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Epigenetic Mimesis: Natural Brains and Synaptic Chips

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The purpose of this chapter is twofold. First, it raises a specific issue: how are we to understand the verbs 'imitate' or 'simulate' when we are told that the most recent developments and achievements in cybernetics and artificial intelligence allow technology to 'imitate' or 'simulate' the biological brain, and more precisely its epigenetic capacities? On the other hand, it will situate this issue in a more general context, namely that of my own philosophical trajectory, or at least the part of this trajectory that started with my first book on the brain, *What Should We Do With Our Brain?* (2004), and recently continued on with *Morphing Intelligence: From IQ Measurement to Artificial Brains* (2019). Recounting the main steps of this trajectory does not respond to a narcissistic trend but is used to outline the continuous attempt at trying to find an accurate concept of 'imitation' when it comes to the relationship between the natural and the artificial. To characterise such a relationship, the old, platonic notion of 'mimesis' is no longer relevant, as it limits imitation or simulation to the simple act of copying. AI does not 'copy' the brain – which does however not mean that the brain is in*im*itable. Getting out of this aporia, if such a thing is possible, took and is still taking me a lot of effort.

Let me first expand on epigenetics and what current neurobiologists call the epigenetic turn in the history of neurology. Then, I will present some recent technological achievements that sustain the idea of an epigenetic turn in the history of cybernetics and AI. Thirdly, and finally, I will propose a few philosophical reflections on the concept of imitation.

On 15 February 2001, the American scientific journal *Nature* published the virtually complete sequence of the three billion bases of the human genome (IHGSC 2001). The result was surprising: the human genome is made up of only 30,000 genes, in other words, just 13,000 more than drosophila (commonly known as fruit flies). Furthermore, it appears that genes only make up 5 per cent of the genome. Assembled in bunches and clusters, they are separated by vast expanses of so-called 'gene deserts', made up of DNA labelled 'junk' or 'repetitive', that is, non-coding. According to studies, this 'non-coding' DNA accounts for a quarter or a third of the totality of the genome. This means that within chromosomes there are long DNA sequences which, according to current understanding, do not appear to match the genes and cannot be given any particular function (cf. *Le Monde* 2001; my translation). The sequencing of the genome did not, therefore, offer the expected revelations. On the contrary, it indicated the weakening of genetic determinism. These discoveries marked the passage from the genetic to the epigenetic paradigm.

Epigenetics is a science that is currently dramatically transforming all previous (that is essentially genetic) conceptions of inheritance. This branch of molecular biology studies the relations between genes and the individual features they produce, in other terms the relation between genotype and phenotype. Derived from 'epigenesis', the term 'epigenetics' is a neologism created in 1940 by British biologist Conrad Waddington.

> Some years ago (e.g. 1947) I introduced the word 'epigenetics', derived from the Aristotelian word 'epigenesis', which had more or less passed into disuse, as a suitable name for the branch of biology which studies the causal interactions between genes and their products which bring the phenotype into being. (Waddington 1968: 9–10)

Epigenetic mechanisms concern the expression, transcription or translation of the genetic code into the phenotype, that is the biological unique constitution and physical appearance of an individual. These mechanisms act essentially through the activation or silencing of certain genes, that is through a series of modifications. These changes in gene expression do not involve changes to the underlying DNA sequence. Epigenetic changes occur at the chemical internal level (DNA *methylation*, histone modification and *non-coding RNA* [*ncRNA*]) but can also be influenced by several factors including age, the environment, or lifestyle.

If the DNA is like a book, or a musical score, its readings are its epigenetic translations or interpretations. In the second half of the twentieth century the concept of 'programme' dominated genetics. It is exactly the idea of a programme that is in question today with the acknowledgement of the importance of epigenetic mechanisms.

