DARWIN'S TWO HUNDRED YEARS: IS NOT TIME FOR A CHANGE?

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ABSTRACT. Two hundred years after Darwin's birth, the evolution of living systems is an accepted fact but there is scope for controversy on the mechanisms involved in such a process. Mainstream neo-Darwinism champions the role of natural selection (NS) as the fundamental cause of the evolutionary process as well as of random, contingent events at the genetic level as the main source of variation upon which NS performs its causal role. Thus, according to neo-Darwinism the course of biological evolution is quite unpredictable and the past can only be partially reconstructed by means of a historical narrative. This second-class status for biology within the natural sciences as a merely descriptive, historical science results from the chronic neglect of biological form in the neo-Darwinian discourse. Hereunder I discuss the need for reintroducing form as the central object of biology, aiming at the identification of the general and fundamental principles of biological form. Such a formal biology may go beyond simple historical description achieving a complete, rational explanation of how previous and current morphologies corresponding to identifiable species were established, and so providing a rational foundation for predicting the possible outcomes of future biological evolution on earth and perhaps elsewhere in the universe.

KEY WORDS. Neo-Darwinism, natural selection, form, constraint, history, contingency, necessity, possible, morphology, nomothetic, systematic.

INTRODUCTION

One hundred and fifty years after the publication of Darwin's *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*, the evolution of life forms is an accepted scientific fact and yet there is scope for controversy concerning the mechanisms involved in such a process. According to Darwin and his many and varied followers that have produced further and modified versions of the theory of evolution, natural selection (NS) is the fundamental, if not the only, mechanism responsible for the appearance, diversification and modification of species along the history of life on earth. For Darwin and

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the apostles of the modern synthesis or neo-Darwinism, that blends the notion of NS with the study of population genetics, NS is a sort of creative agent that directs changes in living species, orients chance and gradually produces more complex living structures and new species. At the core of mainstream Darwinism is the notion of contingency playing a determining role in the course of evolution in such a way that the future of evolution on earth is rather unpredictable, as the past was also the result of the peculiarities of earth's history. This means that we can only get an incomplete, paleontological and thus historical account of how and when the current and past species came into being, based on the rather discontinuous fossil record and some molecular data processed according to contrived assumptions, leading to myriad remakes of Rudyard Kipling's *"Just so stories"* for children, those that tell us how the whale got his throat, how the camel got his hump or how the leopard got his spots, no matter if several of these "just-so-stories" that populate the pages of academic publications come disguised as abstract dissertations with plenty of equations and mathematical paraphernalia.

Thus, evolution *à la* Darwin is basically a historical (if not a *'storical'*) science, marred by some longstanding inconsistencies such as the lack of a unified and consistently accepted definition of NS (which is a must if we pretend to study and measure the effects of such a vaguely-defined agent on evolution) or the lack of consensus about the actual level or unit upon which the action of NS occurs. Indeed, it has been pointed out that in the current Darwinian literature circulate at least four different definitions of NS: a) Differential survival or preservation of individuals. b) Differential reproduction. c) Alteration of gene frequencies. d) Differential elimination of individuals [1]. The first definition is very much the one sponsored by Darwin. The second is the mainstream definition sponsored by the so-called modern synthetic theory of evolution. The third is the province of mathematical evolutionists, and the fourth is the consequence of overwhelming evidence indicating that most changes at the genetic level, that means mutations, are selectively neutral and appear as a consequence of molecular and physical constraints acting on the genetic material (DNA), meaning that evolution understood as change at the level of genes is mostly a neutral, unselected process [2]. However, this last definition considers NS merely as a sieve for eliminating deleterious mutations and favoring the propagation (reproduction) of beneficial ones, thus almost completely eliminating the directing or creative role for NS implicit in the first two definitions. Extollers of neo-Darwinism fight against any attempt to consider further factors intervening in the process of evolution that may brought down NS from its traditional role as the fundamental cause of evolution, as exemplified by Ernst Mayr statement that "the proponents of the synthetic theory maintain that all evolution is due to the accumula-

tion of small genetic changes, guided by natural selection, and that trans-specific evolution is nothing but an extrapolation and magnification of the events that take place within populations and species [3]." On the other hand, the unit of selection has been variously ascribed, depending on the particular evolutionary narrative involved, to the individual (Darwin himself supported this view), to the species or group, or to the kin of individuals sharing a common genotype and ultimately to the gene itself in the most radical versions of neo-Darwinian fundamentalism [4].

