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Hayek and the Epistemology of Connectionism

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.

Friedrich Hayek, '*The Sensory Order* after 25 Years' [1977][1]

Homo sapiens is about pattern recognition . . . Both a gift and a trap.

William Gibson, *Pattern Recognition*, 2003[2]

1 Friedrich Hayek, 'The Sensory Order after 25 Years', in *Cognition and the Symbolic Processes*, vol. 2, ed. W. B. Weimer and D. S. Palermo, Hillsdale, NJ: Erlbaum, 1982, 287–93. Originally a lecture delivered in 1977.

2 William Gibson, *Pattern Recognition*, New York: Putnam's Sons, 2003, 22.

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.[3] In his 1952 book *The Sensory Order*, Friedrich Hayek propounded a connectionist theory of the mind already far more advanced than the theory of symbolic AI, whose birth is, redundantly, celebrated anno 1956 with the exalted Dartmouth workshop.[4] In *The Sensory Order*, Hayek provided a synthesis of Gestalt principles and Warren McCulloch and Walter Pitts's idea of neural networks to describe 'the nervous system as an instrument of classification'.[5] 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.[6] 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' seen in chapter 6 – Hayek was an economist who studied the self-organisation of the mind in a similar way but in order to support a political belief: namely, the spontaneous order of markets. The perception 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 transformed it into a neoliberal principle of market regulation.

3 Donald Hebb introduced the term 'connectionist' in his 1949 book *The Organization of Behavior: A Neuropsychological Theory*, New York: Wiley & Sons, 1949. Rosenblatt adopted the term in 1958 to define his theory of artificial neural networks: Frank Rosenblatt, 'The Perceptron: A Probabilistic Model for Information Storage and Organization in the Brain', *Psychological Review* 65, no. 6 (1958).

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

5 Hayek, *The Sensory Order*, chapter 3, 55.

6 Rosenblatt, 'The Perceptron'.

Hayek began work on his theory of the mind in 1920, when he was an assistant in the laboratory of neuropathologist Constantin Monakow in Zurich, and continued developing it across a long list of publications throughout his career.[7] He provided an impressive synthesis of ideas, from neurophysiology, holistic neurology, Gestalt psychology, system theory, empirio-criticism, and cybernetics – although he mobilised this armamentarium of cognitive science with the purpose of making neoliberal principles look natural and universal.[8] A striking example of this is that Hayek described the decentralisation of knowledge across the market in the same way in which Constantin von Monakow and Kurt Goldstein's theories of neuroplasticity described the decentralisation of cognitive functions across the brain.

As seen in chapter 6, between the 1940s and the 1960s, the theory of self-organisation in markets contributed to the theories of self-organisation 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. Indeed, nothing looked less spontaneous than a market order within the sphere of influence of a nuclear superpower.[9] As noted earlier, historians of science and technology usually stress the influence of US military funding on the development of cybernetics and artificial intelligence. However, another front of the Cold War has to be acknowledged to complete the picture: the formation of neoliberal doctrines in response to the socialist calculation debate (described below) and Keynesian

7 See Friedrich Hayek, 'Scientism and the Study of Society' part 1, *Economica* 9, no. 35 (1942): 267–91; Friedrich Hayek, 'The Theory of Complex Phenomena', in *The Critical Approach to Science and Philosophy: Essays in Honor of Karl R. Popper*, ed. Mario A. Bunge, New York: The Free Press of Glencoe, 1964; Friedrich Hayek, 'Rules, Perception and Intelligibility', *Proceedings of the British Academy* 48 (1963): 321–44; Friedrich Hayek, 'The Primacy of the Abstract', in *Beyond Reductionism: The Alpbach Symposium*, ed. Arthur Koestler and J. R. Smythies, London: Hutchinson, 1969.

8 Discussing Hayek's legacy in the conceptualisation of information, Philip Mirowski and Edward Nik-Khah have noticed that 'the place of information in economics was broached in heated disputes over the politics and possibilities of socialism'. Philip Mirowski and Edward Nik-Khah, *The Knowledge We Have Lost in Information: The History of Information in Modern Economics*, Oxford: Oxford University Press, 2017, 65.

9 See Hayek's 1977 visit to Chile and the meeting with the dictator Augusto Pinochet.

policies.[10] Just as much as the decentralised 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 centralised planning and Keynesianism.[11] Reading Hayek through this lens helps to illuminate the influence of economic rationality on the early paradigms of artificial intelligence and trace the circulation of those 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 in the epigraph to this chapter, they were implicitly envisioned as 'a stock of capital being nourished by inputs and giving a continuous stream of outputs'.[12] In this sense, Hayek's theory of the mind was but a variant of *mercantile connectionism*.

