Evolutionary Analogies

Evolutionary Analogies:
Is the Process of Scientific Change Analogous to the Organic Change?

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Table of Contents

List of Figures and Tables

PREFACE

Our aim in this volume is to analyse what we will refer to as 'the evolutionary analogy', a particular form of evolutionary epistemology which claims that scientific change is governed by the same mechanisms, or by mechanisms analogous to those at work in organic evolution, mainly natural selection. In terms of questions, the overall aim of this volume is to answer the following: "Is the process of scientific change analogous to or even the same as organic change?"

Scientific change is and has been the subject of major philosophical debate. Science is now largely perceived by the layman as the enterprise capable of giving the best explanations of what reality is. The Philosophers, more subtly and depending on their orientation, discuss the truthfulness, the verisimilitude, the usefulness, the applicability of those explanations, or even whether there is a reality we can explain at all. If we exclude this latter case, all philosophers interested in science have addressed, in varying depth, the question of the change of scientific knowledge over time. The answers produced can be categorised, at first approximation, as normative or descriptive in varying degrees. Normative answers analyse the steps or general principles which scientists should follow when choosing or altering their theories, in order to produce new theories which would be better at doing what they are supposed to do. Their focus is on the *objectives* of scientific change and their character is primarily logical. Descriptive answers show how scientists or scientific communities actually behave. Their focus, thus, is mainly on the *process* of scientific change and their character is sometimes largely sociological. Most of the philosophers who proposed evolutionary theories of scientific change – evolutionary analogies – were able to overlap these two categories. By drawing analogies or even equating the mechanisms of organic and scientific evolution they described the process underlying the latter but also justified its value, implicitly or explicitly, by a simple analogy: better theories are those which survive old ones, as better species are those which survive previous ones. The results of these philosophers, however, have not been satisfactory. Most of them have embarked on only limited or sketchy analysis, while others, who were more persistent in their attempts, failed to provide persuasive answers. The reasons for these failures are manifold: the philosophers misunderstood or oversimplified the evolutionary biology concepts they employed; or forcefully introduced in their view of scientific change mechanisms which seem counterintuitive but that closely resemble biological ones; or employed an inadequate methodology – or none at all – for assessing the analogy. A novel approach, which does not incur the same problems, is thus needed.

In this volume we are interested in a purely descriptive philosophy of science and our position will be based on the critique of the most recent and comprehensive attempt to defend the evolutionary analogy, made by David Hull. In order to answer the question we have formulated above, the following issues will be addressed: what is organic evolution; what is meant by 'evolutionary analogy'; how analogy/identity can be evaluated; how evolutionary analogy/identity has been defended by philosophers; how these defences perform; what is the best defence available; whether it passes the evaluation and, if not, whether it can be improved; if all the positions fail, whether it is possible to conceive alternative analogies between other relevant processes which do not incur the same problems. By addressing these issues, we will be able to conclude that the process of scientific change is different from organic change and that only loose analogies can be defended.

In the first chapter, the tools needed for the analysis are illustrated. In particular, a short account of what is meant today by 'organic evolution' and natural selection is given, together with a sketched survey of the main claims of most evolutionary analogies and common objections raised against them. Finally, current views on analogies and metaphors are discussed and some points of reference for the scrutiny of individual evolutionary analogies are provided. In the second chapter the most influential scholars who have endorsed an evolutionary analogy are discussed. In the analysis of their views, the tenability of their positions is evaluated in the framework of principles set out in the first chapter. The strengths and weaknesses of different positions are made clear and several detailed concepts and lines of argument are constructed. This constitutes a basis for the third chapter, where the approach we regard as the most coherent and fruitful is analysed and further developed. In this approach, the process that makes scientific concepts and theories persist and evolve is an instance of a general process of selection, and natural selection is another instance of it. Individual concepts and features of scientific and organic change are generalised and an evaluative framework for such generalisations is proposed. In the fourth chapter, after the roles of direction and convergence are further analysed in scientific and biological change, the same framework is used to evaluate alternative analogy views. One view compares scientific change to evolution by orthogenesis, the other compares more general cultural change to evolution by natural selection, with the purpose of investigating whether these analogies perform better than all the others. A brief conclusion summarises the most salient points of the volume.

