). In this way, the abstraction of market exchange preceded and influenced the evolution of philosophical and scientific "conscious" abstractions.

Sohn-Rethel was convinced that the general ideas of philosophy and analytical mathematics historically emerged when the first coined money (made of *elektron*, a naturally occurring alloy of gold and silver that was abundant in Asia Minor) started to circulate as a stable general equivalent in the ancient Greek colonies.[50] According to his telling, once money was liberated from the control of the despot, its numeric form galvanized philosophy as the first form of secular abstraction (religion and mythology being regimes of abstraction already in operation). Few generations after *elektron* coins entered and boosted commerce, the Greek colonies witnessed the first generation of the canonical Western philosophers, including Thales, Anaximander, and Anaximenes. Sohn-Rethel argued that the notions of identity, substance, divisibility, and infinity, typical of the pre-Socratic

philosophers, mirrored the same properties that had to be measured in the new metallic medium of commerce. For Sohn-Rethel, however, secular thinking was born as a conscious and critical reaction to the ills that money brought to Greek society.

Reducing the genesis of symbolic forms only to the monetary general equivalent can open all too easily onto fatalistic readings of the pernicious influence of capitalism on the mental order, creating a state of affairs wherein it would be difficult if not impossible to think outside the logic of capital. In his account of the emergence of conceptual tools, Sohn-Rethel stressed only the influence of the sphere of circulation (mercantile exchange) and thus minimized the sphere of production (social division of labor). In doing so, Sohn-Rethel overlooked the activity of reflection of labor with tools and language, which, according to other materialist epistemologies (see, for instance, Jean Piaget's and Peter Damerow's work), gave rise to mathematical abstractions long before mercantile exchange.[51] In other words, the real abstraction of the social division of labor predates the real abstraction of monetary exchange and wage labor: abstract thought existed in societies where money was not circulating but the division of labor and, in particular, slavery were enforced. Hayek would have been comfortable seeing the discipline of philosophy as a mirror of the market abstractions with no reference to the potential autonomy of labor and toolmaking. If Hayek's sophisticated connectionism is but a sublimated version of "market rationality," what would be an alternative epistemology of neural networks that would not echo the neoliberal mind?

In the *Grundrisse* Marx provided a critique of Hegel's epistemology that can also be extended to Hayek's mercantile epistemology. In the introduction to that work (written in 1857, a decade before *Capital*), Marx described the dialectics of abstract and concrete ideas as "the method of political economy," in this way synthesizing German idealism and British political economy. Questioning the given categories of everyday language as Hegel himself proposed in the *Phenomenology of Spirit*, Marx stressed that a familiar expression such as "labor" is the result of the long combination of different abstractions rather than a simple and originary notion from which reflection should start.[52] According to Marx, the "scientifically correct method" starts by breaking an idea (*Vorstellung*) into simpler concepts

(*Begriff*) and then moving again from these simple concepts and recomposing the whole "as a rich totality of many determinations and relations."[53] Hayek's description of the scientific method as the making and unmaking of the abstractions (classes, patterns, etc.) through which reality is perceived appears not dissimilar from Marx, though their political extrapolations obviously diverge. The creation of new ideas is for Hayek a subjective affair, an exercise of individual freedom, while for Marx it is influenced by the social relations of production and often organic to the logic of capital. Marx took the example of labor, which appears to be an old, familiar, and simple category but which modern capitalism has transformed into an abstraction. According to Marx, in fact, industrial capitalism emerged via the imposition of "abstract labor," that is, labor indifferent to the specificity of "concrete labor," labor that is transformed into a commodity, into a general equivalent of labor that any worker can perform.[54] Unlike preindustrial concrete labor, abstract labor is measured in abstract time units, and workers are paid proportionally to such units.[55] Historically, the working class in its modern sense was constituted, as a new political subject, by the imposition of the general equivalent of abstract labor during the industrial age.[56]