This chapter aims 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 backwards to his theory of cognition. Hayek tried to forward the following lines of argumentation: (1) that the economic problem is about the limited knowledge of free individuals which establish the optimal price of commodities on the basis of incomplete information; (2) that 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) that classification happens via the self-organisation of connections in the brain, or neural networks – in other words, that 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); and (4) that the mind is a dynamic mental order of

10 On Cold War rationality, see Paul Erickson et al., *How Reason Almost Lost Its Mind: The Strange Career of Cold War Rationality*, Chicago: University of Chicago Press, 2013.

11 Slava Gerovitch, 'InterNyet: Why the Soviet Union Did Not Build a Nationwide Computer Network', *History and Technology* 24, no. 4 (December 2008): 335–50.

12 Hayek, 'The Sensory Order after 25 Years'.

connections that is related but not identical to the external order – under which logic, 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 for justifying the 'methodological individualism' of neoliberalism.[13]

The decentralised 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 in the absence of commodity prices as a unit of account, rational economic calculations would be impossible under the centralised 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 labour time in the formation of prices. Hayek agreed with his mentor Mises but framed the anti-socialist 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 which is not given to anyone in its totality'. For this reason, neither centralised institutions nor technical apparatuses of calculation could grasp and embody such knowledge efficiently. Hayek's famous passage on the decentralised 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

13 See Francesco Di Iorio, *Cognitive Autonomy and Methodological Individualism: The Interpretative Foundations of Social Life*, Berlin: Springer, 2015; Francesco Di Iorio, 'The Sensory Order and the Neurophysiological Basics of Methodological Individualism', in *The Social Science of Hayek's the Sensory Order: Advances in Austrian Economics*, vol. 13, ed. William N. Butos, London: Emerald, 2010.

> 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 which is not given to anyone in its totality.[14]

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.'[15] 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 from Hayek but is derived from the non-localisation 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 delimited in one specific part but are distributed across the whole brain. He coined the term 'diaschisis' (from the Greek for 'shocked throughout') to describe how an injured brain can recover cognitive functions through neural reorganisation.[16] Monakow's holistic model of the brain (what nowadays would be called a model of 'neuroplasticity') was further systematised by another author Hayek read and often quoted, the Gestalt neurologist Kurt Goldstein.[17]

14 Friedrich Hayek, 'The Use of Knowledge in Society', *American Economic Review* 35, no. 4 (1945): 519–30.

15 Mirowski and Nik-Khah, *The Knowledge*, 63.

16 Walther Riese and Ebbe C. Hoff, 'A History of the Doctrine of Cerebral Localization: Sources, Anticipations, and Basic Reasoning', *Journal of the History of Medicine and Allied Sciences* 5, no. 1 (1950): 50–71.

17 Kurt Goldstein, *The Organism: A Holistic Approach to Biology Derived from Pathological Data in Man*, New York: American Book Company, 1939. On Goldstein's influence on cybernetics, see David Bates, 'Creating Insight: Gestalt Theory and the Early Computer', in *Genesis Redux: Essays in the History and Philosophy of Artificial Life* (2007): 237–59. On Goldstein's influence on French philosophy, see Matteo Pasquinelli, 'What an Apparatus Is Not: On the Archeology of the Norm in Foucault, Canguilhem, and Goldstein', *Parrhesia* 22 (May 2015).

Hayek's idea that the market is a place of distributed knowledge therefore 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 neurophysiologist Karl Lashley's idea of the brain's equipotentiality, which bears similarities 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'.[18]

As von Neumann, among others, has suggested, holistic neurology influenced not only Hayek's idea of distributed knowledge across the market but also the architecture of distributed memory in computing machines.[19] 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.[20]

Alongside the decentralisation of knowledge in his economic paradigm, Hayek performed another important operation of decentring: the

18 Hayek, *The Sensory Order*, 148.

19 '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. 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 von Neumann, *The Computer and the Brain*, 63–8.

