Difficulties in teaching evolution due to the influence of teleology

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Abstract: One of the most famous iconographies related to evolution is the "evolutionary march". It represents a linear progression from apes towards *Homo sapiens*. The origins of this progressive view can be found in Aristotle's ideas, which were also based on species' fixity, essentialism and teleology. Even though Aristotle's framework has been overthrown by Darwin's evolutionary theory, its influence can still be seen in general thinking. The concept of adaptation is commonly misunderstood and phrases with teleological meaning are often used in evolutionary explanations. For that reason, students might create an erroneous idea that some characteristics could have been selected for a specific reason. Thus, it is important that students properly know the structure of evolutionary thinking from a philosophical perspective, regarding not only adaptation but also a view of evolution as a branched process. The present analysis aims at discussing the multiple meanings of the term teleology, based on the proposal established by Ernst Mayr (1904-2005), going backwards to its origins. Furthermore, it aims at analyzing the importance of this discussion to the teaching of evolution as a tool to dismiss some of the most common evolutionary misconceptions.
Keywords: teleology; teaching evolution; evolutionary thinking

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Dificuldades no ensino de evolução devido à influência da teleologia

Resumo: Uma das mais famosas iconografias relacionadas à evolução é a "marcha evolutiva", que representa uma progressão dos macacos aos *Homo sapiens*. A origem dessa visão de progresso pode ser encontrada nas ideias de Aristóteles, que também se baseia no fixismo das espécies, no essencialismo e na teleologia. Embora o *framework* tenha sido contraposto pela teoria evolutiva de Darwin, sua influência no senso comum ainda pode ser encontrada. Em adição, o conceito de adaptação é comumente mal compreendido e frases com sentido teleológico são utilizadas com frequências em explicações evolutivas. Por essa razão, estudantes podem criar a concepção de que houve um propósito intencional para a seleção de algumas características. Logo, é importante que se discuta no ensino a estrutura do pensamento evolutivo do ponto de vista filosófico, não apenas com relação à adaptação, mas também a visão da evolução como um processo ramificado. A presente análise pretende discutir os múltiplos significados do termo teleologia, baseado na proposta de Ernst Mayr (1904-2005), retornando as suas origens. Pretende-se, também, analisar a importância de tal discussão no ensino de evolução como uma ferramenta para desmistificar algumas das concepções alternativas sobre evolução.
Palavras-chave: teleologia; ensino de evolução; pensamento evolutivo

1 INTRODUCTION

Although evolution is considered the unifying theme of biology (Dobzhansky, 1973; Futuyma, 2002), its understanding is still very limited and represents a great educational challenge (Bizzo, 1994; Smith, 2010), which means that teaching evolution is not an easy task in every scholar age. Among the difficulties teachers find when going through this subject, we point out: 1) temporal assimilation of evolutionary changes; 2) populational thinking (it is very common to think of individual changes over time, as in Lamarck' theory, and not of populations); 3) difficulties in finding ancestor groups; 4) recognizing kinship among humans and other living beings; and, 5) the idea of progress in evolution (Santos & Calor, 2007a).

The idea of human superiority, related to a progressive view of evolution, is not scientifically sound, but it is widely spread in common sense. Authors such as Ruse (1996) sustain that a translocation of the cultural meaning of progress, such as technology, social and scientific progress, could influence the understanding of biological evolution. In addition, many misleading information is spread by media (internet,

television, comic books, newspapers, publicities and others) affecting such concept formation (Santos & Calor, 2007b).

Amidst such misleading information, one of the most famous figures spread by media is the "evolutionary march", in which some primates are lined up as if marching from left to right, progressing towards humankind. According to Gould (1990), this is the only iconography immediately understood by everyone and it reinforces this comfortable idea of human superiority and inevitability. Although it is a very accepted image, it emphasizes the misleading idea that evolution has a pre-established direction towards "perfection", in a progressive way. Nevertheless, evolution is not a linear process from basal species to superior ones. It is a bush, a branching process of species, based on variation, natural selection, genetic drift, and common ancestors (Santos & Calor, 2008).

According to Crivellaro and Sperduti (2014), the greatest challenge of teaching evolution relies on natural selection, once it is very common for the public to have a teleological, essentialist and anthropocentric thinking. In other words, besides the progressive view of evolution, there is a functional understanding of natural selection, in which explanations about adaptation are made based upon purposes (Gregory, 2009).

