Organisms

SAPIENZA UNIVERSITÀ DI ROMA

History and Science

Vol. 4, No. 2 (2020)
ISSN: 2532-5876
Open access journal licensed under CC-BY
DOI: 10.13133/2532-5876/17021

The Construction of the Genetic Order: A Short Critical History

Daniel Papillon [a*]

[a] *PhD, independent scientist*

***Corresponding author:** Daniel Papillon, Email: shrese@riseup.net

Abstract

Genetics, as all human activities, is a situated practice. Given its enormous cultural and epistemological influence, the young age of the discipline may be surprising—not even 150 years old. The creation of the science of transmission and production of traits in organisms responded to 19th century's epistemological needs in biology, as well as political and social developments: the transmission of characters and their variations throughout generations needed a new theory, the embryological development of organisms had to be explained, the unrest and disastrous living conditions provoked by the industrial capitalism and the colonial project in the West called for a reaction from the elites. The trajectory of genetics is one of permanent co-production between the different ontologies and practices it is situated in. As a science, it draws its legitimacy from the stories it tells (about the world or about itself), the interests it serves and the existing power relations it is part of. Given this background, the present work tries to shed some light on several aspects of the history of genetics that may help clarify its role and impact on our societies. The set of ontological and material transformations it underpins is referred to as the Genetic Order, and this is explored particularly in the context of the irremediable past and present association of genetics with eugenics, the construction of key notions such as heritability and the dichotomy Nature/Nurture, the enormous influence of cybernetics over biology and genetics after the second world war and the alliance between biotechnologies, genetics and neoliberalism in more recent years. One central notion that wanders throughout this text is that of control over bodies and life in general. This is illustrated by the recent explosion of the genomic prediction industry and its impact on contemporary subjectivities. In the end, it is a world of statistics, algorithms, predestination, risk management and control that the Genetic Order offers, echoing the hegemonic influence of the neoliberal cybernetic project where all that lives must be engineered, modelled, monitored, predictable and transparent.

Keywords: genetics, eugenics, history, genomic prediction, capitalism, neoliberalism, control, heritability, nature/nurture, cybernetics

Citation: Papillon D 2020, "The construction of the genetic order: A short critical history", *Organisms: Journal of Biological Sciences*, vol. 4, no. 2, pp. 69-97. DOI: 10.13133/2532-5876/17021.

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Introduction

"We are painfully aware that genetic science has, for more than a century, played a central role in producing the ideology that supports systemic racism. [...] We understand that we cannot simply disavow this history, because many of our field's fundamental concepts and approaches were established for the purpose of advancing eugenics, under the assumption of extensive racial differences within a social hierarchy."

Department of Human Genetics, University of Chicago, *Statement on Police Violence, Racism, and Genetics* (2020)

Few modern sciences have had such an impact on our ontologies (the ways we define what the world is made of) and on the materiality of our lives (e.g., the food we produce and eat, how we heal ourselves, our relationships with each other and with other organisms, how we conceive ourselves as humans) than genetics.

The trajectory of the science of transmission (heredity) and production (development) of traits in organisms is one of permanent co-production between these ontologies, these practices and the science itself. New imaginaries and new sciences, here seen as context and content, do not generally come one after the other, but co-create each other, as Latour reminds us (Latour 1993). Born—alongside the eugenics project—during the industrial revolution and the colonial project in the West at the end of the 19th century, matured throughout the first half of the 20th century (through the first World War, the explosion of agribusinesses, the rise of fascism in Europe, the horrors of the second World War...) and literally taking over the whole of biology in the second half of the 20th century (through molecular biology, genetic engineering and the influence of cybernetics), genetics has reached a point where its original shortcomings are biting back. Pichot is one of the historian of science who has shown with most clarity the epistemological failure of genetics in helping us interpret and understand life phenomena in a coherent way: "The theory is that heredity is the transmission of an ordered substance (DNA) that controls the organization of an organism. But as experimental results accumulated, the order of this substance became increasingly uncertain and its correspondence with the organization of the organism more and more vague. So much so that today there is practically nothing left, neither of this order nor of this correspondence." (Pichot 2003, transl. by the author). He therefore affirms that "genetics has no object, it only has a function." (Pichot 2001, transl. by the author). The interpretation of the world that genetics promotes has lead to changes that need to be looked at critically and challenged. The set of ontological and material transformations underpinned by genetics will be referred to here as the Genetic Order (GO). This GO presents several well known characteristics that will be further discussed throughout this article. One is Geneticization, understood as the "the ongoing process by which priority is given to differences between individuals based on their DNA code" (Lippman 1993) but it also refers here to the fabrication of DNA and the gene as cultural icons and god-like entities (Kupiec & Sonigo 2000; Nelkin & Lindee 2004). Another feature of the GO is its reductionist and mechanistic aspect, described by many authors, for example Lewontin (1991), Morange (2003) or Nicholson (2014a). Geneticization is therefore a cultural process that produces genetic essentialism (the DNA molecule perceived as our essence, our "truth within" that defines our identity) and genetic determinism (our DNA dictates our morphology, our health, our personality, our behaviors).

The main specificity of an ontology is that it is extremely difficult, usually impossible, to think outside of it. However, the past months constitute an example where events have taken place that were unthinkable only few weeks before that. I am referring here to the shift of consciousness and to the possibilities opened by the recent wave of unrest against police violence and systemic racism, particularly in the USA. An element of this shift occurred in university departments, for example, departments of genetics and human genetics, which were forced to react to the massive uprisings taking place in their cities (see the opening quote from the Department of Human Genetics in Chicago). One of the most interesting aspect of this reaction was the acknowledgement of the contribution of genetics to systemic racism and its epistemological connection to the eugenics project. This shift has to be understood also in the context of the global Covid-19 pandemic, which had already raised similar issues. Not only, and unfortunately unsurprisingly, poor and racialized sections of the population are hit much harder by the virus, but dominant classes' engrained eugenic beliefs (and readiness to mass sacrifice vulnerable populations) were suddenly brought to light notably through the push for "herd immunity" or the discussions of "hospital resources allocation". Therefore, a perhaps not-so-expected consequence of the Black Lives Matter movement is the emergence of a decisive counterstory against the official narrative that genetics' link with racism and eugenics is a thing of the past, solved after the second world war, and was the deed of some "bad apples" in the field. As an illustration, and mirroring the removal of slave owners and colonial figures' statues in many countries, genetics departments and other institutes are slowly changing their names or the names of their buildings that were related to famous eugenicists, in some cases after many years of dismissed and ignored local activism to achieve the very same thing (for example in University College London, UK).

Given this background, what I hope my contribution to be is to bring some light on several aspects of the history of genetics that may help clarify its role and impact on our societies. Drawing from the work—published in English—of critical biologists (Lewontin, Kupiec, and Noble) and social scientists (Nelkin, Lindee, Keller, Bliss, Cooper, and Rouvroy) as well as from untranslated French literature (Pichot, Bonneuil, Sonigo, and Lafontaine), this paper originates from the established understanding that genetics, as any other science, has been influenced by the epoch, the political context and the world views it has been practiced in, and has influenced them in return. In other words, genetics is a *situated* practice. One central notion that will run throughout this text is that of *control*: genetics as a recurrent project of control over (human) bodies, (human) evolution, the living world and the planet in general. This is explored particularly in the context of the irremediable past and present link between genetics and eugenics, the enormous influence of cybernetics over biology after the second world war and the alliance between biotechnologies, genetics and neoliberalism in more recent years.

1. Origins and structuring

1.1. Origins

There is no need to describe at length the main scientific theories about the natural world of the 19th century, other authors have described the birth of biology as an independent science and the paradigms shifts accompanying it (Kupiec & Sonigo 2000; Mayr 1982; Morange 2017; Pichot 1999). The 19th century biology inherited a predominantly fixist, essentialist, mechanistic (to be more exact, machinistic) and reductionist view of the living world. Species would reproduce their form, or essence, to the identical throughout generations, and the organism itself, perceived as a Cartesian machine, could be entirely understood through the study of its independent and separate parts. The strength of this mechanistic view of life is that it provided a good description and understanding of how an organism works and its "internal" causality mechanisms. Its weakness is that it could not explain developmental (under preformationism, the mode of generation associated with mechanistic biology, development does not need to be explained as organisms are always-already entirely present) nor evolutionary processes (Pichot 1999).

In the terminology of Pichot (2001), the reproduction of the same exemplified by preformationism is called the reproduction-generation mode. He points out that the identical reproduction of organisms is an ahistorical conception of life: if nothing changes, there is no history. When the living world is seen as ordered and fixed, then what biology needs to explain is the variation between individuals. A way to solve the dilemma about observed differences between beings was to establish a distinction between specific differences (the ones between the different forms/essences/species; the "real" differences that have a significance) and accidental differences (they do exist between individuals but they do not really matter for the understanding of the organisms). In this system of thoughts, the oppositions essence/existence and species/individuals are associated with these specific/accidental differences. Pichot partly explains the longevity of the preformationist ideas for theological reasons, as it complements perfectly the finalist and deterministic way of understanding organisms and the world: the organism's plan (its form or essence) pre-exists to its existence, and the unfolding of its life is determined by an external cause (Pichot 1999).

During the century, transformism (or evolutionism, the idea that species have evolved throughout history) will be more and more widely accepted. Fixism and essentialism will be slowly replaced by a historical, processual understanding of life (Kupiec & Sonigo 2000; Mayr 1982). One of Darwin's contribution was to put forward variation as a fundamental property of organisms, and he asserted that these variations were transmitted from one generation to the next. According to Kupiec (2019) and Rosanvallon (2012), this is a paradigmatic change. First, this is a blow to the idea of a well "ordered" living world. Second, if variation is a characteristic of organisms and can be transmitted, therefore, what needs to be explained from then on are the similarities between beings (and not their differences). One of the main question of biology emerges then, the one about the "reproduction of the similar", or in other words: what are the biological mechanisms that explain the similarities between parents and offspring?

This new historical and processual vision of life provoked epistemological issues in biology: one was the need to articulate the physico-chemical explication of the organism with a historical explanation and another was the questioning of the notion of species. Because of the latter, the concept of species could not refer any longer to eternal and separate entities. Indeed, as Kupiec and Sonigo (2000) propose, a "species" is more of an instant (like a photograph), whereas life is actually a historical process, the genealogy of lineages over time (a sequence like a video). Mayr (1982) insists on the importance, for the future establishment of genetics as a discipline, of what he calls "population thinking" (focusing on the diversity and variations between individuals within a population, rather than the essentialist thinking that focuses on the differences between species) and, from there, the necessity to compartmentalize and separate all the visible characteristics of organisms into individual traits. Therefore, the notion of the *specific form* was gradually replaced by the notion of an organism as a sum of individual characters, of which only a part are transmitted (even though it was still not known how). These characters will be called hereditary characters for two reasons: the previous observation of a kind of vertical transmission of exceptional characters such as hereditary diseases, and the construction of an equivalence to the legal/economical notion of heredity (transmission of wealth and properties, accumulation of possessions throughout generations...). Heredity, as a substantive, is imported to biology at this moment (Pichot 2001). This importation of concepts from the legal/economic field in biology is a reminder of the famous influence of Townsend and Malthus on Darwin for the formulation of the natural selection theory (which itself will influence back social sciences through social Darwinism) (Pichot 2000), illustrating this constant back and forth movement between natural sciences and politics.

Heredity, therefore, is the answer to the first epistemological issue mentioned above: the necessity of a historical component in the explanation of the organism. To have continuity between the generations, there needs to be a transmission of characters (and their variations). This is, in Pichot's terminology, the transmission-generation mode (Pichot 2001). Mayr (1982) describes the trajectory of ideas at the turn of the 19th/20th centuries that lead to the establishment of genetics, and especially the influence of mechanistic and reductionist thinking as well as physics methodologies. It is fascinating to follow this gradual narrowing down of the scientific focus from the cell (the Cell theory), to the nucleus then to the chromosomes (the Chromosome theory) and finally to the DNA and the gene, revealing the obsession for the search of "the" corpuscular unit of genetics (which was thought as the unit of heredity or the unit of development depending on the context and the specialty of the scientists involved). As the physiology of reproduction is better described, another central question of biology emerges: how can complex organisms made of so many different organs and types of cells can be produced from a single cell?