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CHAPTER ONE

EVOLUTIONARY ANALOGY

This chapter provides introductory answers to the following questions: What is the current status of the theories of evolutionary biology and natural selection? What is an 'evolutionary epistemology' and what is meant, in this volume, by the terms 'evolutionary analogy'? What is an analogy and how can analogy/identity be evaluated? The answers to these questions will be further shaped and detailed in the following chapters, where required by the context.

1.1 Natural Selection

We shall provide here a brief account of one of the existing views of *natural selection* and its relation to biological evolution. This is the view mostly accepted by leading biologists at present and in what follows we will refer to it exclusively.

With some exceptions, advocates of evolutionary epistemologies – although they are grouped under this title – mainly focus on natural selection. Several other related concepts, though, will be encountered in individual sections of the book, for example 'genetic drift', 'species', 'lineages' and 'ecological niches' to name a few. They will be introduced and defined appropriately when first encountered.

Natural selection[1] is a mechanism, originally proposed by Darwin, for adaptive change in the biological realm. While at the time the occurrence of evolution was accepted by many biologists, the idea that natural selection was behind it was universally rejected. In the early 1930's it was shown that Darwin's natural selection could function within the Mendelian theory of genetics and with the kinds of variation observable in natural populations.[2] This established what is known as *Neo-Darwinian Theory* or *The Modern Synthesis*.

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[1] Often abbreviated to NS hereafter.
[2] This was done by Fisher, Haldane and Wright (Futuyma 1998: 24).

Natural selection is now widely agreed to be the principal force that changes allele frequencies within large populations.[3] In biological populations, a competition for survival usually occurs because more offspring than can survive is produced. Because of genotypic variety, greater capacity to survive and reproduce is usually possessed by some individuals, whose genotypes produce phenotypes better equipped for their environment. Succeeding generations will preferentially inherit their alleles, which will increase in frequencies in the population.

> Sewall Wright, François Jacob and other evolutionists have pointed out that selection, owing to its two-step nature, combines chance and necessity in a unique manner. At the first step, the production of genetic variation, chance predominates. At the next step, the survival of individuals of the next generation, chance plays only a minor role, and the survival depends largely on the adaptedness of the individuals exposed to selection. (Mayr 1991: 133)

It is important to stress the relevance of differences in genotypes; selection among genetically identical members of a clone, which only differ in phenotype, cannot have any evolutionary consequence. Even more importantly, though, it should be noted that the distinction between *evolution* and *natural selection* is often forgotten. They are two different phenomena: evolution can occur without natural selection, by genetic drift for instance;[4] conversely, there can be natural selection without evolution, for instance when individual "genotypes differ in each generation in survival or fecundity, yet the proportions of genotypes and alleles stay the same from one generation to another" (Futuyma 1998: 365).[5]

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[3] The enormous importance of natural selection to the evolutionary process is not questioned by any serious biologists; nevertheless a controversy concerns the power of natural selection to overcome constraints on evolution. Doubts about its power have led some to think that other processes may have an importance comparable to that of natural selection in evolution, such as for instance the tendency to self-organisation, suggested by Kauffman (1993). This tendency, however, is not proposed as an alternative to natural selection.

[4] This is an important mechanism of evolutionary change, which explains the differences with respect to traits with little or no influence for the survival of a species. When there is selectively neutral variability, it can still be the case that slight differences occur between the offspring and the parental generation.

