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Introduction

> So what hinders the different parts [of the body] from having this merely accidental relation in nature? As the teeth, for example, grow by necessity, the front ones sharp, adapted for dividing, and the grinders flat, and serviceable for masticating the food; since they were not made for the sake of this, but it was the result of accident. And in like manner as to the other parts in which there appears to exist an adaptation to an end. Wheresoever, therefore, all things together (that is all the parts of one whole) happened like as if they were made for the sake of something, these were preserved, having been appropriately constituted by an internal spontaneity; and whatsoever things were not thus constituted, perished, and still perish.[1]

Charles Darwin inserted this extraordinary passage from Aristotle's *Physics* in a long note in 'An Historical Sketch of the Recent Progress of Opinion on the Origin of Species' with which the fourth edition of the *Origin of Species* (1866) opens, commenting: 'We here see the principle of natural selection shadowed forth, but how little Aristotle fully comprehended the principle, is shown by his remarks on the formation of the teeth.'[2] With this brief comment, very cautiously, Darwin partially transposes and then translates the ancient intuition on adaptation, extinction and randomness into the new-born system proposed by the theory of descent with modifications by variation and selection. Aristotle is thus explicitly counted among the precursors of the concept of evolution in the text which was about to irrevocably change the destiny of contemporary biology.

The interpretation proposed, however, not only errs on account of its partiality, but also represents a memorable oversight. It is true that the text contemplates the possibility of extinction and the birth of new

species, which Darwin interprets in terms of the principle of natural selection. However, in addition to this, it also lays out a heuristic template that rests substantially on the idea of explaining natural processes as random. Thus, a random combination of organs leads either to the generation of adapted individuals – that is, of species that preserve themselves – or to the generation of non-adapted individuals – that is, of species that become extinct. It is randomness that is Aristotle's main theme here. Darwin's interpretation is, therefore, partial.

Darwin's interpretation, moreover, demonstrates a memorable oversight because when the passage is drawn to his attention – by way of a letter from Clair James Grece[3] – he completely mistakes the origin of the ancient intuition, most likely because he had never opened Aristotle's *Physics*.[4] The notion that contemplated the extinction of species and thus 'shadows forth' the principle of natural selection is not Aristotle's, but Empedocles'; in fact, in its entirety the last phrase of the quoted passage reads: 'and whatsoever things were not thus constituted, perished, and still perish, as Empedocles says of his "man-faced oxen".'[5] Actually, here, Aristotle is discussing Empedocles' biological theory in order to subject it to a ferocious critique aimed at demolishing its basic presupposed theoretical principles. The systematic recourse to randomness had to be proscribed, or rather marginalized, in favour of an eminently finalistic approach. More precisely, the priority given to the search for 'final causes' was emphasized, as emerges unequivocally from what follows immediately after the passage cited by Darwin:

> Such and suchlike are the arguments which may be urged in raising this problem; but it is impossible that this should really be the way of it. For all these phenomena and all natural things are either constant or normal, and this is contrary to the very meaning of luck or chance. [...] Accordingly, if the only choice is to assign these occurrences either to coincidence or to purpose, and if in these cases chance coincidence is out of the question, then it must be purpose. But, as our opponents themselves would admit, these occurrences are all natural. There is purpose, then, in what is, and in what happens, in Nature.[6]

This is an argument that – as we shall see in Chapter 1 – is nothing but a restatement of the solidly teleological orientation at the basis of the entire Aristotelian naturalist edifice, both in physics and in life sciences, centring on the thesis that 'all provisions of nature are means to an end, or must be regarded as coincidental to such means.'[7] In short, in all his treatises Aristotle never tires of repeating that nature does nothing in

vain, nothing useless, nothing superfluous, nothing random, nothing without a purpose; hence the affirmation of the age-old motto *natura nihil frustra facit* (nature does nothing in vain). It is a motto that should be understood not so much as a general regulatory principle of enquiry but rather as a fundamental theoretical presupposition. Every part, every organ of every living being has an explicit end; therefore, analysis must always strive to demonstrate that everything is useful directly, or indirectly, for a specific purpose. The paramountcy of the principle of utility is established. In Aristotelian terms, it is always the 'final cause' that must be identified.