Prior to preformationist ideas, heredity was mostly understood as the transmission of entities (humors or materials) "collecting" the different parts of the body, or, as Pichot puts it, a kind of "representative sample" transmitted through the generations (Pichot 1999). In early 1890s Weismann, a German biologist drawing from the "representative sample" notion, will establish the bases of genetics as a science with his germ plasm theory and the germ/soma opposition. The germ plasm is a substance representing the germinal line, it is the structure that bears the heredity and is responsible for the transmission of characters. The soma is the rest of the body, it does not transmit anything. The birth of genetics relies therefore on a fundamental and irreducible new separation: between the organ of heredity and the rest of the body. This is reflected, in Weismann's theory, in the opposition between hereditary (the characters contained in the germ plasm and that can be transmitted) and acquired characters (that are related to the soma and that cannot be transmitted). Genetics becomes the science that studies the transmission of these hereditary characters. Keller, reflecting on these shifts, writes about internalization and substantiation (Keller 2010). The substantiation is the notion that what is transmitted is a substance, a material entity made of particles that resides in the body. This particulate form of heredity will be discussed further in the next part. The notion of internalization is summarized by Moore commenting on Keller (2010): "the word 'innate' came to be associated with heredity and the word 'acquired' came to be associated with the environment (i.e., that which is external to the body). This internal/external dichotomy allowed nurture to be disjoined from nature" (Moore 2012). The emergence of the new ontological alignments internal-innate-hereditary and external-acquired-environment will define genetics. Pichot (1996) clarifies the importance of this transition. Before Weismann, the fundamental opposition was between the acquired and the inherited characters – but all were inheritable, or hereditary. The fundamental opposition of the nascent genetics is different, it is the one between the in-principle-hereditary characters (be they inherited or not) and the in-principle-non-hereditary characters (acquired). This may seem very subtle as a difference but the implications are significant. It is indeed very difficult to clearly define what is a purely in-principle-hereditary character (this is further discussed in section 3.1).

With his theory, Weismann manages, according to Pichot (1996), to bring together the ideas of preformation as well as epigenesis (the ancestor of modern embryogenesis and the mode of generation associated to vitalism, the main rival theory to mechanistic biology at the time). Indeed, although it does not contain a pre-formed being, Weismann's germ plasm is supposed to contain the instructions of its formation. A digitalization before its time. Moreover, in this theory, the construction of the organism, while pre-written, is effectuated by epigenesis. The germ plasm acts as the material form of a "memory", a vision that will lend itself particularly well to the cybernetic framework 50 years later. Thus, by reconciling the two dominant theories of biology Weismann provides a framework that will satisfy the majority of biologists, a kind of neo-preformationism (Mayr 1982; Pichot 1996). The germ line would therefore be the only part of the organism that shows continuity in time; it is immortal, therefore timeless. Drawing from Weismann, geneticists will slowly deny any influence of the environment on the germ, making heredity a purely structural and a-historical phenomenon (Bonneuil 2015a). According to Kupiec, Weismann (together with De Vries) is responsible for a major leap in the foundation of genetics: introducing dualism into the theory of heredity by postulating that macroscopic traits are determined by the structure of microscopic elements, thereby giving the theory an Aristotelian structure (Kupiec 2019). Despite the upheavals of evolutionism in the 19th century, the organism is once again detached from its history and its environment – it is back to "order". In *Le siècle du gène* (2015a) Bonneuil argues that the emergence of this vision echoes the appearance of the mass production of objects during the industrial revolution. Previously, the value of an object was strongly linked to its history, its origin, who made it, by what technique, where, under what conditions... With mass production, the link between an object and its origin disappears, as does the link between an organism and its history.

Another explanation for the success of Weismann's theory, and its perpetuation in current genetic essentialism, lies in the idea of immortality. What could be the reasons explaining the powerful resonance of this idea of immortality with this particular era? The first that comes to mind is again the link with industrial capitalism. What is a business, a corporation? It is an entity whose existence can last a much longer time than that of the human scale, an entity whose hosts (owners, shareholders) are just passing through, although they must act in the "interest" of the company (Waters J, personal communication). The similarity becomes even more striking when one considers the familial character of certain companies, inherited from generation to generation within "entrepreneurial" dynasties. This echoes Lewontin's work on the adequacy between the mechanistic and reductionist ontology with the individualist view of the world (Lewontin 1991). With the development of industrial capitalism, and the concomitant change in social organization, a completely new vision of society emerged: the individuals as the primary and independent entities (in a permanent competition between themselves); society as a consequence, not a cause, of individual properties; organisms determined by internal factors, the genes ("the modem form of grace"). Just as genes determine individuals, individuals determine communities—thus, genes make cultures and determine societies: "We have become so used to the atomistic machine view of the world that originated with Descartes that we have forgotten that it is a metaphor. We no longer think, as Descartes did, that the world is like a clock. We think it is a clock." (Lewontin 1991)

Genetics, the actual name of the discipline, was then coined by Bateson in 1906 and Weismann's theory was quickly formalized with the creation of the terms gene, phenotype (first the average apparent type of a population but now defined as the set of the apparent traits of an organism) and genotype by Johannsen in 1909 (Mayr 1982).

1.2. End of the 19th century, genetics under the influence: eugenics

During this pivotal period between the 19th and 20th centuries, several core concepts in genetics emerged. One of the scientist most representative of these changes is Galton and the main thrust of this early bubbling is the creation of, and the articulation between, the notion of heritability and the Nature/Nurture dichotomy. Both ideas were associated to the political project of eugenics, a project aimed at controlling human populations and their evolution. One of the priorities of genetics became then the "improvement" of the human population. At the root of all this, as narrated by Keller (2010) was Galton's concern about how to stop the ongoing "degeneration" of his nation and ensure that more "geniuses" are produced. Old ideas that will flourish in the context of the emerging genetics and Darwinism. Of course, this "concern" must be understood in the light of the particular historical conditions of the late 19th century: the explosion of industrial capitalism and the massive urbanization (i.e., the expulsion of thousands of humans from the countryside to the cities) leading to horrendous living and sanitary conditions (the "degeneration" that provoked anxieties in Galton and many others), the enormous workers' movements and revolts, the formulation of the communist and anarchist theories, the beginning of feminist struggles, the colonization project and the conflicts it provoked, etc. The elites were worried about so much upheaval and resistance. Here Royer's intervention about the essence of capitalism as a "project against life" offers a striking perspective (Royer 2017). He argues that the immeasurable anthropological transformations of the 19th century in the West were marked by the triple alliance between the new mode of scientific production, the thermo-industrial capitalism (coal then oil) and the formation of the modern nation-state as we know it. According to him, this alliance is at the origin of what is going to become eugenics, which will constitute the ideological basis of a new mode of social engineering characterized by the transgression of the (mass) murder taboo. All of this being legitimized by the discourse of the new mode of scientific production built throughout the 19th century, the "Science with a capital S" as Carnino calls it (Carnino 2015). Eugenics is a true mass movement. At the time, most geneticists were eugenicists, including progressives, and the importance of promoting and creating a new human was widely accepted (Pichot 2000). From Royer's perspective, the eugenics project accompanies the West and capitalism towards the realization of their essence, a project of total death, embodied by the two major and concomitant events of the atomic bombs launched on Japan and the Holocaust (Royer 2017).

Pichot's perspective is that, in short, eugenics can be considered as the natural continuation of Darwinism—although not necessarily of Darwin himself (Pichot 2000). As mentioned, the industrialization associated to the massive urbanization lead to the multiplication of diseases and ill-health in big cities. For many established scientists of the time, this was interpreted as a sign of the degeneration of the occidental civilization. From 1859 and the publication of *On the Origin of Species*, Darwinism provided a "scientific" explanation to this phenomenon: this multiplication of diseases and social problems were not due to social conditions, but to the absence of natural selection in human societies. The solutions proposed were twofold: social Darwinism (the liberal *laissez-faire* promoting the survival of the fittest, or rather the elimination of the inferior, without any state intervention aiming at supporting the most vulnerable) and eugenics (a social selection driven by state intervention to replace natural selection) (Pichot 2000). This process went hand in hand with the construction of Science as the only institution able to help improve humanity (to advance it in the direction of betterment and happiness and progress; Carnino 2015) leading to mass sterilization policies targeting "criminals" (in practice, those considered mentally ill, the poor, the racialized people and other non-citizens) in several countries (for example in the United States or Sweden, where they will last until the 60s and 70s) and, eventually, to the Nazi exterminations (Pichot 2000; Royer 2017).

1.2.1 The construction of the Nature/ Nurture dichotomy, part I

A first step in the establishment of eugenics as a discipline is the construction of the dichotomy Nature/ Nurture. It is Galton who, in 1874, will inaugurate the conjunction "Nature and Nurture" as fundamental in genetics (Keller 2010). Previously, according to Keller, the ideas of Nature and Nurture were present but they were neither considered as fundamentally distinct categories nor in opposition. Keller uses the analogy of the seed (Nature) and its culture (Nurture) to describe the ontology of the time: one cannot go without the other in the production of an organism. The semantic operation of Galton's locution "Nature and Nurture" and then quickly "Nature versus Nurture" is not innocent. Indeed, two terms can only be brought together if they can first be considered disjointed and separate. Their coming together and their interaction imply their separation. Their separation implies that they can be studied and measured independently, compared and debated...

A central element of this new construction is the substantiation already mentioned: heredity is carried by a corpuscular substance (made of elementary, molecular and independent particles) that resides within the organism (although, in a way, it is separate from it) and is transmitted through the generations. The contributions of Mendel, Weismann and Galton were central to the double shift from blending (holistic) and *soft* inheritance to a particulate and *hard* inheritance (see Mayr 1982 and Bonneuil 2015a; this double shift is called "discretization of heredity" in Pichot 1999). This is exemplified by the comparison between Darwin's and Galton's view of heredity. Darwin, along many others at the time, accepted the particulate form of inheritance (he called these particles *gemmules*), that is to say he did not believe that heredity was a blending process of two complete organisms where the offspring was a mix of its parents (a holistic view). However, he considered that they were still influenced by the environment, still malleable (*soft*). With Galton, these particles will become fixed, discrete, independent and invariant entities (*hard*, see Keller 2010 and Mayr 1982). Nature and Nurture are then separated, among other things, by the elements of which they are composed of. Galton will establish for the following decades that : 1) the elements that make up Nature (the innate, or genetic forces) are the elements of heredity; 2) the elements that make up Nature are in competition with the elements that make up Nurture (the acquired, or environmental forces), this is the shift from Nature and Nurture to Nature versus Nurture; 3) the elements that make up Nature are, in the last resort, always more powerful than the elements that make up Nurture (Nature-first approach) (Keller 2010).

How does this theorization serve the eugenics project? This "discretization of heredity" and the creation of the Nature-Nurture divide were, I would propose, a necessity for the eugenics project. Both were framed as such and were essential for the hegemonic role of genetics in shaping our ontologies. Below are preliminary ideas that would of course need further exploring.

First, Keller (2010) suggests that in order to understand the origin and persistence of the separation and opposition between Nature and Nurture, it would be possible (or even preferable) to set aside eugenics. I would however propose that the construction of the categories Nature and Nurture is not distinct from the eugenics project that produced them. Neither is their hierarchization. Let us for a moment step aside towards Delphy, who offers a framework for interpreting the processes of creation of categories and their hierarchization (from a feminist but also anti-racist point of view) (Delphy 2008, 1993). She assumes that categories (such as male/female, black/white) do not exist in the "natural world". Divisions are social conventions, always created by humans, which order the materiality of the world (this echoes the debate around the concept of species between essentialists and nominalists). In the case of the male/female categories in humans, Delphy suggests that, contrary to the usual view, sex (biological or natural) does not precede gender (social or cultural): gender precedes sex. In other words, gender hierarchization (the patriarchal system) is not a phenomenon resulting from categorization but precedes it (and then the two phenomena reinforce each other). Hierarchy is at the origin of categorization. It is because the justification of a system of domination is necessary that categorization criteria, usually sought in the body/nature (naturalization), are established as universal and timeless. For Delphy, a similar mechanism is at work in the scientific justification of racism. The creation of the categories Nature and Nurture by the eugenics project could be interpreted in the same way. It is because there was a eugenic project that required a framework of thought in which the differences between humans had to be biological and inherited that the dichotomy was constructed in this way: a hierarchization and separation of Nature and Nurture (with Nature as the primary force in the transmission and formation of characters).