From a philosophic point of view, teleology, or the science of final causes, was a very important Aristotelian concept. Aristotle's teleology assumes that everything in nature has specific purposes – therefore, there is nothing vain in nature. His influence in human thinking is seen until current days, even if in an implicit way, especially because his investigation about the living world was based on his experiences and direct observations of natural phenomena (Ariza & Martins, 2010).

Even though teleology has been questioned in a number of instances, since the first edition of Darwin's *On the origin of species* (1859), especially in light of natural selection, it seems to be common sense to notice teleological language when one talks about evolution, including biology classes. According to Mayr (1998), teleological terms are used to describe organic functions, physiological processes and individual's behavior, usually characterized by the words "purpose" or "goal". Thus, the concept of teleology has been used in many different cases

with heterogeneous phenomena. For this reason, Mayr (2004) has created categories to differentiate and classify these various term meanings.

Due to the importance of confronting biological misconceptions with scientific ones, this paper aims to discuss the teleological polysemy according to Mayr's proposal, going back to Aristotle's teleology and, then, to think about its influence in evolutionary comprehension and teaching. The comprehension of difficulties and the historical origins of our thoughts, thus emphasizing philosophical aspects of evolutionary thinking, could be a pedagogical strategy to dismiss misleading ideas as progress in evolution.

2 ARISTOTLE'S TELEOLOGY

Tradition based on Aristotle had been the main life conception until the Scientific Revolution of the 16th century, when there was a mathematization of space and a change in reasoning. Although it happened on the scientific field in general, it has had a more important influence in Physics. In Natural History, however, Aristotle's principles played important roles far longer than in Astronomy and Physics.

Aristotle is a very important reference for the constitution of Natural History as a field of research. His investigation about the living world was based on his experiences and direct observations of natural phenomena, which had more importance than abstract rationalization (Ariza & Martins, 2010). That is probably why it is possible to find some of the Aristotle's ideas among people who never studied Greek philosophy, including children, young students and people in general.

According to Solinas (2015), three Aristotle's pillars were inherited by modern natural history: species fixity, essentialism and teleology. In his words:

> It is safe to affirm that in all three disciplines [Botany, Zoology and Human Physiology] the conceptual framework of reference, the guiding principles [were] […] the three pillars of teleology, essentialism and fixity of species, of Aristotelian devising, [which] continued to remain central to biological research until the late Middle Ages. The same doctrinal innovations were taken as extensions and gradual rectifications of the descriptions and classifications offered by Aristotle

> and later, by other classical writers (Galen, Pliny, and so on). (Solinas, 2015, p. 46-47)

His belief on universe's eternity, without a beginning or an end, implied that species were immutable and perfectly adjusted to the environment. Such a static equilibrium and permanence of species were also supported by essentialism, which is the concept that species have an immutable essence (random variations and contingency were generally marginalized). Teleology, on the other hand, can be understood as the science of the final causes. Aristotle, on his text *On the soul* (trans. Hett, 1964), emphasized that provisions in nature were means to an end. Thus, every trait would be useful for a specific purpose and nothing in nature would have been made in vain.

Another important aspect in Aristotle is the so-called human superiority. He believed in an organization of living beings according to an increasing scale of progress and complexity, also called afterwards *Scala Naturae* (the idea that organisms can be organized as a ladder). Even though it did not have an evolutionary connotation, such idea can be seen in Aristotle, who said on *De generatione animalium* that animals can be organized according to a linear increasing of perfection from the most primitive organism to humankind, on the highest place (Ariza & Martins, 2010).

In short words, the life conception that was inherited from Aristotle is characterized by a stable and static world, in which there are inferior and superior organisms, all of them well adapted with a specific preestablished role in nature. As mentioned before, the Scientific Revolution transposed the Aristotelian epistemology, except in the living world. In Natural History, Aristotle had great influence until the middle of the 18th century. It is seen, for instance, on Linnaeus' *oeconomia naturae.* Aristotelian crises began only with the transformational theories, as Lamarck's in the 19th century. Lamarck counterpoised Aristotelian fixism, but his evolutionary mechanism was teleological, and it resulted in an endless process increasing complexity and perfection (Ferreira, 2003).

Only Darwin's evolutionistic revolution represented a gradual epistemological overthrow of Aristotelian matrix in Biology. According to Solinas (2015), all of the three Aristotle's pillars have been opposed by Darwin. Fixity has been opposed by species modification through time.

Essentialism, or the idea that species are imperfect manifestations of an immutable essence, has been overthrown by the recognition of variation, of both occurrences in nature and under domestication. And, teleology has been questioned in a number of instances, since the first edition of *On the origin of species* (1859), especially in light of natural selection.