DARWINISM, A THEORY FOR ALL SEASONS

It has been recently argued that the Darwinian theory of evolution by NS is a theory moving with the times adapting itself to the new challenges posed by new biological data, and so it is ready to be applied for studying the evolution of complex adaptive systems such as human societies, based on the claim that societies are constituted by many different independent replicators (biological individuals and cultural elements) each with its own strategies for reproduction and survival [5]. Hence evolution by NS is a multifarious device that may be applied to no matter what system or problem in an *ad-hoc* fashion. It is worth remembering that this all-embracing versatility of NS has led to the publication of 'scientific' papers suggesting that Aztec human sacrifice arose as an adaptive solution to chronic shortage of meat protein in pre-Columbian societies, since the limbs of victims were often ritually eaten by members of the high-classes [6], and this rather strange hypothesis has been further used to illustrate the existence of an adaptive, genetic predisposition for carnivory in humans [7]. The absurdity of these adaptationist narratives was pointed out by Gould and Lewontin in a famous paper that faults the adaptationist program for its basic failure to distinguish any possible current utility of a given trait from the reasons for the origin of such a trait [8]. For example, from the strict adaptationist position both courage and cowardice can be adaptive behaviors to the challenge posed by war. Thus, in a typical *post-hoc* neo-Darwinian narrative the courageous survived because he was able to kill the enemy before being killed, but the coward also survived because as soon as the battle began he dumped himself in a hole in the ground pretending to be dead and so was spared by the violence that killed a lot of those who marched against the enemy positions. Therefore, both the hypothetical genes for courageousness and cowardice will be highly represented in the next generation descending from such surviving soldiers, although we have no real clue about the origin of such behaviors. Moreover, as plausibility becomes the only criterion for accepting adaptationist narratives, we come to the problem of what would happen if there were infinite numbers of potential niches or ways of life for organisms to fill. Under such a

situation it cannot be argued that a given species is adapted to a given environment, because anything could do well.

Certainly it is thanks to Darwin that evolution is a currently important scientific topic, and it is impossible to deny that evolution, understood as change, among individuals of a single species, occurs and that some of these modifications may be adaptive such as the changes in beak shape that adapt a specific bird to a specific food [9]. These adaptive modifications within populations over time constitute the domain of microevolution resulting from a process of continuous and gradual change, and perhaps such microevolution represents the true explicative domain of Darwinian theory. However, the origin of new, morphological different species and divisions of taxonomic hierarchies above the species level, as well as the origin of complex adaptations such as the wing or the vertebrate eye, constitute macroevolution, which is the domain that holds the really crucial biological questions. Macroevolution is a daunting problem for Darwinism that predicts gradual transitions between the small-scale adaptive changes and these large-scale phenomena; besides, there is little evidence of these transitions in nature, since the fossil record has many gaps or discontinuities. While, higher taxonomical ranks are separated by gaps without evidence of a transition between them [10]. Great morphological innovations like wings and eyes are fully formed and working in current organisms without hard evidence of intermediary structures that may provide an idea of how such finished structures evolved. For example, a website concerning the evolution of dinosaurs says the following about the evolution of wings:

> Wings evolved over many, many millions of years. Scientists have extensively studied the wings of modern-day birds and have identified many important anatomical details. Especially important are those not found on the "arms" of non-birds. Major efforts have gone into finding early occurrences of such details in the fossil record, but unfortunately it is far from complete. Wings generally have thin, hollow bones that do not fossilize well and it appears that few of the animals that had them died in environments suitable for fossilization. The lack of fossils makes it difficult to establish the time that each feature first appeared. The times listed below are documented, but do not reflect an even progression from one step of development to the next. (www.dinosaur-world.com/feathered_dinosaurs/wing_evolution.htm).