Second, to assimilate the elements of heredity only to Nature is to give natural scientists full responsibility for the study, interpretation and manipulation of the transmission, the development and the distribution of heritable traits, since Nature is the domain reserved to hard experimental sciences and no other.

The third line of thought is related to the understanding of the emergence of eugenics as one of the consequences of the scientific revolution in biology in the 19th century. Indeed, modern science had fundamentally been based on an opposition between the object being studied (nature, animals, plants etc.) and the subject (the one who conducts the study, i.e., humans). With the emergence of evolutionism and the increasingly clear positioning of humans within animals (starting with Linnaeus up to Darwin), the object/subject boundary is less and less clear. If humans are part of the animals, they can therefore be the object of science itself and its experiments (Rey 2015). Can we interpret the emergence of the Nature/Nurture dichotomy as a response to the blurring of the object/subject boundary after the Darwinian paradigm shift? It is not clear, but the naturalization of the elements of heredity in humans has undoubtedly provided the justification for the use of breeding and selection techniques (applied in the past to plants and non-human animals) on humans. Moreover, the closer groups of humans are associated to Nature (women, lower classes, mentally ill, enslaved, colonized...), the more they are seen as "objects" and the target of the eugenics project.

Fourth, the historical process of discretization of heredity played a major role in the creation of imaginaries echoing the eugenics project. Indeed, to consider the organism as an arrangement of independent, particulate traits, recombinable at will, responds to the demiurgic promise of human control over evolution (Bonneuil, 2021). For De Vries, one of the founders of modern genetics (although not a supporter of eugenics, see Pichot 1999), only "[s]uch an hereditary character, isolated from the rest, can now become the object of an experimental treatment." (De Vries 1889, cited in Bonneuil 2021). Pichot suggests another argument: during the first decades of the 20th century, through the discretization of both the phenotype and the genotype, the particles of heredity lost their "physical substance": they became mostly defined through the traits (or rather, the mutations) they corresponded to. This was a complete inversion of the way to study heredity: from a physical explanation (starting from the genotype to explain the phenotype) to a "mutationist" explanation (starting from the phenotype to explain the genotype). Pichot qualifies this second approach as "phenomenist" and statistic, a kind of "semiology" (an "interpretation of signs"), and argues that because of its practicality, all sorts of characters ended up being interpreted in this way, including psychological and social ones. Moreover, because these traits were usually identified through mutations associated to "monsters" or pathologies, this created an obsession of the "good" and "bad" genes (Pichot 1999). Using Darwinism, as mentioned above, the "proliferation" of these bad genes was interpreted as the consequence of the disappearance of the process of natural selection in human societies, leading to eugenics.

Finally, in this vision centered on genetic material, the body of the organism is excluded (see Nicholson 2014b). Organic complexity, the interactions between different biological elements, or between the biological and the social/environment... all are gradually being left aside in the analysis of heredity phenomena or the formation of phenotypic traits. The ontological scale, the one in which the explanation of the living is found, becomes that of the genetic factor, the molecule. In other words, since the traits of humans are mostly genetically inherited, society and culture have only a very limited role in the unequal distribution of these characteristics (in short, inequalities are "natural"). Politics and social or collective action are then of little use, since what counts in explaining who we are is the individual lineage, i.e., the traits directly transmitted by our parents. What would therefore allow us to "improve" our situation is the positive selection of "superior" natural characteristics or, and this has been the main methodology of eugenics, the negative selection of "inferior" characteristics (i.e., the elimination or sterilization of people with these traits). This exclusion of the body, associated with reductionism and eugenics, echoes and contributes to a deep, ancient and general affect characteristic of the West: the fear of the body (see section 3.3.1).

1.2.2 The construction of the notion of heritability, part I

Under the influence of the eugenics project, and following the ontological alignments identified by Keller (2010), the central question of genetics will then become the study and measure of the respective effects of Nature (innate) and Nurture (acquired) in the formation of traits. This question is still central today. These traits, in humans, will include the different parts of the body as well as personality traits and behaviors (like intelligence, a very early obsession of geneticists and eugenicists) and they are all conceived to be produced, entirely or at least partially, by the elements that make up natural forces. It should be reminded that there is nothing neutral about the choice of this research methodology. It can be partly explained because of the influence of physics and its methods on biology. Louart (2018) reminds us how much the direct transfer of these methods from one discipline to the other is inadequate (because of the necessity of simple and isolated objects from their environment, of the total control of parameters etc.). On another hand, underneath the differential measures of Nature and Nurture effects on traits development is a desire to develop ways to intervene on human reproduction and the necessity to define scientific criteria to justify and determine who will be able to reproduce or not. To measure the relative importance of genetic, the notion of heritability is created. Galton and others will use twin studies for this purpose (see Keller 2010). This era also marks the development and standardization of intelligence quotient (IQ) tests by the eugenics movement (for the control of reproduction of the feeble-minded and others considered "deviant"). The link between the measure and the studies of IQ's heritability and the science of eugenics is therefore historical, structural and fundamental. In 1918, Fisher, one of the founders of population genetics (also a eugenicist), proposed, according to Keller (2010), the most significant reformulation of the issues raised by Galton: 1) the question of causality between genetic elements and traits should be formulated in terms of differences in traits, and not on the basis of the traits themselves; and 2) there is a need to shift the analysis of heredity from individuals to populations. Until today, genetics is still struggling with this reformulation and has not yet escaped the political and linguistic traps that surround it. Since that founding moment, there has been a perpetual confusion between causality and correlation, causality and perturbation, individual and population, transmissibility and heritability, character and character variation etc. All of this will be discussed in more details in section 1.3 and 3.

But let us stay a moment longer on the hold of the eugenic ideology on genetics and biology at the beginning of the 20th century. It is worth mentioning the new obsession of the time: the genetic purity of beings. Genetic purity, i.e., the establishment of a lineage coming only from an individual and presenting no variations of the studied trait throughout generations, becomes both a quest and a standard of knowledge on heredity (Bonneuil 2015a). "Pure" genetic lines are established for flies (the fruit fly, a model animal for the study of the transmission of traits), cereals, yeasts (for beer), vaccines, etc. Bonneuil (2015a) recounts very clearly the ways genetics followed, supported and encouraged the entry and rationalization of living organisms in industry and agriculture (most of the main geneticists of the time were deeply associated to the agribusiness). Genetically stable, predictable, reproducible and calibrated life forms are produced in connection with the industrialization of the western world. At this time, the gene (as an abstract unit for the transmission of hereditary traits) is thought of as an inert, selectable and storable brick. As it is carried by chromosomes, it is therefore present only in the nucleus of the cell, which is then perceived as the control center of the organism, echoing the division of labor of the major industries of the time. Bonneuil (2019a) is also exploring another interesting line of research. This set of properties attributed to the gene feeds a vision of organisms in terms of genetic resources (which will lead to the notion of biodiversity) where they are perceived as a catalogue of properties that can be classified, hierarchized, exploited and "conserved". With respect to the link between the agribusiness and eugenics, it is interesting to note that in the 1930s, the Nazis began by banning plant seeds deemed "unproductive or susceptible to disease" (Bonneuil 2015a).

1.3 Genetic structuring and development

One mythical figure of genetics that has not been mentioned yet is of course Mendel and his famous laws of heredity (formulated in the 1860s) which, because they were established from very carefully selected characters and organisms, served mostly as counterpoint to all the exceptions that were later observed. This sequence of the history of genetics has been extensively covered, for example by Mayr (Mayr 1982) or, more critically, by Kupiec (2019) or Pichot (1999). From the "re-discovery" of Mendel's work in 1900 and during the first half of the 20th century, genetics developed in different branches (population, physiological and formal genetic). Genetics, from its very foundations, is therefore very heterogeneous in its methods and in the epistemological status of its components—one of the causes of the inability of genetics to become a "proper" science (Pichot 2001).

The beginnings of formal genetics (around 1915) focused mainly on locating mutations on the Drosophila chromosomes. The American biologist Morgan and his team (the main actors of this branch of genetics) worked frantically to map hundreds of mutations. Their laboratory infrastructures testified to a very profound evolution and scaling up of scientific practices, mirroring the general industrialization of the time. For Bonneuil (2015a), this is part of the "revolution of control" and the *systematic management* that was taking place in the large organizations and industries at that time, which inaugurated new forms of information management and biopolitics. This obsession with mapping will manifest itself again later with the hysteria of DNA sequencing, genomics and post-genomics. Morgan inaugurated in genetics the confusion between modelization and theorization, where the repetition, auto-confirmation and accumulation of experimental data constitute the basis and the aim of all inquiries (Pichot 1999). One might think that mapping is a neutral endeavor. It is, after all, only a matter of measuring, deciphering, observing, indexing, and representing a phenomenon in a graphic form. And yet, as The invisible committee reminds us in a fulgurant way: "One never maps a territory that one doesn't contemplate appropriating" (The invisible committee 2015). This interpretation is shared by Nelkin and Lindee: "the apparent precision of a map may make invisible the priorities and interests that shaped it. As forms of knowledge, all maps ... are the product of cultural choices." (Nelkin & Lindee 2004). What is represented, and how it is represented on a map, is as much a choice of visual power as it is a choice of persuasion and appropriation. A map is not an objective representation, it is contextual: "Mapping is the process of claiming territory—that was its historical purpose and it remains so today in molecular genetics. The 'commons' of human heredity has been divided up among the mappers, and the human genome is essentially, entirely patented..." (Nelkin & Lindee 2004). This is one of the fundamental thrust of genetics, established at the earliest stage of the discipline: cataloguing and mapping genomes for the purpose of appropriation. If there is one example of obscene clarity about the role of mapping in the conquest of territories, it is the colonial situation in Palestine. Against the mapping of the colonial power, Said proposed a counter-mapping, a counter-cartography of resistance: "In the history of colonial invasion, maps are always first drawn by the victors, since maps are instruments of conquest. Geography is therefore the art of war but can also be the art of resistance if there is a counter-map and a counter-strategy." (Said 1995). Echoing concerns about contemporary genetic essentialism, could we imagine a counter-mapping of the human genome?

Another contribution of Morgan and his team is the consecration of the conflations already mentioned: between the study of a character and the study of the variation of a character, between the population and the individual scale and between statistical measurement (correlation) and causality. Pichot tells us that the methodology of Morgan's school is part of the legacy of the role of hereditary diseases on the development of genetics, when they were used to establish the notions of hereditary characters and heredity, introducing a conceptual mistake. Indeed, a disease is not a biological trait, it is the alteration of one or several biological traits. The conceptual error (that of confusion between character and variation in character) will be reproduced on an industrial scale with Morgan's studies of the mutations/deformations of Drosophila. For example, his team claimed to study the heredity of the "white-eye" character, but in reality they were studying the heredity of a mutation that would cause a disease in which one of the most obvious symptoms were white eyes. It is therefore the study of the heredity of an alteration (amongst other alterations) of a trait, not the heredity of that trait (Pichot 2001). Keller shows that this conflation occurs through a three-step process: 1) the cause of a phenotypic difference observed in a population is attributed to a putative gene mutation, 2) the presence of a putative gene mutation signals the presence of a gene, and 3) the responsibility for the formation of that trait in an individual is attributed to that putative gene (Keller 2010). The existence of the mutation and the associated gene are, at the start, only hypotheses of Morgan's method. There is a shift from what begins as comparative genetics (the comparison of different phenotypes) to individual genetics (the study of the role of a particular gene in the production of a particular trait). Similarly, Mayr notes that “Galton’s worst mistake ... was that he transferred what was statistically true for the genotype as a whole to the mode of inheritance of individual characters.” (Mayr 1982). The operation is so inherent to genetics methodology that it is generally invisible. However, this is very significant. To consider the gene simply as a *difference maker* (producer of variations) is not enough for the hegemonic project of genetics, it must also be a *trait maker* (producer of phenotypical characteristics) in order to have the power to act and create life, justifying its mobilization to control (human) evolution (Keller 2010). In other words, at the early stages of genetics, the notion of direct and unequivocal causality between a gene and a trait is essential to the justification of the eugenics project. Through the methodology developed by Morgan, genetics is enshrined as a science of the differential: it will henceforth focus of studying alterations, mutations and differences (the mutant type) in relation to a predefined norm (called the “wild type”). This is the distinction between “differential heredity” (the heredity of a difference, of the modification of a trait by mutation) and “absolute heredity” (the heredity of the actual trait) drawn by Pichot (Pichot 1999). It is therefore not by accident, or because some geneticists are ill-intentioned, that genetics is often used to define norms (natural and at the same time, because of its political aspect, social). This is its very essence, its methodological necessity and its way of constructing the world.