This teleological framework rests in turn on a second presupposition, concerning the structure of the overall system of living species, according to which nature has made, and then distributed, organs to each species with the aim of ensuring its preservation. Indeed, Aristotle considers and then reaffirms the classical notion that nature, behaving like a wise man, adopts a pseudo-egalitarian criterion for the distribution of 'means of defence' – that is to say, of organs and mental faculties so that all living species are able to preserve themselves over time notwithstanding constant conflicts between them (predators *versus* prey, and so on). What follows is a static and harmonious equilibrium which precludes, *pace* Empedocles, the possibility of any species becoming extinct. This permanence is further supported, on an ontological level, by the so-called 'essentialist' thesis, according to which each species can be traced back to an unalterable and unengenderable essence, given always and forever – thus fixed for eternity – which is passed down (through semen) from generation to generation. Essentialism thus radically marginalizes the epistemic significance of contingent and random variations observed in generational processes.

In short, when, in undertaking an enterprise of such momentous importance, Aristotle proceeded to construct the life sciences from scratch, he developed an extraordinary naturalist edifice of great analytical complexity and theoretical refinement. At the same time, he created the openly anti-Empedoclean teleological, essentialist and fixist framework, which Darwin's theory subverts. The closer Darwin may be to Empedocles's intuition, the further away he is from the theory effectively outlined by Aristotle. In other words, while, with regard to Empedocles, we may be dealing with a meaningful but actually rather vague convergence, with regard to Aristotle, the distance is clearly defined and on deeper analysis is revealed to be a direct counter-position. Schematically, the three core elements of the theory of descent with modifications by variation and selection give a clear and precise

negation of the three cornerstones of the Aristotelian framework. (1) The descent with modifications thesis is set against the ahistorical thesis of the fixity of species. (2) The appreciation of individual variations is set against anti-random essentialism. (3) The recourse to natural selection, and so to extinction, is set against immanent functionalist organs/ends teleology and its systemics. It is precisely this radical counter-position that makes Darwin's oversight so significant and interesting, in the first instance, on a historiographical level.

Darwin's misunderstanding throws light, in an extraordinarily emphatic way, on the nineteenth-century disavowal of the fact that the traditional fixist, essentialist and teleological framework had Aristotelian roots. The disavowal is based on eighteenth-century scientific culture, when the influence of the Peripatetic treatises had become ever more indirect. This was because it was being exerted increasingly through the writings of sixteenth- and seventeenth-century authors, such as Cesalpino and Harvey – all openly Aristotelian – and then through naturalists, such as Ray and others, in whom it was partially clothed in a markedly theological disguise. This disavowal and disguise in the late seventeenth century is attributable to many factors. Amongst others, there was the decline in the authority of Aristotle as a natural scientist occasioned by the great seventeenth-century scientific revolution, as well as the revival of the centrality of creationist dogma within the framework of natural history. This long-term process continued into the twentieth century. Despite the fact that in the last decades of that century many contributions emerged showing how, in the realm of the life sciences, the Aristotelian framework was still very much alive throughout the first half of the seventeenth century (see the works of Pagel, Schmitt and Berti), very little was written on the influence, direct and especially indirect, that Aristotle exerted on natural theology and on the overall conceptual framework of traditional natural history in the eighteenth and nineteenth centuries. Indeed, most of these studies concentrate in particular on the positive impact of the Aristotelian tradition on the seventeenth-century progress in the life sciences, starting from their appreciation of observation, cardiocentrism and epigenism – the influence of the latter orientation was actually also analysed in the eighteenth century. However, the dialectic between the late seventeenth- and then eighteenth-century heritage of the theoretical Peripatetic system in its entirety and the emergence of transformist and evolutionary theories that signalled its demise, has hardly ever been tackled. What I hope to achieve with this work is to contribute to the reconstruction of this development in its entirety.

I will proceed from the basic thesis that (a) the conceptual system, the template, or what I prefer to call the framework, which almost uninterruptedly determines the course of modern natural history up to the birth of evolutionary biology is of an Aristotelian mould, and that (b) the evolutionary revolution is therefore to be interpreted as the abandonment and overturning of this framework. This approach immediately implies a revision of the classic argument of the perfect and exact correspondence between fixism and creationism in favour of a more nuanced vision of their convergences, which rests on a broader reconstruction of the traditional fixist framework, both in theoretical and historiographical terms. When the historical perspective is opened up, so as to proceed from the origins of the traditional concept, it becomes clear that its cornerstones rest rather on the reception and reinterpretation of the Aristotelian treatises begun by late medieval Scholasticism and revived in the Renaissance. In more detail, I will try to show that it was primarily on the theoretical and conceptual structure (teleology, essentialism, fixism, and so on), on the analytical and doctrinal apparatus (empirical observations, classifications, dissections, and so on), and on the categorical equipment (notions of 'species', the form/material dichotomy, and so on) of the life sciences forged by Aristotle that the multiple variants of late medieval and Renaissance creationist doctrines and, especially indirectly, eighteenth- and nineteenth-century natural theologies were projected, re-modulated and readapted.

