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MOLECULAR BIOLOGY IN A DISTRIBUTED WORLD. A KANTIAN PERSPECTIVE ON SCIENTIFIC PRACTICES AND THE HUMAN MIND

1. Kant's theory of biology: a cognitive turn

Although in his works Kant only occasionally refers to natural researchers and life scientists, he seems to be fully aware of the main findings and theoretical accounts about life and living beings that circulated in the eighteenth century. Moreover, Kant's thoughts about organized beings, teleology and the opportunity of a teleological approach in the life sciences still inspire scientists and theorists, in a time pervasively dominated by Charles Darwin's evolutionary account, as exemplified by Dobzhansky's famous *dictum* that «nothing in biology makes sense except in the light of evolution»[1].

Generally speaking, the interest of scholars in Kant's theory of biology has followed in recent years two main threads of research. On the one hand[2], scholars have focused on Kant's thoughts on organized beings to counteract a more and more evident shortcoming in contemporary evolutionary theory, namely, the removal of the concept of *organism*, «disappeared with the rise of the modern synthesis in evolutionary theory» and «replaced with the categories of gene and population, since evolution

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[1] T. Dobzhansky, *Nothing in biology makes sense except in the light of evolution*, «The American Biology Teacher» 35 (1973), 3, pp. 125-129.

[2] See for instance M. Quarfood, *Transcendental idealism and the organism: essays on Kant*, Stockholm, Almquist & Wiksell, 2004; M. Quarfood, *Kant on biological teleology: towards a two-level interpretation*, «Studies in History and Philosophy of Biological and Biomedical Sciences» 37 (2006), pp. 735-747; D.-M. Walsh, *Organisms as natural purposes: the contemporary evolutionary perspective*, «Studies in History and Philosophy of Science» 37 (2006), 4, pp. 771-791; A.A. Cohen, *A Kantian stance on teleology in biology*, «South African Journal of Philosophy» 26 (2007), 2, pp. 109-121; P. Huneman, Ch. Wolfe, Introduction to *The concept of organism: historical, philosophical, scientific perspectives*, «History and Philosophy of the Life Sciences» 32 (2010), pp. 147-154.

was defined as a process of change in allele frequencies within a population»[3]. In this sense, Kant's account of biology has been taken into consideration as a fundamental complement, able to add an (according to many scholars) missing piece in the field of contemporary evolutionary theory, under the assumption of a general homogeneity or, at least, a compatibility between Kant's theory of biology and Darwinian evolutionary biology.

On the other hand, Breitenbach[4], Ginsborg[5] and others have argued that Kant's theory of biology can be informative to contemporary life sciences precisely because it has nothing to do with Darwinian (empirical) evolution: it belongs to a meta-empirical level. In other words, in the frame of this second thread of research, scholars draw on Kant precisely because Kant's theory in question and evolutionary biology situate themselves at two absolutely different levels of discourse.

Both the first and the second thread, although adopting different perspectives, largely converge on the same point: a seemingly crucial relationship or, even, dichotomy between Kant's theory of biology and contemporary Darwinian biology, with particular attention being given to the concepts of teleology, function, organism, and their respective roles in scientific practice.

In the present paper, we attempt to provide an alternative perspective. Rather than asking what Kant's theory of biology can add (if any) to contemporary evolutionary theory or how evolutionary theory can benefit from a revival of interest in Kant's teleological account, we focus our attention on the epistemology of the life sciences and, more in particular, on the increasingly influential practices of molecular biology. Very generally speaking, molecular biologists "unravel the mystery of life" by identifying and elucidating different molecular mechanisms. It is fair to say, thus, that the concept of mechanism plays a central role within the field, as a number of philosophers have repeatedly remarked in recent years[6].

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[3] P. Huneman, Ch. Wolfe, Introduction to *The concept of organism* cit., p. 147.

[4] A. Breitenbach, *Teleology in biology: a Kantian approach*, «Kant Yearbook», 1 (2009), pp. 31-56.

[5] H. Ginsborg, *Oughts without intentions: a Kantian account of biological functions*, in I. Goy and E. Watkins (eds.), *Kant's theory of biology*, Berlin-New York, De Gruyter, 2014, pp. 259-274.

[6] See, most notably, P. Machamer, L. Darden and C.F. Craver, *Thinking about mechanism*, «Philosophy of Science» 67 (2000), 1, pp. 1-25.