Unlike Hayek, Marx questioned the political genealogy of the categories of economic thought. For him, the categories of thought—specifically that of labor—are not neutral and can be intrinsic to the capitalist logic. They thus contribute to a certain normalization, control, and exploitation of society. However, unless one is indulging in political fatalism, one must recognize that the faculty of abstraction has never been an exclusive attribute of power only. To contest abstract labor in a capitalist sense, one should consider that the faculty of abstraction belongs to the human mind in its dialectical relation with the world, with tools and techniques, not just to a sovereign apparatus, capitalist or otherwise. As Hardt and Negri justifiably remark, "Abstraction is essential to both the functioning of capital and the critique of it."[57] Any abstraction, any classification, is the result of a social division of labor, of contradictions and conflicts, that are generative of knowledge. Similarly, Hayek's neural networks and artificial neural networks in general remain an extension of this very social division of abstract labor.

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Notes

1. Donald Hebb introduced the term *connectionist* in his 1949 book, *The Organization of Behavior.* The term was picked up by Rosenblatt in his 1958 paper "The Perceptron" to define his theory of artificial neural networks, which was inspired by McCulloch and Pitts's 1943 paper "A Logical Calculus of the Ideas Immanent in Nervous Activity." Since then connectionism has broadly defined theories of cognition and computation that are based on the activity of computing networks of interacting nodes (logic gates or brain cells) in which a large input is rendered into a simple output. Despite its references to neurophysiology, connectionism is a paradigm of computer science that migrated to cognitive science, not vice versa.
2. Hayek, *The Sensory Order.* This work is a development of the manuscript "Beiträge zur Theorie der Entwicklung des Bewusstseins" ("Contributions to the Theory of the Development of Consciousness"), which Hayek wrote in German as early as 1920.
3. Hayek, *The Sensory Order*, 55.
4. Rosenblatt, "The Perceptron."
5. Hayek, "Scientism and the Study of Society."
6. Discussing Hayek's legacy in the conceptualization of information, Philip Mirowski and Edward Nik-Khah have also noticed that "the place of information in economics was broached in heated disputes over the politics and possibilities of socialism" (*The Knowledge We Have Lost in Information*, 65).

7. See Hayek's 1977 visit to Chile and the meeting with the nonspontaneous dictator Augusto Pinochet in Caldwell and Montes, "Friedrich Hayek and His Visits to Chile."
8. On Cold War rationality, see Erickson et al., *How Reason Almost Lost Its Mind*.
9. Gerovitch, "InterNyet."
10. Hayek, "*The Sensory Order* after Twenty-Five Years."
11. See Di Iorio, *Cognitive Autonomy and Methodological Individualism*; and Di Iorio, "The Sensory Order and the Neurophysiological Basics of Methodological Individualism."
12. Hayek, "The Use of Knowledge in Society," 520.
13. Hayek, "The Use of Knowledge in Society," 519–20.
14. Mirowski and Nik-Khah, *The Knowledge We Have Lost in Information*, 63.
15. Riese and Hoff, "A History of the Doctrine of Cerebral Localization."
16. Goldstein, *Der Aufbau des Organismus*; Goldstein, *The Organism*. On Goldstein's influence on cybernetics, see Bates, "Creating Insight"; and Bates, "Unity, Plasticity, Catastrophe." On Goldstein's influence on French philosophy, see Pasquinelli, "What an Apparatus Is Not."
17. Hayek, *The Sensory Order*, 148.
18. "The main difficulty with the memory organ is that it appears to be nowhere in particular. It is never very simple to locate anything in the brain, because the brain has an enormous ability to re-organize [*sic*]. Even when you have localized a function in a particular part of it, if you remove that part, you may discover that the brain has reorganized itself, reassigned its responsibilities, and the function is again being performed. The flexibility of the brain is very great, and this makes localization difficult. I suspect that the memory function is less localized than anything else" (von Neumann, *Theory of Self Reproducing Automata*, 49). See also *The Computer and the Brain*, 63–68.
19. Rosenblatt, *Principles of Neurodynamics*, 10. On Lashley, see page 4 of Rosenblatt. See also Lashley, "The Relation between Mass Learning and Retention"; and Lashley, *Brain Mechanisms and Intelligence*.
20. The notion of tacit knowledge was used by Michael Polanyi in his 1958 book, *Personal Knowledge*, as opposed to verbalized or explicit knowledge. It is the form of everyday knowledge that is expressed in skills difficult to transmit as verbalized and procedural knowledge: for instance, the skill of riding the bicycle or playing a musical instrument.
21. Ryle, "Knowing How and Knowing That." The distinction between know-how and procedural knowledge has been dear to neoliberal