Between the 1930s and 1950s, the main story of modern biology emerged: the synthetic theory of evolution (STE or Modern Synthesis, also sometimes called neo-Darwinism). It is presented as a reconciliation between the young genetics and Darwinism. It is a theory of evolution centered on the gene (and later on the Genetic Program), reductionist, deterministic and that deepens the direct link between genes and traits and the exclusion of the environment (both the outside of the organism, the inner environment and even the composition of the gametes) (Noble 2015). Newman also notes that the STE theorists consciously set aside certain aspects of Mendel’s and Darwin’s work that were embarrassing to neo-Darwinism, but that will re-emerge throughout the 20th and 21st centuries (Newman 2013). This is the case for example of saltationism, rejected in favor of gradualism (see Mayr 1982). Gradualism is the idea that evolution takes place through a slow and regular accumulation of mutations causing tiny variations, selected as they go along when they give a certain reproductive advantage to individuals in a certain context (a reminder of the idea of the progressive accumulation of capital and wealth). The other aspect is of course the already mentioned dismissal of *soft* inheritance for a *hard* conception of heredity that will be perfectly complemented by the notion of the DNA molecule as independent, isolated from the outside and with a “perfect” replication system.

2. The construction of a hegemony

2.1 Cybernetics and genetics, an all-encompassing imaginary

The 1940s saw the birth of cybernetics, a science created by a group of mathematicians, logisticians, biologists, anthropologists, engineers, etc. One of their main goals was to try to forge a “theory of the mind” to understand and model how the mind, and therefore the brain, works. The analogy between the brain and the computer took root, nourishing both our perception of the brain (and by extension of organisms) but also, in turn, the proto Information technologies (IT) industry. Generally speaking, cyberneticists were very invested in the development of technologies and a large proportion of them had links with various industries, IT but also the military complex (the early work of cyberneticists in the 1940s is directly related to the Second World War and the development of weapons, notably prediction tools, for the United States’ army). Cyberneticists eventually worked towards the modelization of a large number of cognitive, biological and social processes through mathematics and computer science. Concepts such as information, signals, networks, interactions and feedback loops acquired new fame. Cybernetics is therefore an essentially mechanistic science that tends towards a complete modelling of all biological and social phenomena. A central political aspect of cybernetics was its emergence as a science of *government* in response to the existential crisis experienced in the West in the first half of the 20th century, an ontological crisis stemming from the two wars and their respective atrocities, added to the major upheavals in the mathematical and physical sciences—a veritable crisis of modernity (Lafontaine 2004; Tiqqun 2020). Cybernetics was constructed in relation to a new need for order and certainty in the natural and social sciences, to an active desire for a new totality. By responding to the necessity of the times, "the metaphysical problem of creating order out of disorder" (Tiqqun 2020), it became a science of prediction, control and management, terrified by all that is unpredictable, i.e., life itself. In other words, cybernetics went beyond the modelization and mapping of territories (be they bodies, societies or anything else) to a project of (re)building these territories according to the constructed map. Last aspect of this crude summary of the discipline: cybernetics gave a central role to the concept of information. Not only did it reduce any problem to an information problem (and its communication), but it also worked stubbornly towards the idea of a transmission process that would neither alter the information being transmitted nor cause "background noise" (Tiqqun 2020). Lafontaine refers to an epistemological reversal of the interiority-exteriority axis where the interiority and substance of studied objects are no longer relevant to science, only their exteriority (the patterns of their relations and communications with the outside). For her, cybernetics is at the origin of an Informational paradigm, in which information and its communication is constructed as a response against the world tendency towards entropy and disorder. She traces the genealogy of this paradigm and shows that it has influenced most sciences throughout the second half of the 20th century: structuralism, ecology, anthropology, psychology, post-structuralism and of course biology, molecular biology and genetics (Lafontaine 2004).

At the same period, a new theoretical framework for biology emerges. This is imagined in 1944 by the physicist Schrödinger, who, echoing the question of "creating order from disorder", conceived heredity as the transmission of a physically ordered substance (Schrödinger 1944). According to him, the order of this substance commands the order of the organism, so there must be a correspondence between them (what he called a "code"): a microscopic specific signal (a pre-established original order) produces the macroscopic order of living organisms. For Schrödinger, the chromosomes constitute this substance and are both a law/code and a power of execution; they are the architect's plan and its execution by the craftsman. Schrödinger pointed out that his thesis of such an order required special physical laws for living beings. Indeed, Schrödinger's fundamental idea was that biological systems are of a different nature than physical systems (see Pichot for a summary of Schrödinger's contribution to the ideas around heredity, Pichot 1999). As pointed out by Kupiec, this principle of the biological macroscopic order originating in a microscopic order is the opposite of physics, which is able to comprehend the macroscopic order of matter from a microscopic disorder (Kupiec 2009).

After Avery's work (1944) suggested experimentally that the DNA is the support of heredity, and especially after Franklin, Watson and Crick's discovery of the structure of the DNA molecule in 1953 (the work of the former was kept invisible for many years), Schrödinger's conception became, with some accommodations, the theory of the Genetic program in the early 1960s (see Mayr 1982 and Morange 2003 for more details on this period). Thus began, as Bonneuil (2015a) calls it, the period of the gene-program, or the gene as "chief planner and factory cell engineer". Again, an imaginary in sync with the global economic system of the time. The gene is then seen both as a DNA segment and an informational molecule, and heredity is its message. In the purest Fordist logic of the time emerges the Central Dogma (Crick 1958). Although the Dogma's formulation is a little more subtle than many critics seem to think, it is nevertheless an instructive model with a predominantly unidirectional flow of coding information from top to bottom: from DNA to RNA and then to proteins. The genotype/phenotype dualism finds here a new justification. During the 1960s, the famous "genetic code" was elucidated. In fact, biologists simply understood in more details how cells use DNA to make proteins. Here, the influence of cybernetics is obvious. The production of proteins is ultimately simply a chemical reaction (the interaction of DNA with proteins and other molecules resulting in the production of other proteins), but it is the only one that is specifically described in terms of a "code" or "transmission of information". As proteins are, at the time, seen as the fundamental element of organisms, if DNA is the "code" used to build these proteins, it can therefore be considered as the source of all the information necessary for life. The DNA becomes the matrix of life. The ordered substance theorized by Schrödinger is assimilated to DNA. However, for Pichot (2002), the Schrödingerian principle is "relaxed" in this case, in the sense that the global correspondence between the order of genetic material and the organization of organisms has been replaced by a local correspondence between the internal order of genes and the internal order of proteins (the "genetic code"). This period of gene-as-a-DNA-segment is a culmination of molecular biology. Not only it recapitulates all main previous theories of heredity (Weismann, Morgan, Schrödinger) but it is a direct legacy of the late 19th century all-encompassing biological theories and their attributes: imperialist theories based on a single substance that is at the origin of all truth, a total physical and chemical explanation of the organism bordering with religion (Pichot 1999). Another significant shift effectuated by molecular biology is the inclusion of proteins and enzymes within the phenotype. Previously, it was thought that the factor of heredity was of proteic/enzymatic nature: the "gene" was a protein. Therefore, the expression of heredity was understood as *protein/gene → trait*. However, with the gene now identified as a DNA segment responsible for the production of a protein/enzyme, the expression of heredity became *DNA/gene → protein/enzyme → trait*. The physiological mechanisms between the protein and the traits were evacuated from the domain of genetics and heredity, which focused thereafter mostly on the explanation of the relation between the DNA and the protein (Pichot 1999).

This vision of the organism is sanctioned by Jacob and Monod and their work on the functioning and regulation of a particular region of a bacterial DNA, the lactose operon. They proposed a model of gene regulation that will constitute one of the foundations of molecular biology and that directly imports concepts from cybernetics such as specific signals, information transmission, regulation and feedback loop. The regulation of a gene will depend on the activity of other proteins that bind specifically to a particular region outside of the gene to transmit an activation or repression signal. In this model, according to Kupiec and Sonigo (2000), the world of signals (regulation) is conceived as separate from that of metabolism (which would be the domain of chemistry). The "signal world" will gradually become a universal explanation of the natural world. If something happens in an organism, it is because it was triggered by a signal. The world we experience is only a reflection of the world of signals, echoing the essentialist Theory of ideas of Plato. The other two important features of Jacob and Monod's regulation model are its instructive nature and the necessity of the concept of stereo-specificity (Kupiec & Sonigo 2000). If an entity waits to receive a specific signal in order to perform an action, this implies that it already possesses the ability to interpret the information carried by this signal: the result of the process always precedes, in a virtual way, the real process. Fitting a lingering and powerful tradition of essentialism in the West, "[an instructive and] deterministic model might seem perfectly relevant at first sight for accounting for the precision in the way an organism functions" (Kupiec 2009). The idea of stereo-specificity not only gives a central role to the DNA sequence (responsible for the amino acid sequence and therefore the spatial configuration of the corresponding protein) but is paramount to the theory/metaphor of the Genetic program. This most cybernetic metaphor (that appeared in 1961 in two independent papers, one from Mayr and one from Jacob and Monod) could be defined as an instructive model (with cascades of interactions, signalling pathways, gene networks...) where differential gene expressions are responsible for the differentiation of cells during embryogenesis and the functioning of the organism until its death. In this theory, proteins interact in an unambiguous way, with each molecule having one or very few partners, excluding stochasticity (see Kupiec 2010 for a critique of this). Information is the cause of the ensuing order and, again, the final form pre-exists the biological material that is transformed, a faithful legacy to the neo-preformationist theory of Weismann, embodying the microscopic order theorized by Schrödinger. In the 1970s new methods of cutting and manipulating DNA are developed, giving rise to genetic engineering (e.g., the manufacture of genetically modified organisms by transgenesis). "Lego" techniques, instructive models of DNA regulation and cellular differentiation, cybernetic metaphors invading genetics, the Central dogma, general genetic essentialism... organisms are perceived as a rigidly functioning machine and the idea of the Genetic program takes hold. This set of ontological representations are part of the Genetic Order, built on the foundations laid by Schrödinger, and it is to be understood as the answer of biology to the metaphysical problem of order following the Second World War.

For Sonigo the success of modern genetics and the world view it offers is due not only to the influence of cybernetics (where everything is only an immaterial exchange of information) but also to the central notion of the individual as a separate and independent biological entity, associated to a vision of the natural world as compartmentalized and discontinue (Sonigo & Stengers 2003). In order to understand the reproduction of the similar, these two influences have pushed the explanation towards an emphasis on the concept of information and denied the idea of a material continuity between generations (which Sonigo claims should be seriously revisited, see Sonigo 2013). But in the same way that the historical vision of life emerging in the 19th century had been a challenge to the centrality of the notion of species (see above), it should also have been a blow to the centrality of the notion of individual. For Sonigo and Kupiec, the species and the individual are only arbitrary snapshots of ongoing oscillating processes, respectively the evolution and the ontogeny—both processes that are considered equivalent in their model of ontophylogenesis (on these questions see their respective works Kupiec 2019, 2012, 2009; Kupiec & Sonigo 2000; Sonigo & Stengers 2003).