[5] An example is provided by the persistence of deleterious alleles in a population. Such alleles usually persist because recurrent mutation or gene flow from other populations (where the alleles are instead favoured by differences in the

More formally, natural selection is defined by mainstream biologists as "the differential contribution to future generations (differential fitness) of different genotypes as manifested through different phenotypes and thus producing changes in frequencies of the genes giving those genotypes" (Ferguson 2002). In general, we refer to 'advantageous' or 'deleterious' alleles but we have to remember that selection, at least according to the definition just given, does not act directly on alleles. A more articulated, yet compact account of natural selection is provided by Ernst Mayr (Mayr 1993: Chapter 3).[6] According to Mayr the concept of natural selection is formed by five observations and three logical inferences. The observations are the following: all species produce more offspring than can survive; usually populations do not increase exponentially; the limit of natural resources restricts the number of individuals that can survive; in the majority of cases no two individuals are exactly the same;[7] and a great part of this variation has a genetic basis due to mutation and recombination which can be inherited by offspring. The inferences, meanwhile, are the following: the production of more individuals than the limited environmental resources can support causes competition for survival; survival is not totally random but depends in part on genetic make up; evolution (genetic change) is due to the ability to survive and reproduce, which in turn depends on our unique phenotype. Each individual has thousands of traits for which it could, under a given set of conditions, be selectively superior or inferior in comparison with the average of the population. The greater the number of superior traits, the greater the probability that it will survive and reproduce. But it is merely a probability, because even a 'superior' individual may fail to survive or reproduce. In order to grasp the concept of natural selection it is important to remember that it acts on populations, groups of individuals, with each individual in a given population different from the others. According to Mayr, without giving importance to the particular differences among individuals and without considering a species as an aggregate of populations,[8] we would not have the concept of natural selection.

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environment) reintroduce them constantly. Eventually, equilibrium between their reintroduction and elimination by NS is reached and persists (Futuyma 1998: 381).

[6] A clear analysis of the concept of selection was already present in the fourth chapter of Mayr (1981).

[7] This is particularly true for sexually reproducing species, less for asexually reproducing species.

[8] Mayr speaks of population and considers a species as consisting "of a group of populations which replace each other geographically or ecologically and of which the neighboring ones intergrade or interbreed wherever they are in contact or

We acknowledge that there is some controversy over the details. For instance, the majority of scholars consider sexual selection a kind of natural selection, while a minority treats it as distinct from natural selection. Some scholars classify as natural selection only selection at the level of genes, genotypes and individual organism, and exclude the level of groups, such as species or population. Others, such as Endler (1986) and Sober (1984),[9] also extend natural selection to the level of groups.[10] These variations on the mainstream view, however, do not affect what most evolutionary epistemologists regard as the characteristic features of natural selection.

1.2 Evolutionary Epistemologies

Evolutionary epistemologies are epistemologies directly motivated by evolutionary considerations. The expression 'Evolutionary Epistemology' is used to group together different attempts of using biological concepts in philosophy and is traditionally associated with the names of Donald Campbell, Stephen Toulmin, Karl Popper.[11] It is now widely accepted that the various attempts can be roughly divided into two main categories. These categories have been differently defined and named over time but

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which are potentially capable of doing so (with one or more of the populations) in those cases where contact is prevented by geographical or ecological barriers" (Mayr 1942: 120).

[9] Further, there is a special case of group selection called 'species selection'. 'Group selection in which each group is a species has been called **species selection** by Steven Stanley' (Futuyma 1998: 352, emphasis in the original).

[10] It should also be remembered that, in 1962, the ecologist V.C. Wynne-Edwards had already suggested that social behaviours, such as the flocking behaviour of starlings, had evolved as mechanisms of population control. For instance, he maintained that populations are self-regulatory because of individual reproductive restraint, which evolves by group selection. Williams Edwards (1966) extended the examples given by Wynne-Edwards and included senescence and fixed life spans (Futuyma 1998: 350-2).

[11] Mention should also be made of the Austro-German School of Evolutionary Epistemology, which has its origins in a paper published in 1941 by Konrad Lorenz, "Kant's Doctrine of the A Priori in the Light of Contemporary Biology". This is an attempt to interpret Kantian transcendental idealism along biological lines (similar points had also been made by philosophers and scientists such as Ernst Mach and Henri Poincare). Lorenz's paper remained mostly unknown and his later book 'Die Rückseite des Spiegels: Versuch einer Naturgeschichte menschlichen Erkennens' (reprinted as 'Behind the mirror', 1977) raised little interest among philosophers, especially in English-speaking countries.