thinkers since Adam Ferguson, "the master of Adam Smith," made similar comments in the eighteenth century. See Hayek, "The Primacy of the Abstract."

22. Hayek, "Rules, Perception, and Intelligibility."
23. Hayek, "Rules, Perception, and Intelligibility," 55.
24. Goldstein and Scheerer, "Abstract and Concrete Behavior." Goldstein's model of "abstract attitude" or "categorical behavior," however, changed significantly in the 1960s.
25. Mirowski and Nik-Khah, *The Knowledge We Have Lost in Information*, 68–69.
26. Hayek, "Rules, Perception, and Intelligibility," 61.
27. See Pasquinelli, "On the Origins of Marx's General Intellect."
28. Hayek, *The Sensory Order*, 48.
29. Hayek, *The Sensory Order*, 48.
30. See also De Vecchi, "The Place of Gestalt Psychology."
31. Within the English tradition, Hayek mentioned Hanson, *Patterns of Discovery*; and Hardy, *A Mathematician's Apology*, 14 ("A mathematician, like a painter or poet, is a maker of patterns").
32. Hayek, "The Theory of Complex Phenomena." The term *pattern recognition* was popularized by Selfridge and Neisser, "Pattern Recognition by Machine."
33. Later on Hayek also wrote about "patterns in multidimensional space" ("Rules, Perception, and Intelligibility," 53).
34. Hayek, "The Theory of Complex Phenomena."
35. Hayek, "Scientism and the Study of Society," 277.
36. Hayek, "Scientism and the Study of Society," 269.
37. Hayek, "Scientism and the Study of Society," 271.
38. Hayek, "Scientism and the Study of Society," 271–72.
39. On the notion of insight in the Gestalt school, see Bates, "Creating Insight."
40. For the saga of model thinking in the history of AI, see Dupuy, *The Mechanization of the Mind*.
41. Hayek, *The Sensory Order*, 16.
42. Rosenblueth and Wiener, "The Role of Models in Science."
43. Hayek, *The Sensory Order*, 145.
44. "Perceptrons are not intended to serve as detailed copies of any actual nervous system. They are simplified networks, designed to permit the study of lawful relationships between the organization of a nerve net, the organization of its environment, and the 'psychological' performances

of which the network is capable. Perceptrons might actually correspond to parts of more extended networks in biological systems; in this case, the results obtained will be directly applicable. More likely, they represent extreme simplifications of the central nervous system, in which some properties are exaggerated, others suppressed" (Rosenblatt, *Principles of Neurodynamics*, 28).

45. Hayek, "The Use of Knowledge in Society."
46. Lange, "The Computer and the Market."
47. Lange, "The Computer and the Market," 161.
48. Jameson, *Valences of the Dialectic*.
49. Lange, "The Computer and the Market," 159.
50. Marc Shell has noted the ironic coincidence contained in the expression *electronic money*, which happens to completely dematerialize the original valuable substance (*Money, Language, and Thought*).
51. For an extensive overview of Piaget and Damerow's epistemologies, see Renn, *The Evolution of Knowledge*.
52. Marx, *Grundrisse*, 101.
53. Marx, *Grundrisse*, 101.
54. Marx, *Grundrisse*, 296.
55. Labor represented in the value of a commodity is abstract labor, that is, measured on the basis of socially necessary labor time.
56. Marx, *Grundrisse*, 103–5.
57. Hardt and Negri, *Commonwealth*, 127.

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