As early as the 1970s, numerous studies showed that the genome is more malleable and the gene more complicated than previously thought (Morange 2003; Burian 2013). It is becoming increasingly clear that, in eukaryotes, not only is there no strict correspondence between the order of the genetic material and the order of the living being (the direct causal link between genes and traits is particularly difficult to demonstrate, due for example to polygeny and pleiotropy), but there is also no strict correspondence between the order of the gene and the order of the protein. As a consequence, the Schrödinger's principle of the macroscopic biological order originating from a microscopic order requires numerous adjustments, which, for Pichot, are equivalent to a generalised weakening (he uses the notion of "softening" in Pichot 2002). As to the concept of gene, due to these difficulties, it is slowly losing its structural definition to go back to a more abstract, functional and "semiological" one where it is defined after its product (Pichot 1999).

2.2 Genetics and neoliberalism

The world economic order entered a new period at the end of the 1970s, that of neoliberalism. As usual, genetics will be part of this upheaval, while providing it with a powerful imaginary, in this back and forth movement typical of modern science. This can be seen first of all with the boom of genetic engineering, i.e., the birth of an industrial sector of biotechnologies which supplies molecules to the pharmaceutical, agricultural and petrochemical industries. At the academic level, Aguiton (2018) characterizes this pivotal period and the decades that followed by three major transformations: 1) transformation of the figure of the scientist into an entrepreneurial researcher/start-up creator; 2) transformation of intellectual property regulations, with an increasingly massive appropriation of genetic discoveries and modifications; 3) an ever closer link between science and industry, in terms of research programs, funding, curricula, etc.

Perhaps it is not a coincidence that *The Selfish Gene* was published at this time, in 1976. Dawkins offers a vision entirely centered on DNA and the gene. An extreme reductionism where the DNA, as the ontogenetic starting point of all that concern organisms, is both the source and the goal of biological processes. According to Noble's interpretation, what is important in the SGT is the dichotomy between the replicator (DNA, gene) and the vehicle (organism). The replicator is the fundamental element of heredity, and therefore of life, and its evolution. It is the entity whose different variants can replicate identically and, potentially, for eternity—an immortal entity. The organism, the body, is merely the vehicle created by the replicator to pass from generation to generation (Noble 2011). What is at stake in this construction of DNA as an immortal text is that it can reveal the essence of the present, the events of the past and the possibilities of the future. DNA is history and destiny, echoing the centrality of the notion of immortality in the imaginary of genetics, already mentioned in connection with Weismann's theory. The irony of the metaphor must be emphasized. Dawkins, who, despite portraying himself as a perpetual crusader against religious obscurantism, does not seem to realize the extent to which his theory appeals to one of the most classical theological dichotomies (and hierarchies), that of body and soul. DNA—the replicator—is the immortal essence, the spirit, or soul. While the body and the cell—the vehicle—is existence, it is the world that degrades, ages, and ultimately has little significance. It is impossible not to notice similarities with transhumanism, which presents itself as a movement at the cutting edge of technological modernity with marvelous promises but is, ultimately, based on the fear/hatred of the body and of organic, and therefore mortal, existence (Benasayag 2016). A fear shared with institutional monotheist religions.

The SGT opens the period of the 1980s where the gene became more of a unit of intellectual appropriation associated to a more generalised patenting of DNA sequences (Bonneuil 2015a). The general aim of research being to control and command the gene, genetic engineering and molecular biology explode. The frenzy of DNA sequencing (first of genes and then whole genomes) and genomics (the study of these genomes) begins in the late 1980s. Once again under the influence of cybernetic and computer language, and when it is simply a matter of determining an aspect of the structure of a molecule, DNA sequencing becomes "genome decoding". The genome is the key to living beings, and "deciphering" it means opening the "book of life" and understanding its mysteries. With the sequencing of the human genome, starting in 1990, physical and mental illnesses, addictions and homelessness will be overcome (see the incredible editorial of Science in support of the human genome sequencing project, Koshland 1989).

Several parallels can be drawn between the vision proposed by modern genetics (the SGT in particular) and certain characteristics of the developing neoliberalism. One is that all aspects of life are directed and shaped either by the minuscule or the gigantic. On the one hand, organisms, their functioning, development, behavior and all aspects of their existence are influenced or even directed by genes. These genes can be modified on demand, rearranged, ranked, corrected, extracted and then reintroduced. On the other hand, Neoliberalism is the commodification of all aspects of life, the marketization and entry of technology into the intimacy of minds, behaviors and bodies. The embodiment of cybernetics in neoliberalism, as Tiqqun (2020) describes it, is this back and forth movement where beings are emptied of what makes them active, creative and autonomous (through constant capture or extraction, be it bureaucratic, digital or of any other nature) and are then "fed back" (recreated as subjects) by those data that have previously been processed, ordered, hierarchized and arranged. Secondly, this shaping (of who we are, as social individuals or organisms by neoliberalism or DNA) is effected beyond our perception or our reach. The genes, those little elements that direct us, are invisible to us. They are tiny command centers and our bodies, these robot/machines, obey their programs. Similarly, we have almost no control over the extreme financialization of the economy, the fact that a huge part of wealth creation is now dematerialized, invisible, computerized, algorithmic, the way important decisions about this wealth creation and many other aspects of our lives are made somehow, in unknown places (at least with which we generally have no connection to)… Finally, genetics and Neoliberalism both mobilise representations involving an extreme reductionism. DNA is the source and goal of all biological phenomena, while competition and the free market are the sources and goals of all social phenomena. An explanation for the power of this essentialist and reductionist vision could be its simplicity and its complementarity to capitalism. Indeed, the SGT and free market theory are disarmingly simple and all encompassing, egoism and competition being the two main characteristics (King D, personal communication). All phenomena, social and biological, could be explained by these two mechanisms. Nelkin and Lindee (2004) summarize the "advantages" of genetic essentialism: 1) it shifts the source of social problems to the individual (and not to society), 2) it provides a kind of equivalence to moral redemption and/or absolution ("it's not my fault, it's my genes!"), and 3) it also provides a scientific, "neutral" and rational justification for social categories.

What is at stake in this pivotal sequence of the 1970s and 1980s is a paradigmatic shift in the order inspired by computer science and cybernetics. Since the end of the 19th century, the predominant model of order had been roughly that of Fordism: a highly hierarchical structure, with a top-down management of politics and economics. The Fordist model, which had become too rigid, had to change. This marked the emergence of the network society. There is no longer a single source of control, the model becomes that of a network system, made up of more or less equal nodes, regulated by feedback loops. This is the idea of "liquid nature" put forward by Bonneuil (2015b). He describes the transition from the Fordist form of capitalism (one of resource and industrial production) linked to a perception of life as a resource (a stock and a collection of entities and species) to a neoliberal form of capitalism (financial, based on assets and income, services and investments) associated with a perception of life as a set of functionalities and "services", organized in networks and made up of relationships.

Cooper offers a fascinating interpretation of the enormous shift of this era, taking the USA as an example, but that could be applied to the West in general (Cooper 2008). The difficulties of Fordist capitalism caused a transition in the North American economy (and therefore the world economy) towards an "economy of promise" that Cooper calls the Bioeconomy. Already pointed in the famous Club of Rome's report *Limits to Growth* in 1972, the realization of the natural limits of the planet will be all the more relevant in the context of the oil price increases due to the oil shocks of 1973 and 1979. Cooper describes how the American administration then decided to promote the development of both digital and biotechnologies. In fact, while appropriating certain concepts of ecology or theories of self-organization, the capital "realized" that although the planet's fossil energy resources were finite, life was constantly renewing itself. Lafontaine identifies here the cross-influence of cybernetics on certain concepts of the natural sciences (the ecology of systems, the planet and life as a large autonomous and self-regulated whole), on the development of the digital industry and on the birth of neoliberalism (Lafontaine 2004). The biotechnologies characteristic of these developments are GMOs, gene therapy, stem cells, reproductive technologies, synthetic biology, biofuels, etc. It is around these technologies that the Promise economy developed (Cooper 2008; Lafontaine 2014). They organized a speculative imagination, a faith in a future where the limits of life are constantly being pushed back, where the health of future generations is always-already prioritized over that of current generations. This is reflected in funding choices, where, for example, medical biotechnology research will be largely favoured over maintaining or improving public health systems (see also Duster 2003). Here lies an important node in Cooper's story. Neoliberalism and the transition to a Bioeconomy and a Promise economy are accompanied by an attack on the structures of the welfare state. Rouvroy, deciphering the relation between the sequence opened by the Human Genome Project (HGP) and neoliberalism, reaches a similar conclusion. She associates the process and the completion of the HGP to the emergence of a new "mode of governance by genetic risk". A central element to this new mode of governance is the major shift towards an individualized, self-responsible notion of health:

> "The narratives of genetics and the globally dominant messages of neoliberalism converge to make our post-genomic future visible and legible in advance through tales of a genetic mythology that promises a new transparency and precise calculability of individual health risks, behaviors and identities, and through a rhetorical insistence on the liberating virtues of privatising health insurance and dismantling welfare states." (Rouvroy 2008)

The transition to a Bioeconomy/Promise economy is also reflected in a fundamental shift in the economic relationship between the USA and the rest of the world: from creditor (since World War II) to debtor. The promise is therefore also in this debt-based relationship that is established in the following decades. A debt that, in reality, is so enormous and consubstantial to the global economy that it will never be repaid—an eternal promise: "Neoliberalism and the biotech industry share a common ambition to overcome the ecological and economic limits to growth associated with the end of industrial production, through a speculative reinvention of the future." (Cooper 2008). In short, the living, *life itself*, became a central resource for economic development, growth and added value. "Promising" life processes and molecules (giving perspectives of longer lives, miracle cures, stronger and healthier babies etc.) were, and still are, mobilized to leverage enormous amounts of preliminary investments, inflating an economy of bets and risks completely disconnected, for example, to actual public health and its social aspects. Combined with the explosion of information technologies, the neoliberal biotechnologies will have a huge impact. One must read or listen to Lafontaine for an overview of these major changes. She describes how the Bioeconomy is a process of marketization of the body, especially of women's bodies, through the development of reproductive technologies (artificial insemination, *In vitro* fertilization, ovules donation, surrogate pregnancies etc.) which are instrumental in the current trend towards forms of liberal eugenics (see below). This development of a form of bio-citizenship (a new form of citizenship centered on the optimization of the biological and bodily potentialities of individuals), accompanied with a molecularization of culture, has transformed our relations with our bodies and our health: ultra-individualization, redefinition of health in terms of risks, injunction to constant self-monitoring etc. (Lafontaine 2014).

2.3 Genomics and networks—a new ontology?

The genomic obsession starting at the end of the 1980s had the advantage of putting the theoretical difficulties of genetics already mentioned on hold, to give way to mainly technical problems (Pichot 2003). Relying on technology also provided a solution to these difficulties: "Faced with the apparent disorder of genetic material, geneticists have undertaken to 'draw up the text letter by letter' in order to entrust the analytical power of computers with the task of discovering a functional order (which, in the end, shows great loyalty to Schrödinger)." (Pichot 2002, transl. by the author). The mass production of data and the increasingly important role given to bioinformatics in the 2000s testify to a recomposition of methods and skills in biology (Aguiton 2018). However, even if this lead to "impressive" technical achievements, it is the same conceptual error that is repeated, one of the fundamental errors of biologists: thinking of the description of a phenomenon (even in its smallest molecular details) as an explanation of that phenomenon (the way formal genetics believed that "modelization was theorization" at the beginning of the 20th century). Indeed, once the human genome was sequenced, the scientific community realized that the knowledge of its 3 billion base pairs did not provide the fantasized answers to all its questions. But rather than questioning the conceptual errors that led to this research program, the industrial techno-scientific approach has simply moved up a level: it is now a matter of studying how the genome is used by the cell—the era of post-genomics. This is what Bonneuil calls the period of the network gene (2015a). This sequence is marked, amongst other things, by three developments described below.