their grounding has stayed the same. Kai Hahlweg (1986), for instance, differentiates between what he labels '[proper] evolutionary epistemology' and 'bioepistemology'.[12] In his view, if the former mainly deals with the evolution of human knowledge, bioepistemologists are concerned with the evolution of the mechanism of cognition: "[bioepistemology] can be seen as an attempt to base epistemology on results derived from scientific investigations into the nature of knowledge acquisition" (Hahlweg 1986: 172). Analogously, John Losee (2000) draws a distinction between what he terms the "Evolutionary – Analogy View" and "The Evolutionary – Origins View". The former supports a model for a descriptive philosophy of science, whose main feature is a process of competition leading to differential reproductive success. This process occurs both in organic evolution and science development. The Evolutionary – Origins View states, on the other hand, that the application of the epigenetic rules, encoded in *homo sapiens* in the course of evolutionary adaptation, directs the scientific inquiry. Michael Ruse (1995: 157-65 and 1986a: 29-66, 149-68), for instance, has pointed out that there are several epigenetic rules informing human evolution and ascribes the growth of science to the use of evaluative standards which emerged from the struggle for survival. According to Ruse's perspective, these standards are an extension of the perceptual and conceptual abilities that were valuable in the struggle to adapt to environmental pressure.

The dichotomy, however, is now best known in the form and with the labels given to its components by Bradie in his well-known article 'Assessing Evolutionary Epistemology' (1986). Bradie divides evolutionary epistemology into two distinct programmes: the evolution of epistemological mechanisms (EEM) and the evolutionary epistemology of theories (EET).[13] EEM tries to supply an evolutionary explanation of the development of cognitive structures, while EET attempts to give an account of epistemological norms and human knowledge. Advocates of EEM are, for instance, Lorenz (1977),[14] Popper,[15] Plotkin (1982) and Wuketits (1990). EEM and EET programmes, though distinct, are connected. Bradie points out:

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[12] This is the approach of the Austro-German School.

[13] We will usually use the expression 'evolutionary analogy' to refer, in the remaining chapters, to the EET stance.

[14] Konrad Lorenz is important for his biological interpretation of Kantian *a priori*. He maintains that these forms of perception are *a priori* for the single individual, but they are philogenetically *a posteriori*

[15] Popper is also famous for his arguments in defence of an EET programme.

> There is a slippery slope leading from a central part of the EEM program (the attempt to understand the philogenetic development of the biologically material cognitive apparatus) through the claim that all organisms and lineages have “built in” specific cognitive apparatus characteristic of their place in the philogenetic tree to the claim that each organism has its own characteristic “*a priori*” Kantian categories and finally to the central claim of the EET program, viz., that the *content* of knowledge as shaped, in part, by the “*a priori*” categories itself undergoes some form of evolutionary development. (Bradie 1986: 409)

David Sloan Wilson (1990) also suggests that evolutionary epistemologies draw a complex connection between adaptation and knowledge. He distinguishes between the two programmes using the following short formula: EET considers adaptation as knowledge, while EEM considers knowledge as adaptation. EET programme is inclined to consider knowledge as a result of evolution and, biological adaptation is sometimes considered a form of knowledge itself;[16] EEM programme, on the other hand, has a propensity to tackle the ability to know and the knowledge generated as a biological adaptation. Past survival and reproduction are partly a result of these two factors: the capacity to know and the knowledge we have acquired. Briefly, evolutionary epistemology considers adaptation as a form of knowledge and the skill to obtain knowledge as an adaptation, which has evolved biologically.

In this work we will consider exclusively evolutionary epistemologies belonging to the EET programme. These evolutionary epistemologies revolve around what we refer to as ‘the evolutionary analogy’, the claim that scientific change is governed by the same mechanisms, or by mechanisms analogous to those at work in organic evolution. As we already pointed out in the previous section, most evolutionary epistemologies focus on the development of selectionist models to explain the growth of human knowledge. However, an important distinction is needed. On the one hand, some scholars use metaphors of various complexities and, basically, argue that science changes by a mechanism *analogous to* natural selection. Roughly, they regard scientific change as the repetition of a two-step process. A pool of competing intellectual variants is produced in the first step, as a response to certain conditions, such as the presence of an unresolved research problem. At the second step a selection process establishes which variant(s) will ‘survive’. We will call the evolutionary epistemologies based on this view *weak*