The previous narrative is typical of Darwinian literature that dispels its many inconsistencies by continuously appealing to *ad-hoc* explanations, such as the suggestion that animals with hollow bones died in environments not suitable for fossilization. It also quotes without any critical comment the fact that the estimated time-line of fossils that are thought to represent steps in the evolution of wings plainly contradicts gradualism

in the evolution of wings, as exemplified by the fact that *Archaeopteryx* the earliest known bird dated between 150-148 mega-years precedes by several million years the appearance of dinosaurs like *Sinosauropteryx* and *Velociraptor* that in their forelimb bones have partial structures apparently homologous with some found in the wings of birds and, that notwithstanding, their post-*Archaeopteryx* appearance on earth, are offered as examples of structures precursors of wings! As it has been pointed out, the discontinuous appearance and disappearance of taxa in the fossil record constitutes the evidence of the great divide between microevolution and macroevolution [10], and such a divide looks like a big crack in the monolith of the modern synthetic theory of neo-Darwinism

BIOLOGY AS A CONTINGENT, HISTORICAL SCIENCE

Francois Jacob in a very famous lecture [11] pointed out that monsters, both classical and modern, depicted in countless books are nothing more than imaginary products of recombination between organisms living on the earth. Thus, the abominable aliens from science-fiction can be identified as vertebrates, arthropods, mammalian-like, etc. Such figments suggest, according to Jacob, that man's flights of fancy cannot conceive beings truly different from those inhabiting the earth and that, according to our imagination if life occurs anywhere in the cosmos it is bound to produce animals not too different from the terrestrial ones. However, Jacob challenges this view starting from his proposal that evolution by NS do not works as an engineer but as a tinkerer, who does not know exactly what he is going to produce but uses whatever he finds around him to produce some kind of workable object. That is not related to any special project and it results from a series of contingent events. Jacob concludes that even if life in the outer space uses materials similar as those on earth, even if the alien environment is not too different from ours, even if the nature of life and its chemistry limits the way to fulfill certain functions, the fact is that the sequence of historical events could not be the same as those in the earth, and so contingency lowers to practically zero the probability that intelligent beings that may exist elsewhere would have evolved into something looking like human beings. This strong statement supporting and overwhelming the role for contingency in evolution is quite a paradox, considering that Jacob acknowledges the high uniformity of nature at the physical and molecular levels. Indeed, the cosmos seems to be constituted by the same building blocks everywhere and the same fundamental laws and principles of physics and chemistry seem to operate throughout the universe and yet, according to Jacob, this is not enough to guarantee a certain degree of predictability about the future of evolution on earth or the course of living evolution elsewhere in the cosmos. Jacob

as one of the foremost introducers of neo-Darwinism within French academic circles—that up to the early seventies of the twentieth century had on the average being quite skeptical about the Darwinian Gospel—is also a convinced materialist that sees no significant gap between the inanimate and the living worlds, as both are based on the same laws and principles applied to the same fundamental building blocks (atoms). He is as well, as most neo-Darwinians, far away from vitalist temptations like the *élan vital* suggested by Henri Bergson or the guiding *entelechy* resurrected by Hans Driesch for explaining the observed teleological behavior of embryonic developing systems. Nevertheless, in the tug of war between natural constraints resulting from natural law and contingent history as applied to living systems susceptible of NS, Jacob as most followers of Darwin gives the leading hand to history, transforming biology into a purely historical science, inasmuch as according to another famous neo-Darwinian: nothing in biology makes sense except in the light of evolution [12], meaning of course evolution by NS.