Now, the main aim of our paper is, differently from the two main interpretative threads indicated above, to trace a connection between Kant's theses about the so-called "peculiar" or special nature of the human mind (*intellectus ectypus*), advanced in his third *Critique*, and some specific epistemological issues pertaining to the research practice of contemporary molecular biology.

In order to develop this argument, by examining the boundaries between Kant's third *Critique*, cognitive sciences and epistemology of the life sciences, we will structure the present paper as follows: in Section 1, we will concentrate on §§ 76, 77, and the *General remark on the teleology* in the *Critique of the power of judgment*, in which Kant describes how our (human) mind is structured and functions, drawing a thought-provoking comparison between the human discursive intellect (*intellectus ectypus*) and a hypothetical intuitive (divine) intellect (*intellectus archetypus*). In Section 2, we will briefly delineate epistemology of molecular biology, paying particular attention to the notion of "distributed cognition" and its role in the research practice of molecular biology itself and, additionally, bioinformatics. We will ask, in Section 3, how and to what extent it is possible to interpret Kant's *intellectus archetypus* as a *mechanical* model of the mind, by referring especially to McLaughlin *Mechanical explanation* [7] and, to some degree *Kant's Critique of teleology in biological explanation* [8]. Finally, in Section 4, we will point out interesting ways how this area can be further worked out, in particular, as far as Kant's philosophy of biology and its connections to his overall account of the human mind are concerned.

2. Ever since Kant: *intellectus ectypus* and *intellectus archetypus*

In two notoriously difficult sections of his third *Critique* (§§ 76 and 77), Kant contrasts our discursive intellect with a logical possibility of an intuitive intellect within the framework of general discussion on the principle of purposiveness. In that sense, Kant writes:

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[7] P. McLaughlin, *Mechanical explanation in the "Critique of the teleological power of judgement"*, in I. Goy, E. Watkins (eds.), *Kant's theory of biology*, Berlin-New York, De Gruyter, 2014, pp. 149-164.

[8] McLaughlin, P., *Kant's Critique of teleology in biological explanation. Antinomy and teleology*, New York, The Edwin Mellen Press, 1990.

> We would find no distinction between a natural mechanism and a technique of nature, i.e., a connection to ends in it, if our understanding were not of the sort that must go from the universal to the particular, and the power of judgment can thus cognize no purposiveness in the particular, and hence make no determining judgments, without having a universal law under which it can subsume the particular.[9]

The distinction between mechanism and teleology and the firm assumption that there is no «hope that there may yet arise a Newton who could make comprehensible even the generation of a blade of grass according to natural laws that no intention has ordered»[10], have in the special character of our (human) intellect their decisive rationale. «But if that is the case», Kant adds in § 77, then this idea of the "specialness" of our *human* understanding:

> must be based on the idea of a possible understanding other than the human one [...] so that one could say that certain products of nature, as far as their possibility is concerned, must, given the particular constitution of our understanding, be considered by us as intentional and generated as ends [...], thus without denying that another (higher) understanding than the human one might be able to find the ground of the possibility of such products of nature even in the mechanism of nature, i.e., in a causal connection for which an understanding does not have to be exclusively assumed as a cause. [11]

The distinction between the (human) *discursive*, image-dependent understanding (*intellectus ectypus*) and the logical possibility of a superior, intuitive understanding is described, into more details, as follows: whereas the *intellectus ectypus* (our human understanding) «goes from the analytical universal (of concepts) to the particular (of the given empirical intuition), in which it determines nothing with regard to the manifoldness of the latter, but must expect this determination for the power of judgment from the subsumption of the empirical intuition (when the object is a product of nature) under the concept»[12], the *intellectus archetypes*, instead, «goes from the synthetically universal (of the intuition of a whole as such) to the particular»[13]. Now, a few lines after

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[9] I. Kant, *Critique of the power of judgment*, ed. by P. Guyer, Cambridge, Cambridge University Press, 2000, p. 274 [AA 5: 404]. References to the *Akademie* edition (AA), by volume and page number, are reproduced in the margins of the 2000 Guyer and Matthews translation.
[10] *Ibid*., p. 271 [AA 5: 400].
[11] *Ibid*., p. 275 [AA 5: 405].
[12] *Ibid*., p. 276 [AA 5: 407].
[13] *Ibid*.