20 Frank Rosenblatt, *Principles of Neurodynamics: Perceptrons and the Theory of Brain Mechanisms*, report, Buffalo, NY: Cornell Aeronautical Laboratory, 1961, 10. On Lashley: 4. See Karl Lashley, 'The Relation between Mass Learning and Retention', *Journal of Comparative Neurology* 41, no. 1 (1926): 1–58; Karl Lashley, *Brain Mechanisms and Intelligence*, Chicago: University of Chicago Press, 1929.

mobilisation of tacit knowledge.[21] 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.[22] Hayek writes:

> 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.[23]

What we recognise 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 recognise without knowing what we recognise it from.[24]

The holistic neurology of the time shared a similar position. 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, rather, of abstract behaviours as important as the conscious ones. By this account, the unconscious is a space of rules in

21 Tacit knowledge is expressed in skills that are difficult to verbalise and transmit: for example, riding a bicycle or playing a musical instrument. See Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy*, Chicago: University of Chicago Press, 1958.

22 Gilbert Ryle, 'Knowing How and Knowing That: The Presidential Address', in *Proceedings of the Aristotelian Society*, vol. 46, Aristotelian Society, New York: Wiley, 1945, 1–16. See also Hayek, 'The Primacy of the Abstract', in Koestler and Smythies, *Beyond Reductionism*.

23 Friedrich Hayek, 'Rules, Perception, and Intelligibility', *Proceedings of the British Academy* 48 (1962), reprinted in Friedrich Hayek, *Studies in Philosophy, Politics, and Economics*, London: Routledge, 1967, 44–5.

24 Hayek, 'Rules', 55.

the making, of embryonic abstractions to be perfected.[25] Thanks to these studies, Hayek was able to declare that unconscious behaviours also possess the power to make habits, norms, and abstractions. Along similar lines, 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.'[26] Although captivating, the analogy of submerged rationality is not an accurate picture of Hayek's position. Reversing the usual topology of the mind, Hayek suggested that tacit knowledge is not subconscious but rather 'supra-conscious' or 'meta-conscious'.[27] He 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.[28]

What escapes Hayek's assessment is that this decentralised and unconscious rationality is to be found not only in markets but also in other forms of human organisation and cooperation. Marx, for example, recognised the division of labour in workshops and manufactories as a form of spontaneous and unconscious rationality.[29] Capital, according to Marx, does not just exploit workers individually but does so through the social cooperation that is augmented by the division of

25 Kurt Goldstein and Martin Scheerer, 'Abstract and Concrete Behavior: An Experimental Study with Special Tests', *Psychological Monographs* 53, no. 2 (1941). Goldstein's model of 'abstract attitude' or 'categorical behaviour', however, changed significantly in the 1960s.

26 Mirowski and Nik-Khah, *The Knowledge*, 68–9.

27 Hayek, 'Rules', 61.

28 Ibid.

29 See Matteo Pasquinelli, 'On the Origins of Marx's General Intellect', *Radical Philosophy* 2, no. 6 (Winter 2019): 43–56.

labour and machinery. As we saw in chapter 4, Marx assigned the power of the division of labour 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-organisation 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 labour 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 centres, employing the very artificial neural networks discussed by cyberneticians, would be able to trace and compute social behaviours 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 in the generation of new ideas (including those 'ideas' most crucial to economists: commodity prices). In their 1947 paper, McCulloch and Pitts already theorised 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. Even today, Hayek's account of classification remains a valid introduction to the definition of classifier algorithms 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.[30]

The above passage is followed in *The Sensory Order* by Hayek's speculations about the possibility of machines embodying this principle of classification. Hayek provided examples of analogue 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

30 Hayek, *The Sensory Order*, 48.

> machine of this kind is provided by certain statistical machines for sorting cards on which punched holes represent statistical data.[31]

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 recognising 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 recognised 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 must 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 registered a profound influence on Hayek, to the extent that his theoretical framework can be considered the translation of Gestalt principles into the economic and social field.[32] 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 canonised in the Gestalt school's psychology of perception. As seen in the previous chapter, at the 1948 Hixon symposium, cyberneticians questioned Gestalt perception as a unique faculty of the human and advocated its mechanisation 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.[33]

31 Ibid.

32 See also Nicolò De Vecchi, 'The Place of Gestalt Psychology in the Making of Hayek's Thought', *History of Political Economy* 35, no. 1 (2003): 135–62.

33 Within the English tradition, Hayek mentioned N. R. Hanson, *Patterns of Discovery*, Cambridge: Cambridge University Press, 1958; G. H. Hardy, *Mathematician's Apology*, Cambridge: Cambridge University Press, 1941, 14: 'a mathematician, like a painter or poet, is a maker of patterns.'