[16] By Campbell, for instance. He will later change his mind though (see section on Campbell in the next chapter).

evolutionary epistemologies. On the other hand, others claim that science *evolves by* natural selection:

> The evolution of scientific knowledge is, in the main, the evolution of better theories. This is, again, a Darwinian process. The theories become better adapted through natural selection: they give us better and better information about reality (they get nearer and nearer to the truth). All organisms are problem solvers: problems arise together with life. (Popper 1984)

We will call those based on these claims *strong evolutionary epistemologies*. Hull's work, in particular, is also oriented towards the identity of natural selection and 'scientific selection'. He develops an analysis of evolution through natural selection which applies to biological, social and conceptual evolution (Hull 1982, 2006).

Thus, weak evolutionary epistemologies consider natural selection as a metaphor which may be able to illuminate our understanding of the change of knowledge over time; strong evolutionary epistemologies argue that natural selection is an all-purpose 'invisible hand' theory, able to elucidate the emergence of co-ordination and design without calling for the presence of designers.

The most common objections to the EET program are probably the following three (Bradie 1997: 400). Firstly, although an apparent design can be detected in the Universe, a possible mechanism for the development of intelligent life in the absence of evolutionary goal and direction was provided by Darwin's theory and its more recent versions. Life evolution, however, is often pictured using the image of a branching tree and science could not make any use of this representation, since science is goal-directed and appears to proceed along completely different lines: "convergence and unification are often taken to be marks that we have the science right. This hoped-for and anticipated unity at the end of science is a vision inconsistent with a truly selectivist approach" (Bradie 1997: 401). Secondly, many theorists of EET consider the production of conjectures to be a 'blind' process, followed by a selective stage. It is often objected that this cannot be the case: the hypotheses generated by scientists are not random, since they have been formulated in order to solve particular problems. The third point concerns the progressive success of science, seen as a sort of 'fit' between knowledge and the world. In evolutionary biology, however, it seems impossible to identify any sort of general progression of the whole biological realm, because there is no fixed environment to fit even for a single species.

In this volume we will elaborate on these and other issues that arise from strong evolutionary analogies, claiming that science *evolves by* natural selection. This new elaboration is needed because, in the literature available, most of the attempts to criticise evolutionary analogies have erroneously ignored the aims and scope of the individual proponents. For instance, objecting that the production of novel theories is not random in the same way as mutations in the gene pools are is relevant only if the evolutionary analogy being criticised:

- explicitly states this assumption *or*
- is drawing an analogy which critically but implicitly depends on this assumption *or*
- is claiming that the processes of genetic mutation and theory variation are the same.

It is important, thus, to tailor analyses and criticisms on the scope of those epistemologies. More specifically, in each case the analysis will need to take into account whether the processes of biological and scientific development have been considered, by the proponents, the same process or analogous processes in a metaphorical discourse. Clearly, thus, what is needed at the next step is a theory of analogy and metaphor to be used for the evaluation of evolutionary epistemologies. In other words, a theory which would provide a means for measuring the soundness of the claims of such epistemologies on intersubjective grounds.

In the next section we shall introduce some relevant concepts from contemporary theories of metaphor and produce the basis for an evaluative framework. In the third chapter we will expand what we believe is the most advanced theory of metaphor to solve the problem of deciding whether two processes can be regarded as the same process.

1.3 Metaphor

Some history

The first extended philosophical treatment of metaphor is given by Aristotle, who considers metaphors a potent tool to enable the understanding of hidden truths. In *Poetics* metaphors are described as

> giving the thing a name that belongs to something else; the transference being either from genus to species, or from species to genus, or from species to species, or on grounds of analogy. (Aristotle 1941a: 1475b)

The main issues emerging from his works create points of reference for all future debates on metaphor.

First, the metaphoric transfer is located by Aristotle at the level of individual words. Only in the twentieth century has the metaphoric transfer been situated at the level of sentences, because scholars realise that the semantic unit is larger than a word (Ricoeur 1977).