The concept of the gene, already very vulnerable and subject to a chaotic history, is now crumbling. In a little over 100 years, the notion of gene has moved from an abstract nature to a protein nature, an undetermined physical location on chromosomes, an ordered physical structure, a discrete element of the DNA molecule that codes for a protein, a functional unit... only to be challenged by the results of molecular biology itself, reaching a climax in recent years with genomic and post-genomic studies. To exemplify the attitude of biologists towards these difficulties, François Jacob, when asked in 2000 "whether he and other molecular biologists were aware of how much the very notion of gene was threatened by his [late 1960s] findings?", answered: "Yes, we were aware of these theoretical difficulties, but we chose not to speak too much of them; the priority was to move forward." (cited in Gayon 2016). Nowadays, no one knows how to define a gene any more, which is somehow embarrassing for biology and genetics, of which the gene is the object (for a detailed history see Bonneuil 2015a; Burian 2013; Keller 2000; Mayr 1982; Pichot 1999; but also Gerstein *et al.* 2007 for the consequences of the HGP on the definition of the gene).

Epigenetics is a term created in the middle of the 20th century by Conrad Waddington (see Keller 2000), in reference to epigenesis, to refer to all the mechanisms involved in embryonic development including the influence of the environment. For example, the notion of gene regulation, that is part and parcel of the Genetic Program concept, is a form of epigenetics. Since the turn of the millennium, epigenetics has undergone a spectacular development (with the study of the chemical modifications of the chromatin, the non-coding RNAs, and their potential transmission). At first glance, the rapidly expanding discipline seems to call into question certain fundamental notions of genetics. One is the centrality of the gene as the unit of heredity. Since these epigenetic modifications can be caused by external stimuli (toxins, traumatic events, etc.) and be passed on from generations to generations, biology must now grapple with a concept that was rejected at the outset: the heritability of acquired traits (see Boskovic & Rando 2018 for a recent review on epigenetics and Noble 2015 for a discussion of the implications of epigenetics findings). However, other researchers, including biologists critical of the reductionist and deterministic mainstream approach of genetics, are not so enthusiastic about the results of epigenetics. For example, Kupiec understands the recent interest in epigenetic mechanisms mostly as a continuation of an old habit of geneticists' "double discourse" dating back to the notion of "reaction norm" created by Woltereck. In other words, when genetic determinism is being challenged experimentally geneticists invoke/accept some form of influence of the environment, without realizing that this is in contradiction with the theoretical foundations of their discipline. This is revealed, by the actual word itself where "epi-" means "above", so epigenetics would only be an additional layer added on top of genetics, and would not constitute a challenge to the determinism, to the centrality of the gene, nor to the idea of "order created from order" inherited from Schrödinger (Kupiec 2019).

In parallel with these developments, a systems biology is emerging. Systems biology is an ill-defined heterogeneous discipline, but Bizzarri *et al.* (2013) see two branches: theoretical and pragmatic. The pragmatic branch is the one that leads for example to synthetic biology, a techno-industrial approach that works towards the complete engineering of living beings. Starting in the 2000s, Synthetic biology built its promises on a critique of the genetic engineering of the 1970s, which was seen as too slow and approximate. Based mainly on the post-genomic techniques (transcriptomics, proteomics, metabolomics…), it is mostly a technical approach aiming at developing cheaper and more robust genetic modification techniques with better and faster transfer from laboratory to industry. A systematic engineering of life. Synthetic biology is still part of the reductionist paradigm in that it sees the organism as a collection of elements of unique, well-defined types that interact with each other, in the hope of maintaining a vision of life in which the causal relationships between specific entities and a biological function or trait are clearly defined, and therefore patentable. As such, it is a particularly telling example of the evolution of biology towards ever more engineering: the continuation and an acceleration of practices to turn organisms into "living factories" for industrial, pharmaceutical or other products. The story of the world we are telling ourselves, that of humans controlling and exploiting its environment, is exposed here with chilling clarity.

The theoretical branch of systems biology is built on a critique of the reductionist view of genetics and neo-Darwinism and the desire to re-inscribe the organism in the understanding of evolutionary, developmental and hereditary processes. It challenges the notion of Genetic program and the centrality of DNA in what constitutes the hereditary material, and proposes to take into account the non-DNA or cellular heredity (see for example Noble 2017). This new systems biology is both extremely complex and fascinating in its technical achievements and, at times, politically attractive for the imaginary it builds. Indeed, for this part of biology, it is now interactions, networks and systems (i.e., relations) that matter. The millions of interactions between proteins and between proteins and DNA are studied in an automated way, then modelled and represented. It is no longer the genes, or the proteins, but their patterns (configurations of relationships) that are the basis of the explanation. The fundamental entities change, or, as Bonneuil says: "From molecular biology to systems biology, we move from a substantial ontology to a relational ontology" (2015a, transl. by the author). This ontology is extended to the living world, seen as a network and a continuum, as a set of inter-relationships and inter-connected organisms. These ideas are appealing and correspond to a certain idea of relations that goes against the obsession of centrality, separation and compartmentalization, characteristic of biology and modernity in general. Yet, in these statements, as in their implications, there is a clear, if not determinism, at least an influence of cybernetics and its embodiment in neoliberalism. The gene, like life in general, is now seen as flexible, adaptive, connected, hybrid, innovative… echoing Bonneuil's critique of this relational ontology as "liquid nature" (Bonneuil 2015b). There is thus a major challenge here: (how) can biology contribute to (new) relational ontologies while escaping the terms of cybernetic capitalism?

3. The Genetic Order

3.1 The construction of the notion of heritability, part II

As told in section 1.2.2, the focus of the science of heredity shifted early on towards what is conceptualized as "the part of genetics" in the transmission (and formation) of traits in organisms. In other words, there has been a geneticization of the study of heritability. This next part is dedicated to the clarification of issues around heritability, the opposition hereditary/acquired and the notion of causality and its conflation with correlation.

Keller identifies two meanings given to the term heritability: ordinary and technical (Keller 2010). The ordinary meaning (often implied by scientists and the media) refers to a trait and its transmission/formation at the individual level (the transmissibility of this trait). Heritability studies tend therefore to be perceived as the determination of the share of the genetic component, as opposed to the social and cultural component, in the formation of traits. However, the (proper) technical meaning refers to the variation of that trait at the level of a population: a statistical measure related to the proportion of the influence of genetic variation on phenotypic variation in a specific population of organisms. These differences are extremely important. For Keller, geneticists and journalists are perpetually shifting between the ordinary and technical definitions of heritability. The latter definition is a statistical measure, not a measure of causality; it only makes sense in relation to a population, not at the individual level. Heritability studies therefore do not tell us anything about transmissibility, i.e. about the quality of a trait to be heritable. They are studies that are entirely context-dependent and have no implication on the mechanisms of transmission (of heredity) of traits between generations. To better understand the difference between the heritable quality (its transmissibility) of a trait and its (technical) heritability we can turn to a very simple example: the number of hands in humans. The number of hands (two) is an inheritable trait, it is transmitted from generation to generation with almost perfect regularity. Its heritability, the influence of genetic variation on the variation of this trait, is, however, close to 0. Indeed, the variation of the trait in human populations depends almost entirely on environmental causes (the loss of a hand by accident). An inheritable trait can therefore have almost zero heritability.

A similar argument can be drawn, based on one of the theoretical weaknesses of genetics already mentioned: the opposition between in-principle-hereditary (inherited or not) and in-principle-non-hereditary (acquired) traits (Pichot 1996). Pichot tries to unravel this confusion and explain that such defined hereditary and acquired characters are not comparable terms. In the case of acquired traits, one instantly thinks of phenotypic traits (an arm cut off in an accident, therefore an effect) but the acquired quality never applies to the cause (the external determinant that produced the cut arm, e.g. a machine). However, in the case of hereditary traits, are considered inheritable both the phenotypic traits (the effects) and their genetic determinants (the DNA sequences, the genotype, i.e., the causes). This is a fundamental imbalance, a hiatus in definition that has plagued genetics to the present day:

> "these notions [hereditary and acquired] have meaning only in cases where there is, if not a purely genetic (respectively external) determinism, at least an immediate linear relationship between the phenotype and the genotype (respectively the external environment). With the exception of the primary protein sequence (which is directly related to the corresponding genes—as a first approximation because in eukaryotes the structure of the genes is so complex that such a direct relationship could be disputed), however, such cases are very rare. They are almost non-existent at the macroscopic level. As a result, in practice, the concepts of hereditary and acquired are virtually inapplicable to phenotypic traits, even though they are supposed to apply to them." (Pichot 1996, transl. by the author)

Simply asking seriously the question "what is a hereditary trait?" leads to a critical deconstruction of the foundations of genetics. Taken further, the question of "what is a trait?" could also be explored. One can indeed wonder about the equivalence of traits such as the primary structure of a protein, eye color, the shape of the nose or behavior. Are they unique traits? Are they similar in nature? Are some not rather sets of characters? How can they be compared if they are not of the same nature? Genetics does not provide clear answers to these essential questions (Kupiec 2019; Pichot 1996). Moreover, if the amino acid sequence of proteins is an apparent trait of an organism (and therefore part of the phenotype), why not considering the nucleic acid sequence of DNA as an apparent trait of an organism? Is DNA part of the phenotype, and if yes, then what is left to make up the genotype?

Focusing on issues around heritability and the oppositions hereditary-acquired and genotype-phenotype also raises the question of causality in biology and how to establish it. Noble reminds us that, often, functional studies of genes repeat Morgan's conceptual error (studying the heritability of an alteration, among other alterations, of a trait, rather than the heritability of that trait) (Noble 2008). The problem with this method is that it cannot reveal the totality of the functions of a gene since it does not show the common effects between the mutant and the wild type. To illustrate this, let us take a hypothetical example of a gene A, which has five functions related to traits 1, 2, 3, 4 and 5 (the biologist does not know any of these functions a priori). Gene A is mutated and we will observe a major change in trait 5. We will have highlighted one possible function of gene A, but not all of them, since functions 1 to 4 have not been identified. However, the usual conclusion of molecular biologists is that the function 5 is the main function of gene A and the rest is generally dismissed as noise or pleiotropy. Noble also raises the issue of the Differential Genetic Effect. That is, most variations in DNA sequences, including changes in coding sequences, do not cause a change in phenotype. They are compensated for by the organisms, a property referred to as "robustness". The reason why this is rarely taken into account is that modern biology and its reductionism ignore the organism and is based on the idea of a sole upward causality, coming from the lower level (the molecular level) (Noble 2008).

Finally, the conflation between causality and correlation can be illustrated with the recent multiplication of Genome Wide Association Study (GWAS) papers and their Manhattan plots. Yet, in the end, what do these studies show? Only a statistical link, a correlation, between the presence of certain nucleotides and a trait, as the physiological link between the sequences containing (or close to) these bases and the trait has not been demonstrated. GWAS studies generally include comparisons of the genes identified to databases of annotated genes, therefore they can offer indirect leads regarding a link between the presence of DNA sequences and a trait. However, they main outcome is that biology is still confined to the accumulation of data and correlations, with very little theoretical or physiological progress. At this stage, it is useful to recall the study by Calude and Longo, which emphasized that "[t]oo much information tends to behave like very little information" (Calude & Longo 2017). Genetic essentialism finds a new robe and new justifications for the sequencing of even more human genome sequencing, while eugenics endeavors like the search for a genetic basis for intelligence ("educational attainment"), homosexuality or crime ("antisocial personality disorder") flourish (Davies *et al.* 2016; Rautiainen *et al.* 2016; Sanders *et al.* 2017).

3.2 The construction of the Nature/ Nurture dichotomy, part II

Section 1.2.1 was dedicated to the historical construction of the opposition between Nature and Nurture, or genetic and acquired, in relation to the eugenics project. This dichotomy is so "banal" today that it does not even need to be thought of, argued or defended. It is self-evident, a stark example of a belief that can be considered ontological. Some people will lean towards the genetic and natural explanation, others towards the environmental and cultural explanation, but it is rare that the existence, history and role of this dichotomy are questioned.