The idea that will be my guiding light in this is that it is not the meagre Old Testament conceptual apparatus, nor least of all its literal interpretation, that provides the principles, the tools and the methods utilized to re-establish and develop natural history throughout the course of modernity. Under a more or less thick religious skin, the theoretical kernel remained as Aristotle had devised. What this means is that I do not share the classic historiographical thesis that tends to consider the dogma of creation the most important element in the overall theoretical framework of the traditional fixist vision. The creationist dogma, although absolutely central throughout modernity, did not invalidate the Peripatetic system. On the contrary, it was reconciled, from the thirteenth century onwards – as happened in the realm of physics – with the atemporal and eternalist structure derived from the 'photographic' approach also adopted by Aristotle in his treatises on living things. The entire system of species, like the order of the cosmos, continued to be understood as fundamentally static, governed by an overall equilibrium which guaranteed forever the preservation of each species, whose adaptation to their own environment nature had wisely provided for. It was

always against this teleological nucleus, around which the concept of the 'admirable adaptation' of species was developed, presented moreover in the religious guise of natural theology, that the first transformist and evolutionary theorists, Darwin included, had to measure themselves. By adopting this historical perspective, the direct contraposition of Darwinian theory and Aristotelian concept which we began with is therefore configured as an overturning of the teleological, fixist and essentialist tradition.

Now, this reinterpretation of the general course of modern natural history and of the evolutionary revolution, undertaken from the perspective of the centuries-old persistence and then abandonment of the Peripatetic heuristic teleological apparatus, opens up several promising, relatively unexplored, avenues both on the historiographical and theoretical fronts. I will attempt to develop them gradually, proceeding with a rigorously chronological reconstruction, from the past to the present, from Aristotle to Darwin, in the hope that the succession of topics and lines of argument may be more linear, more fluid and easier to follow. For greater clarity I have divided the text into two parts: Part I is dedicated to an outline and acknowledgement of the supremacy of the teleological framework driving the modern Aristotelian tradition from its original foundation to its late medieval revival, and on to Linnaeus' eighteenth-century *systema*. It is a trajectory that, having outlined the structure of the Peripatetic edifice, I will rapidly retrace: I will consider only some of the authors that I believe are expressions of scientific-philosophical tendencies and long-term schools of thought. Part II is dedicated to the scientific milestones which led to a (partial and relative) resolution in Darwin, due to the crisis the traditional framework underwent in the eighteenth century, especially in the debate between Lamarck and Cuvier. Here, I concentrate mostly on the framework of the theory of descent with modification in relation to the heritage of ancient teleology. My approach ultimately leads me to a brief overview of the fundamental revisions effected in the twentieth century of the system of the *Origin of Species*. The two parts each contain three chapters, arranged as follows.

In Chapter 1, starting from the criticism levelled at Empedocles, I will briefly reconstruct the theoretical framework of the life sciences devised by Aristotle. I will especially concentrate on the three pillars that would be inherited by modern natural history: the thesis on the fixity and immutability of species over time; the correlated essentialist concept, which systematically marginalizes the theoretical role of randomness; and the teleology immanent in nature. I will concentrate on this last

element in particular. In fact, teleology represents the fundamental pillar upon which Peripatetic physiological anatomy is constructed, centring on the idea of the solid and atemporal correspondence between organs and functions and thus also on the priority accorded to functions. Furthermore, I will sketch the related systemic concept underlying the empirical analysis, according to which living species are in a harmonious equilibrium that precludes their extinction. Species are distributed along a *scala naturæ* at the top of which stands humankind. While tracing these coordinates, at the same time, I will focus attention on the question of the inutility or indeed harmfulness of certain organs discussed in the ancient treatises, such as the wings of flightless birds, the unseeing eyes of the mole and the antlers of deer. These were themes which posed serious problems for Aristotle, and for which he never managed to find a perfectly coherent solution, thus leaving lacunae, tensions and even contradictions nestling at the heart of his system. And it was these identical questions that were taken to heart, after many centuries, by the young Darwin, who used them as a tool to undermine the ever-pervasive recourse to final causes in the new-born science of 'biology'.