Secondly, metaphor is seen as deviance from normal usage of language. Aristotle maintains that “diction becomes distinguished and non-prosaic by the use of unfamiliar terms, i.e. strange words, metaphors, lengthened forms, and everything that deviates from ordinary modes of speech” (Aristotle 1941a: 148a).

Thirdly, metaphors are based on similarity relations: Aristotle writes:

> The greatest thing by far is to be a master of metaphor. It is the one thing that cannot be learnt from others; and it is also a sign of genius, since a good metaphor implies an intuitive perception of the similarity in dissimilars. (Aristotle 1941a: 1459s)

Furthermore, he maintains that there are two kinds of metaphors: proper ones, which show things in a new light and bad ones, which are obscure. Aristotle explains:

> Metaphors, moreover, give style clearness, charm, and distinction as nothing else can: and it is not a thing whose use can be taught by one man to another. Metaphors, like epithets, must be fitting, which means they must correspond to the thing signified: failing this, their inappropriateness will be conspicuous. (Aristotle 1941b: 1405a)

Lastly, he relates metaphor to simile:

> The Simile is also a metaphor; the difference is but slight. When the poet says of Achilles that he leapt on the foe as a lion, this is a simile; when he says of him ‘the lion leapt’, it is a metaphor – here since both are courageous, he has transferred to Achilles the name of ‘lion’. (Aristotle 1941b: 1406b)

Aristotle’s point of view has greatly influenced the way in which metaphors have been considered through history, and is the basis for the ever-recurring view that metaphor is an elliptical simile. This is the so called ‘Traditional View’ (Johnson 1981), in which metaphor is considered valuable for didactic purposes and for stylistic and rhetorical goals. In this view, metaphors can be translated into literal paraphrases without losing cognitive content.

Empiricist philosophers mistrusted metaphors, viewing them as confusing devices which mislead by making unclear the categorical distinctions between words. Metaphor is regarded as a matter of extraordinary language, a rhetorical flourish. Locke writes: "[a]ll the artificial and figurative applications of Words Eloquence hath invented are for nothing else but to insinuate wrong *Ideas*, move the passions and thereby mislead the Judgement" (Locke 1975: 508). Hobbes fears that the transfer of a name is to be expected to mislead those who consider the name as signifying just the original object. He writes: "metaphors, and senseless and ambiguous words, are like *ignes fatui*; and reasoning upon them is wandering amongst innumerable absurdities" (Hobbes 1962: pt I, chap. 5). He also points out that metaphors can generate an incorrect way of understanding. He considers the human conceptual system to be essentially literal and points out that 'words proper' are adequate to express meaning, as a metaphor's meaning – when it has one – is its literal paraphrase. This stance and variations on it was dominant until quite recently, when the empiricist view was challenged by a series of novel approaches.

Metaphor as a cognitive structure

Current research on the theory of metaphor approaches its subject as a linguistic or as a cognitive phenomenon. Here, our goal is an analysis of metaphor capable of providing evaluative tools for the assessment of evolutionary analogies. Thus, metaphor as a linguistics phenomenon does not offer any insights we could make use of. [17]

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[17] The route of approaching metaphor by tackling it as a linguistic phenomenon is taken by Donald Davidson. Davidson claims that when we hear the statement 'a man is an island' it is naturally assumed that the statement is a metaphor, since it is really clear to everybody that a man is not an island. Davidson does not regard positively any perspective that regards metaphors as creators of new meaning; metaphors have just one meaning (the literal one). He states that "metaphors mean what the words, in their literal interpretation, mean, and nothing more" (Davidson 1978: 32.). Metaphors are utilised to get the hearer to understand or see something differently. They are a matter of pragmatism; they lead us to become aware of something that otherwise we would not have noticed: "I depend on the distinction between what words mean and what they are used to do. I think metaphor belongs exclusively to the domain of use. It is something brought off by imaginative employment of words and sentences and depends entirely on the ordinary meanings of those words and hence on the ordinary meanings of the sentences they comprise" (*Ibid.*, p.33).