Despite the obvious similarity of major physical systems all over the universe, which that makes possible to predict fairly well the course of stellar evolution according to the star type, no matter where in the universe, evolution of living systems by NS is highly contingent and unpredictable in the same way as the history of the Western civilization would had been so different if Cesar did not dare to cross the Rubicon or the Chinese emperor had not finally refused the conversion to Christianity by Jesuit missionaries in the seventeenth century. This is a most uncomfortable situation for biology as a science, since the value of any scientific theory lies in its capacity for explaining facts and things, not only those that have occurred in the past or are actually occurring in the present, but also those that may occur in the future. Imagine a physicist of the late nineteenth century harnessed with mainstream physical theory of his time that can explain the workings of a water pump or a steam engine, and further, that same physicist being brought by the time–tunnel to the current year would be rather puzzled by a jumbo jet crossing the sky, yet once allowed a closer inspection of such a flying device, our physicist may reasonably work out how such a heavy thing actually flies. Of course, continued research adds new facts and new questions to the realm of science, and old theories are superseded by new theories that better explain the observed facts as no theory can be regarded as definitive [13]. However, according to standard neo-Darwinism if the circumstances are right, either the nine-headed hydra or the headless horseman might come into being, and once they become extinct we may only develop educated guesses based on the fossil record about how and why such marvels came to life and then exit the scene.

DARWINISM VS. MORPHOLOGY

Philosophers with a Darwinian bent suggest that even if the *Tyrannosaurus rex* where synthesized in a molecular biology lab and so brought back to life it will not be a true *T. rex*, no matter if it looks, roars and bites like a *T. rex*, as long as the newborn was not the direct result of the exact historical line of descent that produced such an animal during the Cretaceous [14]. Therefore, within neo-Darwinism ontology becomes a side-show of history in agreement with the long-standing fight of Darwinism against any kind of essentialism that may assign the variability of nature to a fixed number of basic types at various levels, establishing a typology by which all members of a given taxon reflect the same essential nature by conforming to the same type. The existence of such a typology would render variation in itself rather trivial and irrelevant. It is a fact that modern Darwinism exhibits a positive dread of form and yet it is a common paradox that the issue of form—that by far was the central question of biology since Aristotle until Darwinism shifted biology towards its current formless pedestal—crops up here and there in biological discourse as shown in the famous lecture by Jacob where he states that:

> What distinguishes a butterfly from a lion, a hen from a fly, or a worm from a whale is much less a difference in chemical constituents than in the organization and the distribution of these constituents. The few big steps of evolution required acquisition of new information. But specialization and diversification occurred by using differently the same structural information [11]

Hence structure, the manner in which the elements of anything are organized or inter-related, comes nevertheless to the fore of biological discourse, much as musicians say: *form* covers the shape or *structure* of the work. So we are back to the old problem of biological form that has been left untouched and unexplored by neo-Darwinism, despite the fact that the first obvious experience of the living world is the apprehension of forms characteristic of animal or vegetal kinds. It is the elephant shape and not its genes that make us aware and wonder about such an imposing being.

THE NECESSARY SCIENCE OF FORM

Currently there is an apparently renewed interest in tackling the problem of form by linking the study of embryonic development with that of evolution in the new fashionable evo-devo discipline. As the promise of the several whole-genome-sequencing projects of revealing the specific genetic blueprints for producing specific organisms has failed—given that the actual number of genes within the sequenced genomes has consistently been much smaller than expected—thus leading ashtray the widely

held assumption that organismic (phenotypic) complexity is a direct consequence of the coding content of the genome, now the bet is on differential gene regulatory networks or differential action-timing of such networks as the source for explaining why basically isogenic organisms like the mouse, rat, chimp and human nevertheless show obviously disparate features at both structural and behavioral level [15]. Therefore, the gene-centered, neo-Darwinian outlook for biology keeps wandering in circles despite its insufficiency for explaining how the very same master genes, endowed by the current mainstream with all-powerful properties for determining living forms, nevertheless give origin to obviously different body plans and bodily structures, depending on which particular developing system operate. Moreover, the same protein coded by the same gene may switch the development of, say, motor neurons from the neural tube and later on of limbs from the appropriate bud in the same developing system, showing that genes and gene products may act as molecular triggers of developmental processes whose specific end result is certainly not coded or specified by the genes involved [16].