In Chapter 2 I will come to the late medieval and modern Aristotelian tradition. I will proceed here from the thesis that, exactly as in the case of physics and astronomy, Western life sciences were re-established thanks fundamentally to the reception, assimilation, institutionalization, reinterpretation and conciliation with the creationism of the theoretical, categorical and doctrinal apparatus gleaned from the *corpus aristotelicum* which occurred especially from the thirteenth century onwards. I will therefore depart again from the classic and almost undisputed historiographical thesis that the natural sciences were reborn as Aristotelian sciences, and remained so until about the middle of the sixteenth century, to concentrate instead on the life sciences. I will give a brief overview of the development of life sciences until the late sixteenth century, to then concentrate on the radical separation of these sciences from physics and astronomy.

I will show in detail how the criticism put forward by Galileo of the epistemological framework of Aristotle's physics revolved particularly around an endorsement of mathematization (in many ways of a Platonic nature). Galileo's approach was one that was not efficaciously transposed – despite reiterated attempts on the part of the Cartesians – to the realm of living things, as is crystal clear in the methodological nature of Harvey's revolution, and more generally in his contributions to physiology. Harvey in fact returned to and explicitly revived the

teleological framework developed by Aristotle, linking it to a distinct experimentalism, so bringing it up to date in a Galilean sense too. This was the system that remained predominant, although no longer exclusive, in the life sciences.

In Chapter 3 I will proceed rapidly with a reconstruction of certain turning points along the path taken by modern natural history, concentrating on the period that stretches from about the middle of the seventeenth century to the middle of the eighteenth century, continuing to proceed from the perspective of the influence of the Aristotelian apparatus. I will maintain that it held an indirect supremacy: even though there was a process of gradual disavowal and in a certain sense repression of the Peripatetic paternity of the traditional teleological, fixist and essentialist framework, its theoretical nucleus continued to remain the original Aristotelian one. I will deal first with Ray, showing how his natural theology fundamentally represents a form of 'Christianised Aristotelianism' (as John Greene defined it).[8] I will then move on to Linnaeus' *systema*, again highlighting the principal lines of continuity between his concept of *œconomia naturæ* and the Aristotelian heritage, despite the ruptures and novelties introduced by the great eighteenth-century naturalist.

So, in Part I, I will try to show that in the realm of the life sciences the theoretical pillars of the Peripatetic edifice, regrafted on to Western culture in the late medieval period and revived in the Renaissance, survived not only Galileo's breakthrough, but also the entire seventeenth-century scientific revolution, to arrive, renewed in an experimental sense, at the eighteenth century. In other words, disregarding an analysis of the mathematicizing tendencies of the Cartesians, which I consider relatively marginal with respect to the path followed by the majority of the protagonists of natural history, I will try to support the thesis that the persistence of the fixist, essentialist and especially teleological framework which extended up to the first transformist and evolutionary theories can, and in my opinion must, be interpreted as a long-term effect of post-Renaissance Aristotelianism, as an expression of the *longue durée* of this framework. It amounts to an attempt to relocate it within the grand traditions of thought that determined the coming into being of the life sciences from the late Middle Ages, passing through the seventeenth-century revolution, up to the late nineteenth century.

In Chapter 4, which opens Part Two, I will sketch the main turning points in the crisis of the Aristotelian framework, in a certain way emerging around the middle of the eighteenth century on philosophical ground from authors such as Maupertuis and La Mettrie, but then