The cognitive approach is largely adopted in linguistics and some scholars claim that we grasp the world only as mediated through our metaphors. Metaphor is undeniably omnipresent in our everyday life, because the nature of our ordinary conceptual system is fundamentally metaphorical:

> The locus of metaphor is not in language at all, but in the way we conceptualize one mental domain in terms of another. The general theory of metaphor is given by characterizing such cross-domain mappings. And in the process, everyday abstract concepts like time, states, causation and purpose also turn to be metaphorical. (Lakoff 1993: 203) [18]

George Lakoff and Mark Turner, among others, argue that metaphors are conceptual mappings: metaphor is "primarily a matter of thought and action and only derivatively a matter of language" (Martinich 1984). The presence of metaphors in our patterns of thought, thus, causes their appearance in our language.

> Nearly always, when we talk about abstract concepts, we choose language drawn from one or another concrete domain. A good example of this is our talk about the mind. Here we use the spatial model to talk about things that are clearly nonspatial in character. We have things "in" our mind, "on" our minds, "in the back corners of" our minds. We "put things out" of our minds, things "pass through" our minds, we "call things to mind", and so on. It is quite possible that our primary method of understanding nonsensory concepts is through analogy with concrete experiential situations. (Rummelhart 1993: 71)

We come to new knowledge in two manners: either through direct physical experience with our environment or through metaphorical understanding built upon some initial direct physical experience. For instance, we have the direct experience of the concept 'up' and happiness is grasped metaphorically through the metaphor 'happy is up'. This understanding is reflected in different expressions, such as 'I'm feeling up today' or 'I'm high as a kite'. In Lakoff and Johnson's perspective, metaphor is directional, since more abstract concepts are metaphorised and grasped in terms of less abstract ones. In the metaphorical pairing one concept is always better delineated and typically more concrete than the other.

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[18] For example on the topic see Lakoff and Johnson (1980 and 1999) For a different perspective from Lakoff and Johnson see G. L. Murphy (1996 and 1997).

These features of asymmetric reduction of abstract to concrete is mirrored, as we shall show, in the use of metaphors and models in philosophy or science to handle the unknown and the excessively complex through the known and relatively simple.

How do metaphors work?

Currently, many theories of metaphor exist: emotive, tension, substitution, anomaly and interactive theories among the others, but only a few are relevant to this context and will be discussed. In particular, because the evolutionary analogies are introduced by their proponents to suggest a possible model for scientific change based on a range of analogies with biological evolution, the most appropriate theories to take into consideration are those addressing, directly or indirectly, the role of metaphor in science. This seems reasonable not because the subject of the investigation is an aspect of *science*, namely its change, but because the use of metaphors by philosophers in this field corresponds to the use of metaphors by *scientists* in their research. Evolutionary epistemologists are confronted with a complex phenomenon to explain and, like scientists, they seek help in the dynamic of another, more extensively – or at least, more successfully – studied phenomenon which, due to some of its features, resembles the one to be explained. This is the way models help scientists to tackle their problems.[19]

Eleonora Montuschi (2000) distinguishes two main views in the interpretation of the role of models in science: the comparison view and the interactive view. The *comparison view* is the approach of the logicist tradition, where models are an elliptical form of simile.[20] Their value is purely illustrative and perhaps didactic and, as such, epistemically void and dispensable. In this view, for example, the sentence ‘science changes by natural selection’ should be rephrased as ‘scientific change is *like* change by natural selection’, meaning that the mechanism we know is at work in scientific change resembles that called ‘natural selection’. In this sense, the similarity is only intended as a means of clarifying – through a model that we assume is more familiar to the listener – a mechanism which is new or more difficult to grasp. The model, however, can be

[19] We will not linger, however, upon the omnipresent question about models and metaphors in science, namely their disposability or necessity, an interesting question but quite separate from our main focus.

