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The Puzzling Inventory of Life

In this paper I introduce the concept of biodiversity by means of its peculiar story and defend the importance of biodiversity as an autonomous object of scientific enquiry (Sections 1 and 2). I then discuss two difficulties, (i) the lack of an agreed definition and (ii) the elusiveness of the notion of biodiversity. While I argue that (i) is a problem that can be handled, I suggest that (ii) follows from the vagueness of the concept of *diversity* and its cognate *kind* (Sections 3 and 4). Yet, the notion of kind, connecting biodiversity to taxonomy, indicates the path to follow in order to explore what biodiversity is, even though it is a way full of hurdles to overcome (Sections 5 and 6).

1. Introduction

The variety of the forms of life has always been a subject of philosophical reflection. Already Plato promoted the idea that life tends to manifest itself in the greatest possible variety of forms—the "principle of plenitude", as A.O. Lovejoy (1964) named it. Aristotle—who, unlike Plato, directly studied the natural world—in addition to producing the first biological taxonomies (*The history of animals* includes the description of nearly six hundred species) was probably the first to reveal a double characterization, scientific and aesthetic, of the diversity of life, claiming in *Parts of animals* that all species, from the most repugnant to the most beautiful ones, are of the same value insofar as each of them embodies both nature and beauty. Leibniz's "principle of variety" is but another example of this long philosophical tradition.

Nevertheless, biodiversity as conceived today seems to mean something peculiar and to imply something more than mere aesthetic or largely anthropocentric considerations. Indeed, the term "biodiversity" was coined only in 1986 to express a politically laden and ecologically centered concept: biodiversity originates with its own crisis, as something to be preserved. The term registered immediately a huge success, and today the debate on biodiversity ranges widely in the life sciences as well as in our daily lives. Biodiversity has become rapidly central to the interests of scientists (biologists, agronomists, ecologists), governments (the Convention on Biological Diversity, CBD, came into force in 1993 and currently involves 193 countries), and the media. However, despite all the events and actions dedicated to this topic, defining biodiversity, understanding what it is, describing it, inventorying it, and establishing appropriate policies aimed at its conservation and improvement are extremely complex tasks, some of which call for detailed analysis. In particular, while a great deal of studies has been devoted to the measurement of diversity and the comparative evaluation of various methods of measurement, relatively little attention has been paid to the *concept* of biodiversity itself. How is 'biodiversity' defined? And what is meant by that definition? Simple as these questions might seem, at present there is no agreement on how exactly one should understand the term 'biodiversity'. Biodiversity is immediately and generically perceived as something to be protected, loaded with scientific, ethical, and political meanings. Why is this so? The emergence of the term is a case of dynamical social construction of environmental problems: the rapid and anthropogenic decline of biological diversity induced U.S. scientists to introduce the term 'biodiversity' and to launch the campaign for the conservation of biological diversity (cf. Koricheva & Siipi 2004; Haila 2004). In particular, two main and intertwined problems have to be addressed: the lack of a shared definition and the vagueness of the term. Most straightforwardly, biodiversity is equated with the variety of life and refers collectively to variation at all levels of biological organization. But such a characterization, *per se*, means everything and nothing. Fortunately, the challenge of clarifying what biodiversity is can rely on a venerable philosophical discipline that has to do with things and their categorization, namely metaphysics, and on a rather well established "philosophy of classification" (see Ereshefsky 2001).

2. A brief history of the naissance of a new scientific object

Biodiversity came to the fore as an important environmental issue through a process of deliberate social construction including the coinage of the name, the scientification of the concept, and the impressive spreading of initiatives devoted to the maintenance and preservation of the object.

Phase 1: Coinage of the name 'biodiversity'

While the *idea* or *concept* of the variety of life has been around since the early days of philosophy, the *term* 'biodiversity' and (I suggest) the corresponding *scientific object* are of rather recent coinage. The expression 'biological diversity' came into usage in the late 1970s. It was blended into 'BioDiversity' by biologist Walter G. Rosen during the organization of the "National Forum on BioDiversity" in 1986 (see Takacs 1996), and this term finally became 'biodiversity' in the title of the volume collecting the proceedings of that conference (*Biodiversity*, edited by E.O. Wilson in 1988). The reason that led evolutionary biologists and ecologists to introduce the name were basically political: the new name was intended as a slogan to draw the attention (and support) of decision makers, governments, scientists, and citizens to the rapid decreasing in the number of species. In particular, the intention was to raise political and academic awareness of species loss and decline caused by human activities. (Some researchers suggested that we are facing an unprecedented loss of species. Wilson 1992 hypothesized that the extinction rate could be between 27,000 and 100,000 species per year, though not everybody agrees on these figures.)

Phase 2: Scientification of the biodiversity *concept*

As I mentioned, when it was coined, the term 'biodiversity' was (implicitly or explicitly) intended to refer to the variety of species. In his contribution to the proceedings of the National Forum, Wilson explicitly identified the amount of biological diversity with the number of species, and the loss of diversity with the extinction of species. The reason for that identification becomes clearer in his *The Diversity of Life* (1992, p. 14):

> Eliminate one species, and another increases in number to take its place. Eliminate a great many species, and the local ecosystem starts to decay visibly. Productivity drops as the channels of the nutrient cycles are clogged. More of the biomass is sequestered in the form of dead vegetation and

> slowly metabolizing, oxygen starved mud, or is simply washed away … Fewer seeds fall, fewer seedlings sprout. Herbivore decline, and their predators die away in close concert.