Now to the brain. The epigenetic turn in neurobiology is of course linked with this scientific revolution, which also revealed that the brain, far from being made of fixed and rigid localisations, was undergoing continuous changes and wirings. The power of neuroplasticity has provoked a very important mutation in the definition of intelligence, still challenging all attempts at considering it as innate and genetically predetermined. We know now that the brain's development is, for its most part, epigenetic, continuing long after birth and depending to a large extent on environmental and cultural factors. In their book, *The Mind and the Brain: Neuroplasticity and the Power of Mental Force*, the authors Jeffrey M. Schwarz and Sharon Begley write:

> Although it would be perfectly reasonable to posit that genes determine the brain's connections, just as a wiring diagram determines the connections on a silicon computer chip, that is a mathematical impossibility. As the Human Genome Project drew to a close in the early years of the new millennium, it became clear that humans have something like 35,000 different genes. About half of them seem to be active in the brain, where they are responsible for such tasks as synthesizing a neurotransmitter or a receptor. The brain, remember, has billions of nerve cells that make, altogether, trillions of connections [. . .] Call it the genetic shortfall: too many synapses, too few genes. Our DNA is simply too paltry to spell out the wiring diagram for the human brain. (Schwarz and Begley 2002: 111–12)

This means that the brain has its own life and development, which does not depend entirely on genetic information. Neurobiologists agree that: 'the brain is more than a reflection of our genes' (ibid.).

Synaptic development is never the mere implementation of a program or code. On the contrary, it 'includ[es] the spontaneous activity in the nervous system in addition to activity provoked by interaction with the environment' (ibid.: 7). Once again, this epigenetic view of the shaping of neural connections enables a break with strict determinism.

For a long time, I have been convinced that the epigenetic nature of brain development was what definitively proved its irreducibility to AI systems, or any cybernetic or robotic processes. Was not epigenetic cerebral plasticity the perfect intermingling of the biological and the symbolic, that marked its difference with technological functioning? By the intermingling of the biological and the symbolic, I mean the indiscernibility between biological development and personal history, materiality and sense, chemical mechanisms and the exposure of the brain to changes, education, the adventures of life. All these developmental directions might be, I thought, summarised in one question: what should we do with our brain? If we can do something with our brain, it is precisely because the brain is not a machine, and we are in part responsible for its plasticity.

However, the recent developments in artificial intelligence made me think differently. It was a shock to realise that I was wrong, that my book *What Should We Do With Our Brain?* should be revised, perhaps even entirely rewritten. This suspicion came to me brutally when I read an article about the most recent computational architectures, and particularly about IBM's recent design of a totally new type of chip, the *neuro-synaptic chip*. The title of the article was eloquent: 'IBM's Neuro-Synaptic Chip Mimics Human Brain' (Murray 2013). Clearly, IBM was releasing a neuro-synaptic computation chip that was able to simulate the neurons and synapses of the brain. Up until now, most computer chips have employed a von Neumann-type architecture, the mathematics-based system at the core of almost every computer built since 1948, that executes instructions in series. By comparison, the synaptic chip is made of different neuro-synaptic-cores or 'corelets' that function autonomously, in a non-synchronic way, so that those which are not solicited remain inactive, thus resulting in a lower energy use. If it is said to mimic the brain, it is because this chip allows interactions between neurons (elements of calculus), synapses (memory) and axons (communications with other parts of the chip). The second reason is that the electronic synaptic components are capable of varying connection strength between two neurons in a manner analogous to that seen in biological systems. In a certain sense, the system develops what we might call its own 'experience'.

In 2011, Dharmendra S. Modha, founder of IBM's Cognitive Computing group at IBM Research, developed with his team the first cognitive chip, thus concretising the SyNAPSE project – SyNAPSE standing for 'Systems of Neuromorphic Adaptive Plastic Scalable Electronics'. Right from the start the ambition was to develop low-power electronic neuromorphic computers that could scale to biological levels. More recently, a still improved chip came to light, called TrueNorth, which is made up of 4,096 neuro-synaptic cores and is able to simulate around one million neurons. On this, Modha explains: 'if we think of today's von Neumann computers as akin to the "left-brain" – fast, symbolic, number-crunching calculators, then TrueNorth can be likened to the "right-brain" – slow, sensory, pattern recognizing machines' (Modha 2016). TrueNorth's corelets are designed for sensory applications that include things like artificial noses, ears and eyes. They are adaptable and can rewire synapses based on their inputs. These chips and processors have experienced exponential growth since then.