[20] In a simile the similarities involved in the comparison are clearly defined and terms such as ‘like’, ‘as’ or ‘not unlike’ are present in the statement of the comparison.

forgotten once the main subject has been well understood and formalised. This view is appropriate, in this context, when an evolutionary epistemology is proposed with no deep commitment. For instance, we shall show that this is the case with Kuhn's analogy. In his case, the limited scope and the ephemeral nature of the metaphor does not require a criticism of the adequacy of the analogies as full correspondence of features between the two domains, because the analogies are meant to be only illustrative. Any evaluation thus, can be only based on the grounds of correctness, for instance on the right interpretation of the concepts in the two domains.[21]

The *interactive view* on metaphors was originated by Max Black in his famous article on metaphors (Black 1962). According to Black a metaphor is composed of two parts: the primary subject and the metaphoric secondary subject, which approximately corresponds to Richards' tenor and vehicle[22] and to what was formerly regarded as the 'original idea' and 'the borrowed one'. The interactive view, going beyond the formalist and purely logical interpretation of scientific theories, incorporates the dynamism of language into the complexity of scientific change. From Max Black's perspective (1962), analogies are dynamically created by the metaphors used by the speakers to put two subjects side by side. In developing this, Mary Hesse (1966) proposed a detailed analysis of the use of models in science, arguing that in developing or refining a theory scientists use a familiar system with a well consolidated and relatively unproblematic theory – the *explanans* – in order to model an unfamiliar system, the *explanandum*. They then draw comparisons and select relevant features from the familiar system to be transferred to the *explanandum*. The successful transferrals – that is, the properties of the model also displayed by the *explanandum* – will constitute the positive analogies between the system to be characterised and its model, while the unsuccessful ones will increase the number of negative analogies. However, some transferrals will be initially undecided, that is, it will be unclear or just unknown whether some properties of the model also belong to the *explanandum*. These undecided analogies constitute the set of

[21] A different version of the comparison view claims that metaphors are based on a literal analogy of this form: *A is to B as C is to D*. Metaphors, thus, are elliptical analogies (isomorphisms between the entities of two systems) and not elliptical similes.

[22] The word 'tenor' together with the term 'vehicle' were introduced by Richards (1936). Tenor is the underlying idea or the principal subject, while the vehicle is what is attributed metaphorically to the tenor. For instance consider the case 'men are wolves'; 'men' is the tenor and 'wolves' the vehicle.

neutral analogies which provide scientists with further material for research, and it is their potentially promising content that constitutes the fruitfulness of a model, that is its provision of research interest.[23]

> Analogies are employed in science to promote understanding of concepts. They do so by indicating similarities between these concepts and others that may be familiar or more readily grasped. They may also suggest how principles can be formulated and a theory extended: if we have noted similarities between two phenomena (for example, between electrostatic and gravitational phenomena), and if principles governing the one are known, then, depending on the extent of the similarity, it may be reasonable to propose that principles similar in certain ways govern the other as well. (Achinstein 1968: 208-9).

In the interactive view, models are an essential constituent of scientific analysis for two main reasons. The first one is the ‘interactive’ element of this position. Black pointed out that, rather than unveiling pre-existing analogies, metaphors create analogies due to the interaction between the two subjects of the analogy. Additionally, this mainly linguistic analysis was used by Hesse to claim that the relation between *explanans* and *explanandum* is also a dynamic one of mutual adaptation, so that both are modified by the use of metaphors. The second reason why models are essential in scientific discourse is the openness created by the neutral analogy, which instigates scientific investigation.

This view is appropriate for the analysis of evolutionary epistemologies which claim to be explicative. In this case it will be legitimate to point out that allegedly positive analogies are in fact negative and that crucial neutral ones are also negative. As a whole, however, the epistemologies will be hard to evaluate due to a single difficulty, namely the issue of weighting positive and negative analogies: if the final judgment on the fitness of an analogical discourse is to be based on the predominance of positive analogies over negative ones, how do we measure this predominance? In order to do so, we need criteria to decide the relevance of analogies within positive and negative groupings, and then finally the whole set. This is because relevant negative analogies might be balanced by a higher number of relevant positive analogies, or by less numerous but much more relevant ones. For example, if it is agreed on the basis of investigation that intentionality and progress belong to the negative analogy between scientific change and natural selection while, say, fitness and replication belong to the positive one, it is arbitrary to

[23] See Callanan (2008) for a clear analysis of the inductive power of analogical arguments in Kant.