Aristotle's teleology assumes that everything in nature has a specific purpose. It is the science of final causes and, therefore, there is nothing vain in nature. In this perspective, there is a static balance that guarantees stability of all species. Nevertheless, the universe is not static and immutable. Environment changes and so do populations over time. Species diversify and go extinct. Stochastic events happen, and natural selection is a differential statistic survival of variations already existing, thus it is not finalistic. Despite it, teleology is still discussed.

3 CURRENT DISCUSSION AND MAYR'S SOLUTION

One commonly uses a teleological language when talking about evolutional process, especially subjects related to adaptations. Teleological terms are used to describe organic functions, physiological processes and individual's behavior, usually characterized by purpose or goal (Mayr, 1998). Thus, phrases such as "the heart evolved to pump blood" are commonly used and we can discuss whether they offer a finalistic meaning or are just an explanatory metaphor. According to Mayr (2004), the problem is that the word "function" refers to two different phenomenal groups: it can be related to an immediate causality or an evolutionary one. In other words, it can refer to some goal-orientated activity or to adaptive systems, in which a metaphysic and teleological meaning cannot be found.

Some biologists, called reductionists, have the intention to eliminate the teleological vocabulary of the field. Even though it is used consciously as metaphors or linguistic strategies, it can cause confusions, especially among non-scientists. The elimination is mainly focused in two kinds of explanations: those referring to present events causing future ones, and those suggesting intentionality-guiding processes and phenomena (Ferreira, 2003). Ferreira also emphasizes that this discussion does not include exactly Aristotle's teleology, neither the medieval theologians, but a transformed teleology in which diverse concepts

have been put together over time. Other authors suggest that teleological explanations are legitimate if they are limited to physiology process and behavior (Carmo, Nunes-Neto & El-Hani, 2012). Although there is no consensus, this possibility indicates the importance of discussing the influence of teleological language. Galli and Meinard (2011) emphasize that it should not be censored if a student uses teleological expressions spontaneously. In fact, debating and explaining should be engaged so these expressions could be object of analysis and then students should be able to confront them with scientific models.

In this context, Mayr (2004) discussed that, actually, the word teleology is being used to describe different kinds of phenomena and, therefore, he has created five categories to think about these phenomena in a broader sense. In these categories, he included both biological and non-biological phenomena, as those referring to natural processes, especially those related to the laws of Physics. For instance, gravity makes objects fall downwards to the center of the Earth, and thermodynamics make hot objects cold until they arrive to the same temperature as the surrounding environment. These examples have a finalistic and pre-determined meaning, but they cannot be applied to Biology. That is why Mayr created new terms to differentiate those patterns. He divided the word teleology in five processes: teleonomic process, teleomatic process, intentional behavior, adaptive features, and cosmic teleology.

Teleomatic processes are those natural processes already mentioned that are guided by physical laws, such as gravity, and they are usually related to the inorganic world. Teleonomic processes, on the other hand, are related to Biology. They are characterized by the presence of a purpose, caused by genetic programming, in cellular development (processes) or animal behavior. Even though there is a genetic program established in the past that guides some processes, there is not intentionality in it. Intentional behaviors are those behaviors oriented by specific purposes, which require planning. They had been thought initially only for humans, but then expanded for other animals (e.g. chimps).

Adaptive features are characteristics that contribute to the organism's fitness. They are often understood as teleological or functional

systems, but from Darwin's theory, all adaptations are evolutionary results, in which variation is very important and allows the differential statistic survival of the fittest that has more offspring. Therefore, adaptation is *a posteriori* result that cannot be established at first. Finally, cosmic teleology is the idea that there is an intrinsic tendency to progress in nature, and that such progress can be transferred to evolution. Darwin understood that evolution is not linear. It is a branched process without a pre-determined direction.

Before Darwin's revolution, the most important conception of life was based on Aristotle's view, already mentioned, and it was characterized by an eternal world with an intrinsic tendency to perfection. This life interpretation was Mayr's cosmic teleology and can be currently understood as a progressive evolution misconception from underdeveloped organisms to more developed ones.

Solinas and Mayr agree with each other about teleology in Darwin's work. At the beginning, Darwin used to believe in final causes and used this idea to build his theory. Then, he put it aside. According to Solinas (2015), teleology was like a scaffold to Darwin's theory. At first, it was a structural thought that helped him to build it, but then he realized that natural selection is not a teleological process, and he further abandoned this idea completely. There is no need to use teleology to explain the natural world.