In a more recent research report on the global neuromorphic chip market, the authors explain:

> Neuromorphic chips come with artificial neurons and artificial synapses that mimic the activity spike that occurs in the human brain. The chip has the ability to learn continuously due to its synaptic plasticity. This results in smarter, far more energy efficient computing systems. Self-learning neuromorphic chips perform on chip processing asynchronously. It uses event driven processing models to address complex computing problems. Further, by combining improved on board learning, reduced latency, and improved energy efficiency, the self-learning neuromorphic chip can push the image recognition and speech processing to new levels of speed and accuracy. (Advanced Market Analytics 2021)

We can then consider that cybernetics and AI have also had their epigenetic revolution, to the extent that the concept of the program is no longer entirely adequate in this domain either. The new systems, like the IBM ones just mentioned, are able to change or adapt their programs. We can also think of recurrent neural networks, or deep learning, which is also more akin to epigenetic than genetic development. In his book *The Singularity is Near*, Kurzweil constantly insists, famously, on the exponential growth of computing capacities and speed. He speaks of a quantitative 'paradigm shift': 'the rate of the paradigm shift (technical innovation) is accelerating, now doubling every decade' (Kurzweil 2005: 25). Nevertheless, the shift is also qualitative. The singularity will also be that of the plasticity of machines. So yes, it is plasticity that is at stake, and not only as a metaphor or a way of speaking. 'Human intelligence', says Kurzweil, 'has a certain amount of plasticity', that is, an 'ability to change its structure, more so than had been understood' (ibid.: 27). Machines to come will also be plastic, more and more plastic, and they will be capable of changing themselves: 'once machines achieve the ability to design and engineer technology as humans do, only at far higher speeds and capacities, they will have access to their own designs (source code) and the ability to manipulate them, just as we manipulate genetics' (ibid.). Further: 'machines will be able to reformulate their own designs' (ibid.). Thus, we see how quantity and quality are intimately tied together.

Let's now turn to the issue of imitation. In the aforementioned article about synaptic chips, the authors write: 'neuromorphic chips come with artificial neurons and artificial synapses that mimic the activity spike that occurs in the human brain. The chip has the ability to learn continuously due to its synaptic plasticity.' How are we to understand 'mimic' here? Should we refer it to the Greek mimesis, from which it etymologically derives? We all know well the usual questions: 'will AI systems replace us?' Or 'can a computer be intelligent? Can it simulate a brain? Do better than us? Do better without us?' Of course I share some of Hawking's fears, expressed on the BBC a few years ago, that: 'the development of full artificial intelligence could spell the end of the human race'. At the same time, I think that such predictions are not substantiated. And in order to avert them, many people are trying to comfort themselves by affirming that 'machines' (using this generic term) are only poor, faulty copies of human brain capacities. Machines, they say, don't *feel*, they can't be affected. In other terms, machines, AI devices, robots, synaptic computers don't have a self (I will come back to this notion of self later). These discursive beliefs are commonly held, while at the same time we constantly hear about new explorations in brain simulation, artificial imagination, artificial creativity, the artificial capacity to improvise and even artificial sexuality.[1]

So are we just witnessing the emergence of new forms of copies? New forms of imitation, analogies, a new epoch of mimicry? Or do we have to bring to light a new concept of simulation? And is philosophy able to help us answer these questions? It is clear that philosophers are currently not answering the challenge and are not proposing a concept of simulation that would be able to profitably substitute itself for the traditional ones, all of which revolve around the act of copying. We lack an updated notion of mimesis that would adequately characterise the imitating power of artificial epigenetic systems. If we consider the most recent achievements in robotics for example, like those accomplished in Japan by Hirochi Ichiguro, we cannot say that these robots are just 'copies'. Even if the concept of *mimesis* has evolved through time, it has nevertheless remained attached to its ancient definition, which involves a determinate relationship between nature and art. There are at least two decisive moments in the history, or genealogy, of *mimesis*. The Platonic moment, and the Kantian one.

Plato's notion of *mimesis* means copy and reproduction. It entirely concerns the status of art – art being a specific branch of *tekhnè*. We have to distinguish, within *tekhnè*, between craft and art. The craftworker who is making a bed for example does not exactly imitate or copy a model, because the idea that serves as the model for such a making is directly imprinted in the craftman's mind, without any possibility for him or her to interpret it, or play or cheat with it. The artist, on the other hand, intentionally uses deceptive means in his or her production, and does this in order to blur the frontiers between the actual reality and its image, thus turning the idea, the *eidos*, into a treacherous copy. *Eidos* then becomes an *eidolon*, a simulacrum.

I think that many critiques of AI today unconsciously retain something of this Platonic conception. They see technological imitation as something voluntary, a delusionary production of replicas, and claim that the original, the natural, is necessarily superior, due to its authenticity in relation to its technological mimics. They think that cerebral epigenetic development, for example, remains absolutely incomparable with – and irreducible to – synaptic chips, neural networks or intelligent robots.