It is an established fact that mixing the molecular constituents of a given living system is not enough for making such a system to take form, since the form of an entity or process is not the sum of its constituents but denotes principles of organization. There are laws or constraints depending on the nature of the material elements of which the system is composed, and also there are laws or constraints that arise from the spatial order of these elements. Accordingly, to know the system is to identify what kind of system it is, and for explaining the system we need to understand the action of the constraints on the components. Matter may take many forms, but it is the existence of a particular organization that defines the particular system. Indeed, common concepts in modern biology such as code, message and information imply form but not matter in itself. Informed matter is matter endowed with a specific organization, and living systems are specific forms of being which, despite what radical materialist may say, manifest further principles of organization that are not found in the non-living world. It is common sense that individuals are what they are because they belong to a certain kind or species and so possess a characteristic nature. From the time of Aristotle onwards the major concern of biology was the characterization of the structure of real kinds so as to distinguish their essential from their accidental properties, resulting in a clear ontological definition or statement of what a thing is. Therefore biological kinds cannot be characterized as unstructured clusters or aggregates of gene products or gene circuits, since even biochemical pathways are isolated and conceptualized in terms of form. The form of an individual, its morphology, has been the basis for the identification and classification of kinds, and yet past and present Darwinism pretends to

replace the notion of natural kind by that of a historical lineage and the essential nature of living beings by the mere accidental collocation of properties. Thus essential form is replaced by accidental form, based on a sort of naive positivism that assumes the absolute independence of coexisting properties and neglects the obvious appearance of emerging properties that result from the ordered interaction of the elements of a system. Any specific taxon, the group of organisms which a classical taxonomy adjudges to be a unit, is not a natural kind from a Darwinian perspective, and so the many existing taxa are not the subject of scientific explanation, but only the excuse for historical narratives, ignoring the basic fact that the form of complex living systems comes into being by a process of development that implies morphogenesis.

Recent discoveries pose quite serious challenges to this formless neo-Darwinism, even at the molecular level. For example, large scale analysis of whole genomes makes evident that increasing organismic complexity correlates with a decreasing relative proportion of protein-coding sequence in the genome, indicating a direct correlation between organismic complexity and the relative proportion of the non-coding but non-repetitive sequence in the genome [17]. Moreover, there is ample evidence that proteins with quite different aminoacid sequences can nevertheless fold into closely similar shapes and display a similar function, indicating that the three-dimensional form of the protein is more important than the aminoacid sequence in determining the protein function [18]. The traditional notion of proteins endowed with isolated specific functions that are independent of the other proteins in the cell, commonly sponsored in textbooks of evolutionary theory, has given way to the evidence that many functional proteins achieve their functional specificity by interacting with other proteins in macromolecular complexes that work as organized molecular machines [19]. Therefore, formal organization that is not specified by coding genes is fundamental for cellular function and so random evolution of protein-coding sequences is not enough for explaining the evolution of protein function.

The goal of a rational morphology is not the classification of living systems *per se* but the eventual knowledge and characterization of the laws of nature that contribute to the real structures embodied in living beings. The organization of living beings into a unified system of kinds has sought to reveal the necessary over the contingent in a rational great chain of being. The two fundamental problems of morphology overlooked by formless Darwinism are the nomothetic and the systematic problem. The first concerns generalities so as to establish the link between the general and the particular (the typical and the individual). The second problem refers to the question of kinds and the relations between kinds. Both problems strive to achieve a rational system of forms. The knowledge of

the rational laws of form can make possible to understand that there could exist no more than a certain number of diverse forms or, alternatively, that there could exist an indefinite number whose diversity is, nevertheless, related in a lawful fashion [20, 21]. Therefore a type is not an accidental result of gene interactions but an irreducible arrangement of different parts that denotes the existence of empirical regularity in living forms that implies the existence of laws or intrinsic constraints on what is possible, in such a way that evolution of living systems is not a simple arbitrary process resulting from contingent chance. The typical properties of a kind need not be universally possessed as such by the members of the kind at all times, since the concept of typical implies the notion of variation but also implies the assumption that normal, variant and monstrous forms are all law-governed and as such explainable. The concept of the typical is necessary for developing a science of form.