this distinction, Kant goes further with his account by describing the case of a "material whole" as it would appear to a non-human *intellectus archetypus*:

> if we consider a material whole, as far as its form is concerned, as a product of the parts and of their forces and their capacity to combine by themselves (including as parts other materials that they add to themselves), we represent a *mechanical* kind of generation. But from this there arises no concept of a whole as an end, whose internal possibility presupposes throughout the idea of a whole on which even the constitution and mode of action of the parts depends, which is just how we must represent an organized body. But from this, as has just been shown, it does not follow that the mechanical generation of such a body is impossible; for that would be to say the same as that it is impossible (i.e., self-contradictory) to represent such a unity in the connection of the manifold for every understanding without the idea of that connection being at the same time its generating cause, i.e., without intentional production.[14]

In a nutshell, a significant "limitation" distinguishes the functioning of the human understanding, and its cognitive performances. When it comes to the explanation of a particular part of nature, i.e., of so-called "organized", living beings, we are cognitively constrained to presuppose the idea of an end, «of a whole on which even the constitution and mode of action of the parts depends»[15]. A mechanical explanation of the biological entities seems not to be possible, and a *mechanical* human mind, as far as its structure and functioning are concerned, seems not to be possible either. This idea lies at the heart of Kant's characterization of the human understanding.

With this in mind, let's turn now to the burgeoning research field of contemporary cognitive sciences. In other words, our leading question will be the following one: what are the results from different areas of cognitive science telling us today about the nature and functioning of the human mind when faced scientifically with highly complex systems, particularly, in the biosciences? The next section aims at responding to that issue.

3. Distributed cognition

As a matter of fact, humans take their decisions and solve their problems relying on incomplete information: this is the way we generally accomplish our cognitive tasks in everyday contexts, al-

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[14] *Ibid*., pp. 277-278 [AA 5: 408], emphasis added.
[15] *Ibid*., p. 278 [AA 5: 408].

ways exposed to the possibility of gaining new pieces of information and, therefore, of revising our previous decisions and resolutions[16]. Our cognition is bounded, in a sense that is apparently not so far from Kant's idea of the "limitations" of human *ectypus* understanding, as has been pointed out above.

Now, some decisive developments in the research and practice of the life sciences, particularly in the field of molecular biology (genetics, genomics and bioinformatics) make this *standard boundedness* of the human cognition even more evident.

It is true, as many scholars have noticed, that the accomplishments of the Human Genome Project, with the rapid development of DNA sequencing techniques, have not unravelled all the mysteries of human and non-human life, contrary to scientists' expectations. However, nobody can deny that, with the HGP, we have entered a time of changes and revolutions that lasts up to current times.

Thanks to the astonishing advancements in DNA sequencing technology, scientists working in the fields of genetics, genomics and bioinformatics – an interdisciplinary area of biological research that uses computer sciences, statistics and mathematics as part of its methodology – have to deal with an unprecedented amount of data[17]. Data must not only be gathered, fused and organized in huge databases, but also analysed and interpreted in order to discover new knowledge. Even one of the most common research techniques in molecular biology, the so-called polymerase chain reaction (PCR), used to amplify a single copy or a few copies of a piece of DNA, reproducing it billions of times and utilized on a daily basis in labs, e.g., for diagnosing diseases and identifying viruses and bacteria, requires a large familiarity with databases and bioinformatics tools (particularly for the primer design phase).

It is fair to say that researchers working today in the field of molecular biology (with all its related sub-disciplines) need unprecedentedly high skills in *memory* (where to go and search for information, usually dealing with huge databases), *learning* (how to relate disparate pieces of information), *comprehension* (understanding how to use the correspon-

[16] See E. Bardone, *Seeking chances: from biased rationality to distributed cognition*, Heidelberg-Berlin, Springer, 2011.

[17] See O.A. Kuchar, J. Reyes-Spindola, and M. Benaroch, *Augmented cognition for bioinformatics problem solving*, in *Proceedings of the Augmented cognition International Conference*, NV, Las Vegas, 2005.

ding databases); and *decision making* (what all this information in fact means)[18].

In other words, scientists, when facing such a quantity of data, must heavily lean on their electronic supports, software and tools to accomplish their work, so that the quality of their scientific research would immediately drop down without them. Electronic devices (such as databases and software products) are *not* optional or ancillary instruments, but real *scaffolds* for scientific cognition. They make cognitive tasks easier or more efficient, to such a point that scientists would not be able to perform in the same way (fast and smoothly) without them[19].