Picking up the history of eugenics and the Nature/Nurture dichotomy where we left it, in the middle of the 20th century, the Nazi exterminations of the Second World War undermined the legitimacy of the eugenics project. While the term eugenics was not to be mentioned any more, official eugenics societies simply changed their names and certain ideas and practices went on (such as forced sterilization programs). With the emergence of medical genetics, the Nature/Nurture opposition was deployed even further. The search began for the "gene FOR" this or that disease, each of them considered a unique and singular trait, repeating again the conflations correlation-causality and gene-mutation. Lippman's definition of geneticization summarizes what is at stake here: "the process by which interventions employing genetic technologies are adopted to manage problems of health. Through this process, human biology is incorrectly equated with human genetics, implying that the latter acts alone to make us each the organism she or he is." (Lippman 1991). It is also worth pondering for a minute what could be the actual applications of medical genetics apart from eugenic preventative acts such as selective abortion and selection of embryos before implantation, or curative acts such as gene therapy (which has been an extremely expensive and, not surprisingly, mostly disappointing approach so far).

Another discipline emerging in those years was behavioral genetics (see Bliss 2018), which was to cause several scandals in the 1970s, particularly around the ever-present issue of the link between genes and intelligence (as measured by IQ). The discipline more or less metamorphosed into sociobiology, whose basic premise was that social behaviors, in a same way that physical traits, are based mainly on genetic foundations, are inheritable and are the results of evolution. Racism, for example, found here a new scientific rationalization (it would only be the result of the innate aggressiveness of humans and/or their propensity to protect those genetically close to them). The central idea of the emblematic work of the discipline (*The Bell Curve*, published in 1994), was that the class structure in the USA is based mainly on individual inequalities in terms of IQ, due to genetic differences. The authors accompanied their argument with "soft" eugenic recommendations, such as the prevention of immigration and the curb of welfare state provisions, which were seen as responsible for the decline and dilution of "cognitive elites" (Bliss 2018). Affected by the scandal provoked by this book, sociobiology morphed into evolutionary psychology. Much could be said about this discipline: its use of analogies, metaphors, circular logic and ad hoc explanations. All with the proclaimed goal of understanding what makes us specifically "human". Like its parent disciplines, evolutionary psychology will mostly lend itself to justify existing social hierarchies and the reactionary political projects that promote them (see also McKinnon 2005).

From the 2000s, the era of Big data in biology and medical imaging, especially of the brain, also witnessed an explosion of disciplines based on genetic and biological essentialism, such as cognitive genetics, neuroeconomics, neuropolitics, neurocriminology (heir to the old tradition of biocriminology) or sociogenomics. What they have in common is their focus on biology and genetics in the explanation of social phenomena. Bliss (2018) concludes that all these disciplines, which are intended to be transdisciplinary (including between the natural and social sciences), always end up reinforcing genetic/biological determinism as well as the opposition and separation between nature and nurture and favoring the "natural" explanation. Of course, these disciplines face many criticisms, coming from the human sciences or from critical biologists, but unfortunately the common point of these criticisms is that they do not try to question the framework of this opposition between Nature and Nurture, and therefore recognize it as valid and operative. The Nature/Nurture debate has therefore proven particularly difficult to escape. As Keller (2010) concluded, not only no one really knows how to define what we put behind the categories of Nature and Nurture, but it is also a haphazard mix of major issues (moral, political, philosophical, biological, sociological, religious, etc.) and the confusion surrounding it is exacerbated by the vagueness and ambiguities of language maintained by biology and genetics on heritability.

3.3 Eugenetics

The main problems with the Nature/Nurture dichotomy are the political vision of the world it carries and the fact that it is, ultimately, inoperative in the context of biological science. The world view conveyed by the Nature/Nurture opposition is complex (Table 1). For example, the "body" may be perceived on the side of Nurture or Nature depending on the context and the epoch. In the context of natural sciences, Nature is the world of essence, signals, DNA and genes, the replicator, the immortal lineage... Nature is understood as the ultimate, necessary and inescapable explanation of living beings. On the other hand, in power relations such

Nature	Nurture
essence	existence
body	spirit, soul, mind
female	male
non-whites	whites
country side	cities
savages, the poor, criminals	civilized
non-humans	humans
biological	social, cultural
permanent	temporary
invariant	varying
immortal	ephemeral
germen	soma
germ line	body
hereditary	non-hereditary
genotype	phenotype
innate	acquired
gene	environment
signal	metabolism
DNA	organism
replicator	vehicle

Table 1: Dichotomies associated to the opposition Nature/Nurture.

as patriarchy, racism or capitalism, what is associated with Nature corresponds to what can be dominated, exploited or massacred (women, racialized people, certain social classes, the planet...). In both cases, to naturalize is to justify. To naturalize is to define Truth; and Truth is the prerogative of Science and scientists. Since God has lost his explanatory power about the world, it has been replaced by another entity: DNA. Genetics, like monotheisms, has its dogmas, its institutions and its "fundamentalists", and "like the Christian soul, DNA seems relevant to concerns about morality, personhood, and social place." (Nelkin & Lindee 2004). Of course, a whole discourse of justifications exists to mask this religiosity of genetics: from the necessity of a more productive agribusiness to the need for industrial innovation, progress and to always "move forward". But the ultimate and overwhelming argument is always the medical one. A reminder of how the fear of diseases and the imperfections of the body constantly gets mobilized to ensure our consent to new biotechnologies and potentially eugenic practices.

3.3.1 Fear of the body

It would have been possible to write this account of genetics not chronologically, but according to the different fears it has mobilized in the course of its history. If I had to choose one that seems to be the central point, it is indeed the fear of the body, characteristic of the West and its project, modernity. Rouvroy reminds us of Foucault's insight to whoever wishes to understand the exercise of bio-power (the governmental techniques for achieving the subjugations of bodies and the control of populations): "One needs to study what kind of body the current society needs..." (Foucault & Gordon 1980 cited in Rouvroy 2008). She also warns us, "the 'genetic information society'... socializes people through fears". In this society, the place we focus on to find commonalities between humans has shifted to "the 'invisible' but locatable and 'calculable' internal, molecular milieu" (Rouvroy 2008). Federici, reflecting on the neoliberal ontology of the body, draws poetically the same conclusion:

> "We internalize the most profound experience of self-alienation, as we confront not only a great beast that does not obey our orders, but a host of micro-enemies that are planted right into our own body, ready to attack us at any moment. Industries have been built on the fears that this conception of the body generates, putting us at the mercy of forces that we do not control. Inevitably, if we internalize this view, we do not taste good to ourselves. In fact, our body scares us, and we do not listen to it." (Federici 2016).

Bonneuil (2019b) situates this ontology of the fear of the body at least since Descartes and his "I think therefore I am". From this, humans can pretend that they do not have a body, nor any world. This is the specificity and the exceptionalism of humans: they have no place. Unlike Nature, they cannot be explained by a material process. Yet what does a body do? It breaks, it grows old, it changes and it dies. Here the fear of the body joins the fear of disease, decay and, in the last instance, death. A body is unpredictable, it is in relation with other bodies, with its environment, it creates its world and at the same time depends entirely on it. There is no body without a world and no world without bodies. Moreover, a body is difficult to define and its limits are not so clear. Modern science would like a body that is predictable, calibrated, perfect, "healthy" and independent of external fluctuations that are unpredictable and uncontrollable. Echoing the fears of the first eugenicists and dominant classes, a body lives and acts, has a power and a will. It organizes itself, revolts and rises, passively or actively, it is difficult to control. Eugenics, transhumanism or synthetic biology are therefore only the most visible symptoms of a morbid science. But are they really symptoms? The relation between genetics and eugenics is radical, in the sense of *root*. The founders of genetics, its methodologies, the ontology it co-creates (of essentialism, prediction, engineering and control) have everything to do with the eugenics project. Eugenics is not a corruption, an "extremist fundamentalism" or a "radicalization" of genetics—it is at the heart of it. *Eugenetics* (Eugenic genetics) lies at the intersection of three powers: fear of the body, capitalism and government (in the sense of the control of bodies, movements and attitudes). It is cybernetics that today embodies this project of total control of all life, an ontology terrified by the unpredictable, the recalcitrant, the chaotic, what escapes, slips or panics, while mobilizing in an almost contradictory manner the unstable, the resilient, the fluid, the connecting and the disruptive to justify a new mode of government. All of this obviously deserves to be explored further.

As a note, the term "Eugenics", coined by Galton, uses the prefix "Eu-", which means true, good or proper (therefore, it refers and promotes the "good and proper" genes, or the "well" born). The term "Eugenetics" is a hacking of this, and refers to what I suggest is the true and proper genetics, the eugenic one.

3.3.2 The genomic prediction industry

It is in this context of the ever present eugenics imaginary in the neoliberal era that we must understand the literal burst of the Direct-To-Consumer genomic testing (DTC) industry, as Rouvroy concluded: "A specificity of biotechnology as a new representational regime and of genetic risks as a new mode of governance is their proximity, the immediacy of their implementation in the body of individuals." (Rouvroy 2008). The rest of this section is dedicated to a closer look at the main components of the DTC industry, and how, in addition to deepening the hold of genetics on our understanding of the world, it vividly illustrates this position of eugenetics at the intersection of capitalism, fear of the body and the ideology of control. In the present work, the prediction industry together with association studies such as GWAS (from which the DTC companies build their scientific legitimacy) are understood as the foundation on which the contemporary eugenics projects deploys itself, notably through reproductive technologies.

The first component of the DTC industry analyzed here is the offer of ancestry tests. A smear from the inside of the cheeks is sent to a private company and results are received online: a table with a percentage of membership of each "ethnic group" among the hundreds included in the company's database, a map, all sorts of graphical representations... and one can self-narrate a new identity, a new existence. As a client of 23andMe, one of the main actors of the DTC market, shares with us: "You can't get any more knowing-about-yourself than processing you DNA" (23andMe, n.d,) strikingly echoing the assessment that Rouvroy made more than a decade ago on the genotype as "...the locus of authenticity and 'inner' truth, uncontaminated by political, social and economic circumstances. Genetic information is represented as particularly powerful and reliable: no other information about a person displays such a level of inalterability and stability" (Rouvroy 2008). And it is, of course, the return through the back door of the biological racial classification, necessary to the eugenics project (Duster 2003). One article from 2019 estimates that more than 26 million people in the United States have already undergone this type of test (Regalado 2019). As if a whole section of the population was obsessively longing for an identity, for stories to tell about their lives and origins. All these genomes are now available to private companies, some of which are openly collaborating with police forces (Hernandez 2019). Not having our own genome sequenced will not spare us. All that is needed is for someone in our family to do the genetic test, since parts of our genome is shared with our relatives. It should be stressed that this constitutes a profound change in contemporary subjectivation, as the genetic subject (the type of human being created by genetics) departs from the traditional autonomous, independent, liberal subject insofar as it extends beyond the limits of its own body to reach the body of its closest relatives (Rouvroy 2008). The ancestry test companies also offer an entirely new mode of socialization in relation to the test results: connecting with unknown family members or with people who share certain genetic characteristics, discussions on forums, organizing trips to our ancestors' countries... DNA is at the center of everything, it tells us who we are, where we come from and who to socialize with. Another consequence, explained by Bliss (2018), is that mass social actions and organizations around common experiences of social injustice (such as anti-racist political actions) are then replaced by these dematerialized and individualized sociogenomic predictions, by socialization on online chats based on the tests and by self-discovery via genomics and its personal development literature.