However, it was thanks to Gestalt theory and not cybernetics that Hayek was able to 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, *Schablone*, mould, 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.[34] 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).[35] For example, he writes:

> 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.[36]

Like other modern philosophers, Hayek made no distinction between the ability to invent a class and to change behaviour: the constitution of

34 Friedrich Hayek, 'The Theory of Complex Phenomena', in *The Critical Approach and Philosophy: Essays in Honor of K. R. Popper*, ed. M. Bunge, New York: The Free Press, 1964. The term 'pattern recognition' was popularised in Oliver G. Selfridge and Ulric Neisser, 'Pattern Recognition by Machine', *Scientific American* 203, no. 2 (1960): 60–9.

35 Later on, Hayek wrote also about 'patterns in multidimensional space'. Hayek, 'Rules', 53.

36 Hayek, 'Theory of Complex Phenomena'.

habits and norms follow the same logic of the constitution of ideas. Hayek extended, in this way, the faculty of constructing classes and patterns to praxis and social behaviours:

> 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.[37]

Nevertheless, what is crucial for any epistemology is not the definition of knowledge per se but the capacity for 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'):[38]

> 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 . . . 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.[39]

37 Hayek, 'Scientism and the Study of Society', 277.
38 Ibid., 269.
39 Ibid., 271–2.

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

Neural networks as a model of the mind

How is a set of different stimuli associated with the same class – that is, recognised 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).[40] 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 none of its parts resembles the knowledge it interprets: there is no localised area of the network that memorises, for instance, the general form of the apple in its recognisable proportions.[41] The correct classification of stimuli depends on the overall behaviour 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 theory *Gestalt connectionism* to distinguish it from McCulloch and Pitts's

40 On the notion of insight in the Gestalt school, see David Bates, 'Creating Insight: Gestalt Theory and the Early Computer', in *Genesis Redux: Essays in the History and Philosophy of Artificial Life*, ed. Jessica Riskin, Chicago: University of Chicago Press, 2007, 237–60.

41 For the saga of model thinking in the history of AI, see also Jean-Pierre Dupuy, *The Mechanization of the Mind: On the Origins of Cognitive Science*, Cambridge, MA: MIT Press, 2000.

logical connectionism and Rosenblatt's *statistical connectionism*. Hayek argued that the mind (which in his view was a mental order, a self-organised 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'.[42] In 1945, cyberneticians Arturo Rosenblueth and Norbert Wiener framed model-making 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.[43]

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 also 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.[44]

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 labour in the industrial

42 Hayek, *The Sensory Order*, 16.

43 Arturo Rosenblueth and Norbert Wiener, 'The Role of Models in Science', *Philosophy of Science* 12, no. 4 (1945): 316–21.

44 Hayek, *The Sensory Order*, 145.

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 mirrors the difference between symbolic and connectionist AI, between an idea of cognition based on representation and one based on modelling. Babbage's project to automate mental labour 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 through 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.[45]

The market as a model of neural networks

In addition to the theory of pattern recognition, Hayek is acknowledged for having employed, *ante litteram*, a technical definition of information. His 1945 essay 'The Use of Knowledge in Society' anticipated Shannon's 1948 mathematical theory of communication, providing an operative definition of information as units of communication – more precisely, in this case, as 'price signals'. Hayek is recognised also for describing 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 computer was not yet a common technology):

45 '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, *Neurodynamics*, 28.

> 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.[46]

Contrary to the hubris of cyberneticians for full automation, Hayek asserted that the magnitude of the market's complexity would exceed the hardware limits of any apparatus of calculation and of manageable equations. Two decades later, from the other side of the socialist calculation debate, the economist Oskar Lange countered that innovation had overcome these limitations, advocating for the use of powerful new computers in solving the mathematical problems of economics: '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.'[47] 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'.[48] Implicitly, Lange suggested the use of the computer as technical mediator between the troubles of market spontaneity and those of centralised 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

46 Friedrich Hayek, 'The Use of Knowledge in Society', *American Economic Review* 35, no. 4 (1945): 519–30.

47 Oskar Lange, 'The Computer and the Market', in *Socialism, Capitalism, and Economic Growth: Essays Presented to Maurice Dobb*, ed. C. H. Feinstein, Cambridge: Cambridge University Press, 1967, 158–61.

48 Ibid., 161.

said planning by corporations; Fredric Jameson, for example, advocated for the nationalisation of the computing power of global logistics giants such as Walmart and Amazon.[49] But to what specific sort of computing technique was Lange referring? Often neglected, the following part of his argument does not mention deterministic computing but something that resembles the training process of 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 *tátonnements* [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.[50]

Along the tradition of Hayek's connectionism, Lange described the market as a social machine solving simultaneous equations by incremental approximations (*tátonnements*), in a way similar to a learning

49 Leigh Phillips and Michal Rozworski, *The People's Republic of Walmart: How the World's Biggest Corporations Are Laying the Foundation for Socialism*, London: Verso, 2019. See also Fredric Jameson, *Archaeologies of the Future: The Desire Called Utopia and Other Science Fictions*, London: Verso, 2005, 153n22.