It is worth noticing that, according to Ronald N. Giere, who has most thoroughly argued for a cognitive approach in the philosophical understanding of scientific practice, the vast majority of contemporary scientific research takes place in so-called *distributed cognitive systems*[20]. By focusing on the boundaries between cognitive sciences and philosophy of science, Giere argues that some new developments within the area of cognitive sciences provide a useful framework for rethinking general cognition in science. These new developments go under the label of "distributed cognition", a framework that, according to Giere's account, launches a bridge across the gap between constructivist (externalist) and cognitivist (internalist) explanations of the ways in which scientific research develops[21].

The "distributed cognition" framework, gradually emerging in the cognitive sciences during the past thirty years, can be traced back to different sources, among which we will just mention here, on the one hand, the work done in the early 1980s by McClelland, Rumelhart and their associates in the Parallel Distributed Process-

[18] *Ibid*.

[19] See Z. Liu, N. Nersessian, and J. Stasko, *Distributed cognition as a theoretical framework for information visualization*, «IEEE Transactions on Visualization and Computer Graphics» 14 (2007), 6, pp. 1173-1180.

[20] See R.N. Giere, *The problem of agency in scientific distributed cognitive systems*, «Journal of Cognition and Culture» 4 (2004), 3-4, pp. 759-774; R.N. Giere, *Distributed cognition without distributed knowing*, «Social Epistemology» 21 (2007), 3, pp. 313-320; R.N. Giere, B. Moffatt, *Distributed cognition: where the cognitive and the social merge*, «Social Studies of Science» 33 (2003), pp. 301-310.

[21] See R.N. Giere, *Scientific cognition as distributed cognition*, in *The cognitive basis of science*, P. Carruthers, S. Stitch and M. Siegal (eds.), Cambridge, Cambridge University Press, 2002, pp. 285-299; R.N. Giere, *The role of computation in scientific cognition*, «Journal of Experimental & Theoretical Artificial Intelligence» 15 (2003), pp. 195-202.

ing Group in San Diego, CA. This project focused on the similarities between networks of simple processors and the organisation and functioning of neural structures in the human brain. On the other hand, there is a project in the abovementioned area, which is concerned with the ethnographic studies of traditional "pilotage" undertaken by Edwin Hutchins and associates at UCSD in the mid-1980s. Hutchins' research, and his famous example of ship navigation[22], is especially worthy to be described here in more detail.

Hutchins describes the ship's navigation as an example of *distributed cognition*, where multiple agents (sailors and shipmen) are coordinated in accomplishing multiple tasks. No one human would be physically able, alone and without the support of engineering devices, to do all the tasks that must be done to fulfil the overall goal, in this case determining the position of a ship while approaching the port. Each sailor has his own task and uses specific instruments in coordination with the partners. What is more important, as Giere is emphasizing in his description of Hutchins' case study, none of the sailors has a grip on the problem as a whole, rather only on a limited set of aspects or component-parts. However, thanks to the distribution and coordination of different cognitive sub-tasks, the main task or overall goal of safely entering the port can be fully accomplished.

There is a clear similarity between Hutchins' case study, regarding the traditional pilotage, and more recent research practice in the biosciences, particularly in molecular biology and bioinformatics.

Today, massive scientific projects such as, for instance, the Human Genome Project (already accomplished), the Human Epigenome Project and the Human Microbiome Project (still underway) involve thousands of scientific collaborators, with specialized tasks and specific instruments at their disposal. None of the scientists working on the project can even aspire to get a grasp on the process as a whole (namely, on its "end", in a Kantian sense), but only on a restricted part of it. The cognitive tasks of gathering, fusing, organizing and interpreting bio-data are organized in a *distributed* way, adding locally new pieces of information without presupposing or requiring a comprehensive understanding of the corresponding research process in its entirety. Moreover, the research process is heavily based on, at all stages, external elec-

[22] See E. Hutchins, *Cognition in the wild*, Cambridge MA, MIT Press, 1995.

tronic devices such as computers, software products and electronic databases.