Another area of genomic prediction is the Inborn talent tests where parents may decide to test their children's DNA to determine their potential skills in many areas: music, mathematics, reading, running, languages, dancing or drawing, but also their propensity for depression, shyness, resilience, sociability, etc. (see Bliss 2018 for a chilling account). The advertising discourse of one of the company offering talents test (MapMyGene) is particularly telling. See http://seminar.mapmygene.com/ [18 December 2020] for a glimpse of the company marketing to advertise their talent tests and the associated "seminars" (the one referred to here is called "Set your child up for success"). It shows a comparison of the efficacy of "normal parenting" and "genetic parenting". The company, based in Jakarta, Indonesia, is not a major player of the DTC industry. Its marketing discourse is particularly shocking and uses quotes from R. Plomin and J. Watson. To my knowledge, no other DTC company dares mobilizing such a forceful genetic essentialism. As such, it merely reveals the inherent tendency of the DTC industry. The tests themselves are advertized here: https://mapmygene.com/services/talent-gene-test/ [18 December 2020]. The selling argument is essentially based on the guilt parents should feel when they do not give their children all the available chances. Parents who raise their children with the help of genetics (Genetic parenting) will make the right choices, save time and money, will know how to choose their children's activities according to their talents revealed by genetic analysis, and in the end, will be the happy creators of real prodigies. The bottom line is that if, as parents, we do not engage in genetic testing, we will spoil our child's potential and we are irresponsible. A glimpse of the world that genetic is offering is revealed in this quote from a client of MapMyGene who did the test with his daughter's DNA: "All in all, this has helped me understand my daughter better in a very scientific way and for that I'm very grateful" (https://mapmygene.com/reviews/ [18 December 2020]). A world where our relationships to others, including our children, have to be *scientific*.

Of course, the next step has already been taken: genetic testing of embryos prior to implantation during in vitro fertilization (IVF) procedures. These genetic tests are already routinely used to detect certain pathologies in the future embryos to implant (this is discussed below), however it is worth focusing on a specific case. A start-up (Genomic Prediction) made the headlines a while ago for proposing prospective parents to genetically test IVF embryos and select the "smartest" ones. According to the company's discourse, the idea is to test for embryos that present a risk for future "intellectual disability" and then to give parents the "choice" of which embryo to implant (https://genomicprediction.com/faqs/ [10 September 2020]. The company has now changed url (https://www.lifeview.net [18 December 2020]) and the FAQ does not mention "intellectual disability" anymore). This discourse of "free choice" needs to be clarified, insofar as choice has become the tool through which the "governance by genetic risk" is exercized (Rouvroy 2008). Justified by this discourse is a clear eugenic practice of selecting which kind of human deserve to be born, but without coercion, only "free choice". The same free choice we are, in theory, exercising when we are going shopping in a supermarket. This has been called "liberal eugenics", "flexible eugenics" or "neoliberal eugenics" and tends to overlook the fallacy of thinking about our choices and desires as completely separated or independent from the power relationships that exist at a given moment (Rouvroy 2008). The founder of Genomic Prediction, Stephen Hsu, made the headlines again more recently, but this time because of a campaign in his university asking for his resignation on the basis of his recent racist and eugenic comments (https://www.geneticsandsociety.org/biopolitical-times/firestephenhsu [18 December 2020]). This campaign sheds an interesting light on Hsu plan to, in the near future, rely on enough millions of human genomes to refine the algorithms that his company uses to predict complex characters (Schwartz 2019). I would however suggest that this only merely reflects the most common and normal scientific discourse. To illustrate this statement, let us take a detour outside genomic prediction to mention a major event of recent years, the creation of the first genetically modified humans: in November 2018, a Chinese scientist, He Jiankui, decided to modify the genome of two twin girls to allow their parents to reproduce biologically and to ensure the good health of the two little girls. The genetic manipulation (using CRISPR) concerns a particular gene that would allegedly prevent the girls from contracting AIDS knowing that one of their parents is HIV positive (there are, of course, already medical and/or social procedures addressing this risk). This type of genetic manipulation is sometimes referred to as Human germ line modification and is prohibited in most countries. The world of genetics and biology is still trying to recover from this earthquake, although it is almost certain that this manipulation has been attempted before, but not in an open, official and public way. There is a lot that could be said on this subject (I would refer to the very valuable work of the Center for Genetics and Society around these issues), but what is the most interesting here is the dominant reaction of the "scientific community". This has not so much focused on the eugenic principle of fabricating a new human being in a laboratory or the ethical and political aspects of such a project, but rather on the technical aspect: these experiments are not yet safe, we cannot guarantee the well-being of these babies, we do not yet control all the parameters of this kind of manipulation, etc. In a reaction to a recent interview of Jennifer Doudna (one of the "creator" of the CRISPR technique who was horrified by He's manipulation) (Doudna & Kearney 2020), Marcia Darnovsky, from the Center for Genetics and Society, highlighted that she "opens the door to using the CRISPR platform she helped develop in the service of a hugely controversial enterprise: altering the genomes and traits of future children and subsequent generations. She does so under the banner of responsible science and policy"(Stoffregen & Darnovsky 2020). Indeed, Doudna does not ask *whether* human germ line should be modified, but *how* it should be done and seems to mostly worry about potential stifling measures and the negative impact that He and other "bad apples" caused on the perception of the CRISPR technique. Another example is the reaction of the Nobel-prize winning geneticist David Baltimore: "[On a potential moratorium on human germ line alteration] With a science that's moving forward as rapidly as this science is, you want to be able to adapt to new discoveries, new opportunities and new understandings. To make rules is probably not a good idea... [An international treaty binding on genetic manipulation] could hold back the science. Right now, there are many countries that have outlawed germ line editing and the way they have phrased it prevents certain kinds of experimental work from being done. That is unfortunate, because I think we want to move forward with experimentation... There's nothing like actually moving ahead with research to teach us what the actual pitfalls are" (Hesman Saey 2019). In reality, none of the aspects of the Chinese scientist's work are called into question here. He applied the ideology of scientism to the letter: there are no rules or limits, scientists must advance as quickly as possible without any restriction nor accountability (especially not from the outside, as they must decide for themselves) and it is only once the damage has been done that one can perhaps wonder whether it was worth doing it.

To conclude on the DTC industry, there are other areas that could be mentioned such as testing for athletic ability, genetically-adapted nutrition or medication etc. the industry is booming. However, the final type of tests discussed here are the medical genomic predictions, the most interesting aspect of the DTC industry as it raises the most delicate and difficult questions. In the public health sector, parents, embryos or fetuses would be tested for whichever list of pathologies the local region or country deems important to pre-empt (like the Down syndrome). In the private sector, adults send their DNA (or the one of their child) to a company and receive in return a table with a list of dozens of "hereditary" diseases and, next to it, a percentage or an estimate (low, medium, high) related to the possibility of contracting this disease in the future. Thus, medical genomic predictions propose an estimation of a risk for a future disease in order to either prepare for it, to eliminate fetuses or to select embryos prior to IVF. However, what does "preparing" for a disease after early detection actually mean? In reality, medicine cannot help us against most of the diseases that are part of these tests, apart from obvious lifestyle advice (diet, exercise) and medical monitoring. Preventive treatments are not numerous and gene therapies, already inherently problematic, are far from fulfilling their promises. Biotech-medicine pushes us to do predictive testing, but has little to offer to prepare ourselves for the fulfilment of its prophecies. What remains is the prospect of personalized genomic medicine, a fantasy that conveys the idea that supposed inequalities due to genetic differences could be erased individually. This narration speculates about a future access to specific individual drugs that will create some kind of total equality in front of diseases. In this way, the real social conditions that affect us are completely ignored. As Bliss comments: "Yes, being able to pop sociogenomically targeted drugs may liberate a person from stultifying depression or paralyzing rage, but it doesn't liberate people from the real social conditions that affect them. In fact, popping a pill will likely lead to pacification, and potentially depoliticization" (Bliss 2018).

3.3.3 Control and Subjectivation

What is at stake here is a shaping of the ways of thinking about our own bodies and health: a new mode of subjectivation based on essentialism, guilt and an overwhelming individual responsibility associated with a cruel lack of control over the world and our own situation. The strength of this shaping, because it mobilizes the medical aspect, is that it plays with these deep fears already mentioned: fear of illness, fear of suffering, fear of not knowing the future, fear that our children will get sick, fear of not offering them the best possible life, etc. One classic example is the breast cancer risk testing: the presence of certain versions of a particular gene is tested because the risk of breast cancer increases significantly depending on which versions of the gene is present or not. It is delicate to criticize the use of this kind of test. Who does not want to know more about their own risk of developing cancer? How can anyone compare these tests with eugenics? These are questions not to be ignored, and challenging the hegemony of *eugenetics* on our ways of understanding our bodies must acknowledge all the fears that it instrumentalizes. The question that matters is not necessarily whether people are right or wrong to do genomic prediction tests, but what are the imaginaries conveyed by these sciences, approaches and technologies (taken individually but above all included in their context)? If one chooses to focus on one explanatory field (genetics), what are the fields that are being made invisible? For the benefit of what or who?

These issues are clarified by Rouvroy's suggestion of the emergence of the mode of governance based on genetic risk information, which is "used as a means of creating the ideal citizen of the post-Keynesian order, that is, the autonomous citizen who makes no legitimate claims on nationally organized collective solidarity but rather exercises his/her capacity for choice and manages his/her own self-care." This mode of governance therefore becomes "a privileged disciplinary tool of post-Keynesian governance: it functions as a 'technology of the self', urging individuals to get the most information they can about their genetic status, to act 'rationally and responsively' after having been so informed, and to take responsibility for the genetic health of their blood relatives"(Rouvroy 2008). A process of ultra-individualization through which the genetic subject reinforces and is reinforced by neoliberalism's subjectivity. In the end, it is a world of statistics, models, algorithms, predestination and control that the Genetic Order promotes, echoing the cybernetic neoliberal project of control and risk management where everything must be engineered, modelled, monitored, predictable and transparent. What will be the impact on our lives, our affects, our relationships with others when, in the near future, genomic prediction will not only be in common use but socially structuring?

Conclusion: Against genetics and its world

Here we are at the end of this story. Let us go back to one of its main characters, the gene, the central entity of genetics—the science of heredity. For Pichot, the succession of the different nature/definitions of the gene, gradually stacked one on top of the other, denotes a glaring theoretical weakness and the intellectual impoverishment of a scientific community that clings to its dogma for mainly sociological and ideological reasons. The gene is such a volatile concept that it is then possible to affirm that modern genetics is a science without an object (Pichot 2002). It has only a few functions left. In addition to its original function of unifying the historical and physical explanations of organisms through the notion of heredity, its "role" has also been to steer biology in a direction very much influenced by the dominant political, ideological and economic interests and imaginaries of the epoch. Louart, in his work on the perception of living beings as machines, reached a similar conclusion: "today more than ever, the conception of the organism as a machine is irremediably linked to the fact that we live in a capitalist and industrial society: it reflects what the authorities that dominate society would like the organism to be, in order to be able to do with it as they wish" (Louart 2018, transl. by the author). By nourishing a pseudo-rational and all-powerful essentialist and mechanistic imaginary, by promising ever more predictive power, personalized medical treatments and increased industrial productivity, genetics emulates strong affects and amasses a phenomenal amount of funding, masking its theoretical weaknesses and its deadly endeavors.

For Kupiec and Sonigo (2000), genetics is a theory of heredity that breaks the material link between ancestors and descendants by substituting it with a virtual link (an information, a program) carried by DNA. But this virtual link cannot constitute an explanation of the reproduction of the similar because it implies the pre-existence of the structures of the organism, and therefore suggests a deterministic vision of the organism, where it is the result of a pre-established objective of the mechanisms of development and evolution: "Biologists have dreamed of an accessible, readable demiurge in the world of molecules" (Kupiec & Sonigo 2000). They have to give up this fantasy.

The Genetic Order has never ceased to be inspired and to nourish the harmful imaginaries of essentialism, eugenics, capitalism and cybernetics. Following Rouvroy's intuition, "genetic knowledge, or 'genetic truth discourses', and the currently experienced shifts in the modes of governance, are in a relationship of co-production" (Rouvroy 2008). Genetics deserves a special attention and radical criticisms. It provides us with a nefarious worldview and a framework of thought utterly limited to help us understand organisms and life in general. Should we try to change it from the inside, decenter it from its obsession with the gene and the DNA molecule to make it a science that makes more sense to the world we are living in and to the direction it needs to go? Or, as the Invisible Committee (2017) invites us to do with institutions, should it be *destituted*?

Acknowledgments

I would like to thank Dr. D. Shaw for her regular support, inspiration and help, including for this paper.

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