Kant's concept of imitation is certainly more complex, but still insufficient for settling our problem. In the first part of the *Critique of the Power of Judgement*, Kant interestingly affirms that fine arts must find their topics in nature but should not 'copy it' (Kant 2000: 188). Art undoubtedly finds its inspiration in nature, but it interprets it, reinvents it so to speak. This is the reason why Kant defines art as a creation of 'genius' (ibid.). Contrarily to a mechanical, purely technological process, art is understood as a production of freedom. A work of art is then no servile copy, plagiarism or counterfeit, but a 'free imitation', as he says in §47. Later this is followed by this puzzling declaration: 'nature must serve as a model not for copying (*nachmachen*) but for imitation (*nachahmen*)'. '*Nachmachung*' and '*Nachahmung*' should be then strictly distinguished from each other (ibid.), with *Nachahmung* designating a reproduction that is inassimilable to a mere copy. However, as we know, genius, for Kant, is a gift from nature: 'Genius is the talent (natural endowment) which gives the rule to art' (ibid.: 186). Through the artistic invention, it is in reality nature that interprets itself. We can conclude from this that art, for Kant, expresses nature's relation to itself. The word 'self' is important there. Art helps the creation of a self of nature. To the extent that artistic mimesis is a gift from nature, it exhibits the identity of nature. Art is the subject of nature. A natural artefact. An artificial naturality. Once again, this concept of imitation is by no means reducible to a copy or a simulacrum.

We can now ask if what Kant says about art can be extended to contemporary technology, and if there is such a thing as a technological *Nachahmung*. We won't find the answer in Kant, unfortunately. Kant comes to technique in the second part of the *Critique of Judgement*, but he precisely opposes technique to fine arts and to life. Because of the harmony and the plasticity of its structure and organisation, a living being seems to be a work of art in itself. It is 'as if' nature were an artist. A mechanism, on the contrary, is never plastic. It does not have an epigenetic development. In §65, Kant contrasts the functioning of a watch to that of a natural organism. Well assembled as they are, the different pieces of a watch do not have the power to repair themselves, contrarily to an organism. Technical objects are just *Nachmachungen*, copies of life.

Kant would therefore have considered synaptic chips and plastic computing processes as similar to watches, as mechanical *Nachmachungen* of the biological cerebral organisation. The problem is that if the internal regulation of the different parts of the watch is not the work of the watch itself, the internal regulation of current cybernetic processes precisely *is* self-induced and maintained, as is made visible in recurrent neural networks. We can then ask whether these new processes are not proving the existence of a relationship of technique or technology to itself? The emergence not only of a technical self, but of a *self of technique*? AI would then be said to exhibit the relationship of technique to itself through the *Nachahmung* of nature. An artificial self would be susceptible to emerge from such a relationship. A technological authentically mimetic self.

Therefore, if it is true that AI systems, deep learning processes and intelligent robots are clearly 'imitating' the human, or rather the natural biological functions such as epigenesis for example, we can't return to Plato's concept of mimicry to understand the meaning of this imitation. Neither can we consider that these artefacts are new versions of artistic genius, nor of the relationship of nature to itself. We have to go deeper, and wonder whether a new form of epigenesis exists, the epigenesis of an auto-affection of technique by itself. Just like nature mimics itself through art – for Kant – technology today mimics itself through nature, producing new mirrors for our brains.

Note

1. The Human Brain Project, a large ten-year scientific research project, established in 2013, coordinated by Henry Markram (from École Polytechnique from Lausanne), and largely funded by the European Union. It is the European version of the American BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies, also referred to as the Brain Activity Map Project) announced by President Obama in 2013, with the goal of mapping the activity of every neuron in the human brain using big data. The programme will develop information and communications technology platforms in six main areas: neuroinformatics, brain simulation, high-performance computing, medical informatics, neuromorphic computing, and neuro-robotics. Again, the goal in the end is to propose a complete and detailed cartography of the human brain: http://en.wikipedia.org/wiki/Information_and_communications_technology. The Human Brain Project will in part develop the results of another project, The Blue Brain Project, also founded by Markram at Lausanne in 2005. The simulations are carried out on a Blue Gene supercomputer built by IBM. Hence

the name http://en.wikipedia.org/wiki/IBM'Blue Brain'. Both projects are to move to the same place: Campus Biotech in Geneva.

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