Bioinformaticians and molecular biologists obviously still deal with "animals" and "plants", that is – in Kant's main terminology – with "organized beings", but the distributed nature of their cognitive tasks preclude any possibility, for them, to grasp that peculiar interdependence between the parts, or the "special" arrangements of the component-parts within the whole that, according to the third *Critique*, constitutes the main feature of our knowledge of biological organisms in general. Bioinformatics evokes today an idea of biological knowledge as a non-individualistic, extended and distributed process. How and to what extent can these new advancements in the life sciences relate to Kant's basic characterization of the structure and functioning of the human mind as described in Section 2 of the present paper?

4. Back to Kant: mechanism and distributed cognition

Over the course of the past years, philosopher of science Peter McLaughlin has offered insightful and thought-provoking perspectives on the notions of mechanism and mechanical processes in the *Critique of the power of judgment*, arguing that «many of Kant's remarks suggest that he means by mechanism a specific kind of causal relation, namely the determination of a whole by its part»[23]. According to McLaughlin, to explain a natural object mechanically means to explain the way in which its parts determine the object as a whole: «a mechanical explanation means the reduction of a whole to the properties (faculties and forces) which the parts have "on their own", that is, independently of the whole»[24].

Now, we have seen in Section 2 that the main feature of our human discursive understanding is that it must presuppose a whole (as an end) in order to be able to make sense of biological entities and their behaviours. In other words, our understanding is such that the parts of an organism (its organs, for instance) can be explained only by the reference to the whole to which they all are related. As the discursive and intuitive intellects are, Kant

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[23] P. McLaughlin, *Mechanical explanation in the "Critique of the teleological power of judgement"* cit., p. 154.

[24] P. McLaughlin, *Kant's Critique of teleology in biological explanation* cit., p. 153; for a criticism of McLaughlin's position see, for instance, A. Breitenbach, *Kant on causal knowledge: causality, mechanism and reflective judgment*, in Allen, Keith and Stoneham, Tom (eds.), *Causation and modern philosophy*, London, Routledge, 2011.

says, opposite to each other (see §§ 76 and 77 of the third *Critique*), we may conclude from this that the main feature of the *intellectus archetypus* consists in being able to determine the whole by its component-parts (instead of the parts being determined by the whole, as our *intellectus ectypus* is constrained to do so). In other words, as suggested by McLaughlin, we may conclude that the *intellectus archetypus* works *mechanically*. It seems to be the prototype of a mechanical model of the mind.

While explicating into more detail his interpretation of the notion of mechanism in Kant's third *Critique*, McLaughlin also puts forward an example that turns out to be suitable and significant for the approach advanced in the present paper. Namely, he remarks that practical mechanics, as used in manufacturing, presupposes that the component-parts produced «will have precisely those properties in the machine that they had before they were put together to make the machine and that the parts of a machine, do not lose any properties when the machine is taken apart»[25].

The process highlighted by McLaughlin shows impressive similarities with what commonly happens within the field of bioinformatics and molecular biology. Researchers involved in massive cognitive endeavours such as, as already mentioned, the project of human genome sequencing, fulfil tasks that have their own properties and value in themselves, all the more so as the "whole" to which these tasks in principle belong, is unattainable by the scientists themselves (considered as singular, individual minds). None of the bioinformaticians or molecular biologists working on the project is able to gain a global vision of the research process as a whole, in its "material" unfolding. The Human Genome Project, as mentioned in Section 3, requires and witnesses a super-individual and mechanical (in Kant's sense) form of cognition.

This allows us to make the final step, drawing concluding remarks from what we have discussed so far.

5. Concluding remarks

We argue that contemporary bio-scientists, doing their research in the cognitive distributed systems, heavily leaning on external electronic devices and with no possibility to get a comprehensive view of the research process as a whole, may collectively count as a peculiar instantiation of Kant's mechanical *intellectus archety-*

[25] P. McLaughlin, *Kant's Critique of teleology in biological explanation* cit., p. 153.

pus. A super-individual, distributed, collective, mechanical *intellectus*, where the whole, as McLaughlin claims, is reduced to the cognitive faculties, which the corresponding parts have on their own, i.e., independently of the whole.

Organisms raise difficulties for any mechanistic account only under the assumption that an *intellectus ectypus* is at work. However, once it becomes clear that the life sciences allows a *distribution* of the cognitive tasks among several actors, both human and non-human, and a substantial *extension* of the human cognition on external, non-human devices, could it be the case that Kant's *intellectus archetypus* comes down from its apparently unattainable pedestal?