Biology can only become a full science after explaining the nature of living organization in formal terms since "function follows form", and let's not forget that such an Aristotelian axiom was the foundation stone of molecular biology [22]. From the work of D'Arcy Thomson to further alternatives found in the current scientific literature [23-26], there is a breeding science of form that may carry biology beyond the current level of trivial explanations, such as that in some birds the shapes of their beaks are so and so because they were selected as an adaptation for breaking either tough or soft seeds or that in a darkening environment the dark butterflies escape predation and so substitute the former dominant population of white butterflies, nonetheless without explaining how the beaks of birds came into being or why both dark and white butterflies keep the very same form that has been preserved even after the color substitution in the butterfly population.

FORM AND KNOWLEDGE

Aristotle was the first to point out that when a thing is known it is known as a form, and anything further known about such a thing it is known as dependent on its form. Thus, the form is the ground for the explanation and understanding of whatever can be understood or explained about a thing. Form supplies the satisfactory reason to the knowing mind; it represents the unit of being and knowledge. In nature there are many individual forms and many of them possess internal complexity. The world then is a system of forms, presenting to the mind the intelligible diversity and ordered interrelation of members, which are implied by the world system. But nature is not only form, it is also matter. It consists of forms that can only exist as materialized or embodied. Therefore, the science of nature deals with formed matter, or bodies, since the particular

things which fill the perceived world are specimens of formed matter. But it is a commonplace that they are in constant change. Hence, all change which is not degeneration or failure is the process by which the relatively unformed becomes formed [27].

It may seem a paradox that while the title of this paper suggests that two hundred years after Darwin's birth biology needs a radical change of outlook, nevertheless I am quoting the ancient Aristotle as background for the new science of form, but let's not forget what Darwin himself said about Aristotle: "...Linnaeus and Cuvier have been my two gods, though in very different ways, but they were mere schoolboys to old Aristotle... [28]".

The historian of philosophy Allan Gotthelf has clearly shown that Darwin had not read any of the biological treatises of Aristotle in his youth and came to read Aristotle *On the Parts of Animals* in the translation by William Ogle very late in his life, just a few months before his death, and yet such a reading had a great impact on Darwin suggesting a common ground between Darwin's thought and Aristotle's teleology [29]. Indeed, the great American botanist Asa Gray who was a staunch supporter of Darwin and arranged the first American edition of *The Origin*, remarked that Darwin did not destroy teleology but rather put it on a scientific footing: "let us recognize Darwin's great service to Natural Science in bringing back to it Teleology; so instead of Morphology versus Teleology, we shall have Morphology wedded to Teleology [30]. " To which Darwin replied: "what you say about Teleology pleases me especially and I do not think anyone else has ever noted that [31]."

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28 Hereunder is the full text of the letter from Darwin praising Aristotle:
Letter to William Ogle, Down, February 22, 1882
"My dear Dr. Ogle, — You must let me thank you for the pleasure which the introduction to the Aristotle book has given me. I have rarely read anything which has interested me more, though I have not read as yet more than a quarter of the book proper. From quotations which I had seen, I had a high notion of Aristotle's merits, but I had not the most remote notion what a wonderful man he was. Linnaeus and Cuvier have been my two gods, though in very different ways, but they were mere schoolboys to old Aristotle. How very curious, also, his ignorance on some points, as on muscles as the means of movement. I am glad that you have explained in so probable a manner some of the grossest mistakes attributed to him. I never realized, before reading your book, to what an enormous summation of labour we owe even our common knowledge. I wish old Aristotle could know what a grand Defender of the Faith he had found in you. Believe me, my dear Dr. Ogle, Yours very sincerely, Ch. Darwin (*Life and Letters of Charles Darwin,* Vol. 2. Appleton and Co. New York. 1887).
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