triggered in fact by the transformist theories proposed by the naturalists, in the strict sense of the word, in the following decades, and exacerbated at the dawning of the nineteenth century by the contributions of Lamarck. Concentrating on the negative aspect of this process of abandonment, I will show that Lamarck's work can also be reinterpreted as an attempt to demolish the traditional fixist, essentialist and teleological framework to be found in the Aristotelian heritage. I will then emphasize how, despite these repeated attacks, the fixist system continued to play a leading role in the international community until around the middle of the nineteenth century. In this regard, I will adopt the concepts of 'crisis' and 'hegemony' to underline the fact that we are dealing with a now only relative supremacy, reaffirmed from time to time through bitter conflict between antithetical positions regarding the theoretical cornerstones of the edifice of natural history. I will concentrate in particular on the spirited defence of the fixist system undertaken by Cuvier, who comes to represent the last great heir and exponent of the modern Aristotelian tradition. With the adoption of a historiographical perspective centred on the long-term persistence of the Peripatetic system, it will become possible to elucidate the vicissitudes of so named 'fixism'. It will also then be possible to trace the process from the indisputable supremacy of fixism to the crisis which befell it, and which was initially only partially resolved by its revival.

In Chapter 5, moving from France to England, I will try to reconstruct the main stages of the process by which Darwin, picking up the threads of the crisis in which the fixist thesis had landed itself and so reworking the previous transformist contributions (from Erasmus Darwin to Lamarck), arrived at an original solution to the classic question of 'admirable adaptation'. This is a problem concerning the theoretical nucleus which was incessantly reintroduced by natural theologians especially in the Anglophone world. It is indeed the tradition reintroduced in the late seventeenth century by authors such as Ray and taken up again at the beginning of the nineteenth century by Paley and others. In this regard, I will show how Darwin's overcoming of this classic question amounts substantially to the elaboration of a framework capable of eclipsing the functionalist and systemic teleological system originally conceived by Aristotle and then inherited and developed in modernity.

Close up, we shall see how the young Darwin originally discussed his first intuitions of the mechanism of natural selection in the literal sense of a 'final cause' and how he at the same time expressed a strong resistance, along the lines of Bacon, to readopting such an instrument. This resistance, in a very brief period of time, took the form of a theoretical

battle against the pervasive recourse made to final causes. This battle was developed above all in terms of an epistemic appreciation of those aborted and atrophied organs bearing, that is, the 'stamp of inutility'. Darwin thus understands these organs as direct evidence of the 'absence of final causes' and thus, more generally, of the inadequacy and contradictoriness of traditional natural theology. The latter, which thus has recourse to 'final causes', betrays the fact that it contains within itself, as its basic theoretical nucleus, the ancient finalistic concept devised by Aristotle.

In Chapter 6 I will focus attention on the teleological character attributed to one of the meanings of the principle of natural selection, rereading it in the light of Aristotelian theory. Here, I will propose a reinterpretation of the classical convergences observed between Darwinian selection and Peripatetic teleology (see especially the work of Lennox and Gotthelf) not as evidence of the currency of Aristotle's thinking in the evolutionary context but rather as theoretical archaisms: signs, traces of the process of gradual abandonment of the framework and traditional conceptual apparatus that develops in the course of the construction of the theory of descent by modification. While again recalling the ambivalence shown by the young Darwin with regard to the discussion of final causes, I will show it was especially the systematic recourse to extinction that rendered his juvenile orientation ever more obsolete. I will come to some of the twentieth-century revisions made to the teleological character of Darwinian selection and to the full re-evaluation of randomness reintroduced by 'modern evolutionary synthesis' (that is, the theory generated by combining genetics and Darwinism) and never abandoned since. I will conclude with a very brief discussion of the teleologism of the contemporary adaptationist programme (along the lines laid out by Gould and Lewontin).

So in Part II, I will try to reconstruct the profile of the evolutionary revolution, from a negative point of view, as a process of gradual overturning of the theoretical framework conceived by Aristotle and guiding modern natural history. This is a breakthrough that would come to be reconfigured, with respect to the seventeenth-century scientific revolution, as a diachronic detachment from the self-same original theoretical stock, but that was achieved thanks to a fundamentally historical, and not mathematical, approach. I will insist in particular on immanent critique, developed on the level of physiological anatomical analysis, with regard to the recourse to final causes and on the level of the related principle that *natura nihil frustra facit*. It is criticism that contemplates an endorsement of randomness. This is a perspective which at the same

time as it recalls the two axes of historicity and randomness, precluded by Aristotle's system, I believe allows us to reinterpret the evolutionary revolution – borrowing the celebrated definition by Alexandre Koyré of the seventeenth-century revolution in physics as 'the revenge of Plato',[9] and retaining the sense of the Darwinian quotation from the passage from *Physics* – as 'the revenge of Empedocles'.

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