Even though the natural selection concept is not teleological, there are a lot of misleading interpretations. One of the possible reasons for this is the analogy with artificial selection. Darwin's explanation in his book *On the origin of species* (Darwin, 1859) began with the artificial selection concept, in which farmers and cattle ranchers drive the selection and choose desired features according to their own interests. It was an argumentative strategy to help people visualize the possibility of species changing and common ancestors (Pievani, 2013). It is important to realize that in artificial selection, there is someone behind the process. Although this analogy between artificial selection and natural selection was a very useful strategy, people can easily transfer the idea that there is also someone or something (a supernatural force) behind natural selection as well. With this misleading conception, adaptations could be comprehended as pre-determined with some specific purpose or function.

Mayr concluded that the first four kinds of teleology are material rather than metaphysical, and that cosmic teleology does not exist. According to him, even though there are natural processes with some kind of purpose, there is no need to use supernatural phenomena to explain them, i.e. there is never a retroactive cause.

4 THINKING ABOUT TEACHING EVOLUTION

As we could see in brief, there are many alternative conceptions regarding evolution and many of those misconceptions are related to a teleological thinking. Gregory (2009) analyzed essential concepts and common misconceptions regarding specifically natural selection pointing out that it is poorly understood not only by members of the public in general, but also by people who have had specific instruction and teachers. The tendency to explain adaptations based on purpose could be a result of human psychology, including a functional bias, because "much of the human experience involves overcoming obstacles, achieving goals, and fulfilling needs" (Gregory, 2009, p. 167). Need-based explanations for natural selection, as the classic giraffe's neck example, are also very common and they are related to the misconception that individuals can change depending on the challenges that environmental pressures put upon them.

In addition, children from late preschool tend to show a promiscuous teleological bias, which seems to strengthen during elementary school (Kelemen, 2012). When trying to elucidate its origins, studies described by Kelemen have discarded parents' influences, the cultural religiosity factor, and media exposure, thus showing that external social forces have a weak potential to explain the teleological explanations. This suggests a natural cognitive teleological intuition that can even influence older students to elaborate need-based explanations.

Once teleological thinking is widespread and clearly influences the comprehension of evolution, it is important to reflect the role of teleology discussion on conceptual changes. Thinking about teaching evolution does not need to distinguish all Mayr's teleological categories. Despite the philosophical importance of understanding the current polysemy of the word "teleology", including a non-biological discus-

sion when teaching evolution, can create further problems. Nonetheless, it could be very useful to introduce and distinguish two of the five categories proposed by Mayr: adaptive features and cosmic teleology.

Regarding the first category related to adaptive features, a very common problem is the way language is used to explain them and to describe organs' functions, maybe because of the cognitive bias already mentioned. Students might comprehend that an organ has evolved for a specific reason, related to the function it currently has. It is necessary to make students understand that the fact that an organ has a function today does not imply that it has always had this function, neither that its functions have been pre-determined. Adaptations are the result of natural selection: the differential survival (or reproduction) of classes of entities that are different from one another in one or more characteristics (Futuyma, 2005). Even though natural selection is a non-random process, mutation (the evolutionary force that creates new variability) is random and cannot have a pre-established purpose or function.

It is common evolution patterns as exaptation, in which the function related to an organ change completely (Pievani, 2005). In other words, a feature might have a function that originally evolved to serve a different use, or it has evolved as another feature byproduct. A famous example is the feather evolution. It is easy to think that feathers are adaptations for flight. Although they evolved earlier, and they were probably related to body temperature regulation. Commonly, the concept of exaptation is not explored in basic education, but it has a great potential to help dismissing teleological thinking. According to Thanukos, there are three reasons that sustain the importance of exaptation to comprehend evolution. First, it replaces the misleading concept of preadaptation, which smacks of anticipation and can make people think that it was inevitable. Secondly, it "emphasizes that many traits of organisms are not perfectly suited to their current function" (Thanukos, 2009, p. 2). Finally, it is necessary to make deeper questions and not to focus only on the current utility of a trait.

Thus, it is important to comprehend evolution as a plural process, in the same way Darwin had understood it, in which some external events might influence (as environmental changes, for instance) and natural selection is only one of the forces that drives the changes in

population over time. Many features seen today are the result of other evolutionary forces, such as genetic drift and migration, or can just be the result of ancestry, not having any function at all.

Therefore, it is important that students properly know the structure of evolutionary thinking. It is important, for instance, that they can distinguish adaptations from other features. Adaptations are features that were favored by natural selection because they had a positive effect in the struggle of life. They are often the focus in evolutionary classes, once natural selection in the main mechanism explained.