50 Lange, 'The Computer and the Market', 159.

algorithm that changes its parameters with trial-and-error adjustments. Lange's example of approximation techniques to solve market equations surely does not echo centralised socialist economies but instead, nowadays, the training algorithms of artificial neural networks (such as back-propagation and gradient descent, among others). As the two passages by Hayek and Lange have shown, in the twentieth century's economic debates, models of market and computation sometimes exchanged positions, but the real issue at stake remained the agency and autonomy of the underlying social processes.

Towards 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 Marxist scholar Alfred Sohn-Rethel. In his 1970 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.[51] According to his narrative,

51 Marc Shell has noted the ironical coincidence that is contained in the expression 'electronic money' that happens to completely dematerialise the original valuable substance. See Marc Shell, *Money, Language, and Thought: Literary and Philosophical Economies from the Medieval to the Modern Era*, Berkeley: University of California Press, 1982.

once money was liberated from the control of the despot, its numeric form galvanised philosophy as the first form of secular abstraction (religion and mythology being regimes of abstraction already in operation). A few generations after *elektron* coins entered circulation 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 him, 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 minimised the sphere of production (the social division of labour). In so doing, he overlooked the activity of reflection of labour through tools and language, which, according to other materialist epistemologies (including those of Jean Piaget and Peter Damerow) gave rise to mathematical abstractions long before the emergence of mercantile exchange.[52] In other words, the real abstraction of the social division of labour predates the real abstraction of monetary exchange and wage labour: abstract thought existed in societies where money was not circulating but the division of labour 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 labour and tool-making. If Hayek's sophisticated connectionism is, then, but a sublimated version of the 'market rationality', what would an alternative epistemology of neural networks, that would not echo the neoliberal mind, look like?

In the *Grundrisse*, Marx provided a critique of Hegel's epistemology that can also be extended to Hayek's mercantile epistemology. In the

52 For an extensive overview of Jean Piaget and Peter Damerow's epistemologies, see Jürgen Renn, *The Evolution of Knowledge: Rethinking Science for the Anthropocene*, Princeton, NJ: Princeton University Press, 2020.

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 synthesising 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 'labour' is the result of the long combination of different abstractions rather than a simple and originary notion from which reflection should start.[53] According to Marx, the 'scientifically correct method' starts from decomposing an idea (*Vorstellung*) into simpler concepts (*Begriff*) and then moving again from these simple concepts to recompose the whole 'as a rich totality of many determinations and relations'.[54] 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 that of 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 is often organic to the logic of capital. Marx took the example of labour, which appears to be an old, familiar, and simple category, which modern capitalism has transformed into an abstraction. According to Marx, in fact, industrial capitalism emerged via the imposition of 'abstract labour' – that is, labour indifferent to the specificity of 'concrete labour', labour that is transformed into commodity, into a general equivalent of labour that any worker can perform.[55] Unlike preindustrial concrete labour, abstract labour is measured in abstract time units, and workers are paid proportionally to such units.[56] Historically, the working class in its modern sense was constituted, as a new political subject, by the imposition of the general equivalent of abstract labour during the industrial age.[57]

Unlike Hayek, Marx questioned the political genealogy of the categories of economic thought. For him, the categories of thought

53 Karl Marx, *Grundrisse: Foundations of the Critique of Political Economy*, trans. Martin Nicolaus, London: Penguin, 1993, 101.

54 Ibid., 101.

55 Ibid., 296.

56 Labour represented in the value of a commodity is abstract labour, which is measured on the basis of socially necessary labour-time.

57 Ibid., 103–5.

– specifically that of labour – are not neutral and are, rather, intrinsic to the capitalist logic. They thus contribute to a certain normalisation, control, and exploitation of society. However, unless one is indulging in political fatalism, one must recognise that the faculty of abstraction has never been an exclusive attribute of power only. To contest abstract labour 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 political philosophers Michael Hardt and Antonio Negri justifiably remark, 'Abstraction is essential to both the functioning of capital and the critique of it.'[58] Any abstraction, any classification, is the result of a social division of labour, 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 labour.

58 Michael Hardt and Antonio Negri, *Commonwealth*, Cambridge, MA: Harvard University Press, 2009, 127.