Nevertheless, it is also important that they understand that the most interesting evidence to comprehend evolution include imperfections, apparently accidental peculiarities, and not the perfect adaptations, which can be easily explained metaphysically, with supernatural creation or design (Allmon and Ross, 2018). Imperfections come, sometimes, out of inherited structural constraints that guarantee an effective rejection if creationists' favor the argument about an intelligent designer. Useless organs have been the weakest point in Aristotle's theory ("monstrosities") and, at the same time, the strongest to support Darwin's theory. According to Allmon and Ross (2018), remnants of evolutionary history, such as homologous features, especially those vestiges that lack of fit to the organism's way of life (as the famous examples of panda's thumb), are the most compelling evidence of common ancestry and should be also accessible to non-specialists.

Cosmic teleology, on the other hand, has probably been the biggest misunderstanding disseminated in human thought. Gould (1990) has defined the history of life as a history of elimination and mass extinction followed by differentiation inside a few survived groups. It is neither a tale of continuing progress towards improvement, nor a predictive scale of progress. Life branches continuously, and extinction represents a very important pattern is this ramification. That is why the image of the tree of life or phylogenetic tree is so useful to teach evolution. According to Santos & Calor (2008), cladograms decrease misinterpretations about human progress because they are branched diagrams, in which both common ancestry and relatedness across species are represented. It is essentially different from a linear representation. To help students develop tree thinking skills and to properly understand what phylogenies say about the relationship among taxa is very

important in evolutionary education (Meisel, 2010) and it is still a challenge (Gregory, 2008).

Solving such misconceptions is not an easy task and needs a clear comprehension of evolution. Sinatra and collaborators (2008) emphasized that the most important thing when teaching about evolution is to help students revise their own previous knowledge to create a new and more scientific way of seeing the world. Studies also suggested that it is important to make students aware of their way of reasoning and find the differences between their conceptions and the scientific model, lighting the "teleological obstacle so as to turn it into the object of analysis" (Galli & Meinard, 2011, p. 148). For this reason, it is relevant to explicitly discuss teleology in biology classes. It might help to mislead some of the common evolutionary misconceptions. Focusing not only upon the biological aspects of evolution, but also on discussing philosophical aspects and the history of evolutionary thinking, can be an important pedagogical tool and should be better explored.

5 FINAL CONSIDERATIONS

First of all, it is important to emphasize that current teleological discussions are ontologically diverse from Aristotle's classic teleology. Summarizing, Aristotle's influence remained across centuries mainly because it was based on what could be directly observed. Teleology is one of Aristotle's pillars and it comes with an immutable world, in which species do not change. Nowadays, instead, evolution is a fact and there is space neither for fixism, essentialism, nor cosmic teleology.

In Mayr's ideas, on the other hand, every possible application of the term "teleology" is related to an idea of movement. Therefore, Mayr's categories are not Aristotelian.

Mayr's teleological categories appear in philosophical discussions, especially in the biological field. When thinking about teaching biology, though, such division is not practical, as it includes non-biological terms. It does not necessarily help non-scientists, including students, to better understand nature and evolutionary process. Thinking in biology and science teaching, it would be very useful to introduce two of the five categories proposed by him: adaptive features and cosmic teleology. These categories may help students to better understand evolution and dismiss some misleading ideas as adaptations that evolved

"for" a reason or that humans have an evolutionary superiority. Correcting one of these misconceptions might not correct the other, that is the reason why both strategies presented previously, about exaptation/remnants features and tree thinking should be actively discussed.

It does not mean, however, that teleological language should be completely withdrawn from biology lessons. It is inadequate to use teleology to explain evolution, but it is legitimate to use teleological explanations regarding behavior and physiological processes. In other words, "function is something that we appeal to explain a capacity of a continental system, not to explain why some item exists in such system" (Carmo, Nunes-Neto & El-Hani, 2012, p. 32).

Thinking that the "perfect" adaptations we see in many organisms are not pre-determined is not something intuitive; similarly, thinking that humans are not inevitable is not comfortable. However, it is very important to comprehend evolution in a non-teleological way, regarding to adaptations and the non-linearity of the process. This comprehension would make us have a different and healthier relationship with the environment and other living beings.

Not only the origin of the human way of thinking would be important but also the dissemination of scientific thinking, thus the philosophy of science and specifically the philosophy of evolution are very important areas when teaching this subject. When teaching evolution, it is possible to decrease the teleology presence without using all Mayr's categories (epistemological discussion), once they are complex and include non-biological conceptions. Making students aware of such contradictions and actively understand the reasons why evolution is not progressive, neither finalistic, could be a way to improve students' understanding and acceptance of evolution.

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