The literature grew fast: from the early monographic volumes by E.O. Wilson to the five-volume *Encyclopedia of Biodiversity* edited by Princeton ecologist S.A. Levin (2001). Koricheva & Siipi (2004) calculated[1] that the number of scientific papers on biodiversity issues has grown exponentially since the late 1980s, exceeding 3,000 per year by 2004 and spreading across different scientific disciplines (mainly evolutionary biology, conservation biology, ecology, and taxonomy, but also paleontology, microbiology, oceanography).

Phase 3: Policies devoted to biodiversity

As said, the main reason to coin the label 'biodiversity' was to draw attention to species loss, with an emphasis on the loss of species caused by human activities. Accordingly, the word (and the concept) rapidly became the center of a large amount of international political treaties, beginning with the CBD (which was signed in Rio de Janeiro in 1992) and the equally impressive Cartagena Protocol on Biosafety (1992), an international agreement devoted to face the potential risks posed to biodiversity by genetically modified organisms. (One of the main (and most controversial) goals of CBD[2] was actually "the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding".)[3] Besides political treatises, several initiatives have been carried out to raise the awareness of the governments and the general public: 2010 has been declared International Year of Biodiversity by the UN, and on December 2010 (also in consideration of the fact that the CBD target for that year, namely "to achieve a significant reduction of the current rate of biodiversity loss at the global, regional and national level", had not been reached), the UN declared the period from 2011 to 2020 the UN-Decade on Biodiversity.

Because of the political demand that is at the basis of the process of its naissance, some authors suggest that biodiversity is not a genuine object of inquiry for natural science and should be abandoned. While I agree that the massive use (and misuse) of the word 'biodiversity' by the media may cause a negative reaction (cf. Ch. Lévêque, *forthcoming*), I think that this objection—and the dismissal of the biodiversity concept—misses the point. The so-called "construction" of scientific objects is a rather common practice in science (see Hacking 1999). It can be understood as a way to focus the attention—in certain historical periods—on certain particular features of the world. Those features have always been there, though; it is just that they had not been deemed significant or worthy of scientific attention.

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[1] The calculation was based on the occurrence of the term 'biodiversity' in biological abstracts. It is worth noting that while biodiversity has already occasioned an enormous amount of scientific literature, the philosophical literature is still rather scarce. As far as I now, an explicit "philosophy of biodiversity" has been addressed in only three books: *Philosophie de la biodiversité* by Virginie Maris (Buchet-Chastel, 2010); *What is Biodiversity?* by James Maclaurin and Kim Sterelny (The University of Chicago Press, 2008); *Philosophy and Biodiversity* edited by Markku Oksanen and Juhani Pietarinen (Cambridge University Press, 2004).

[2] The CBD text can be downloaded at the link: http://www.cbd.int/doc/legal/cbd-en.pdf

[3] The issue of the intellectual property of bioengineered food, and more generally patents' property, is probably among the several reasons that explain why the United States, which was among the champions of the CBD, has not yet ratified the Convention. The CBD was opened for signature on June 5, 1992, at the Rio "Earth Summit" hosted by UNEP (the United Nations Environment Program). It was ratified in 1993 by 193 countries (192 countries plus the EU) with the exception of three outliers: the tiny principate of Andorra; the Holy See (0.44 square kilometers of cobblestones and brick, whose biological concern is not particularly high—although the appropriateness of the Vatican's contribution to the conservation of biodiversity as an humanitarian goal could be discussed, but this is another matter); and the 9.83 million km^2 United States.

(A similar point is made by C.Z Elgin with is notion of 'reconfiguration', see for instance Elgin 2002.) The demands that are at the basis of the process of construction do not seem to affect the autonomy and scientific interest of the corresponding objects. To illustrate, consider briefly two examples: race and gender.

Race became a scientific object in modern times, with the development of the biological conception of race. In antiquity, human beings were not sorted by phenotypical traits. Traits as skin color were of course noticed, but they were not used to sort people into discrete racial categories. Groupings were rather made on the bases of social or cultural characters. Among the Greeks and the Romans, for instance, the main division was based on the political affiliation of citizenship. Even the distinction between Greeks and Barbarians that can be found in Aristotle was based, not on biological traits but on political considerations: Greeks are those who organize themselves into city-states, Barbarians are those who do not. Similarly, in the Western middle ages, the primary division among human beings was drawn between believers and non-believers. And so on. The scientific concept of race, based on phenotypical traits, is a modern construction[4], the result of a multifaceted process that involved naturalists, philosophers, and medical doctors. In particular, it was the result of the prevailing of polygenism (the idea that different human species have different roots) over monogenysm (holding the unity of the human species and its common root). Arguably, it was also the result of the establishing of a genealogical style of reasoning that was foreign to natural history until the middle of the eighteenth century, dominated by a Linnaean logical and classificatory style of reasoning (see Doron 2012). And just as it rose, however, the scientific object of race declined. Thanks to the work of, among others, Federico and Luca Cavalli-Sforza (1993), the biological base of the concept of race was eventually rejected, and today races are no longer considered scientific objects.

Gender is a more recent example. In the late Sixties, the coextensiveness of the categories female/woman and male/man was called into question, mainly in order to oppose biological determinism—broadly, the idea that sexual differences determine cultural and behavioral differences, plus the idea that biological facts justify social norms. In 1968, psychologist Robert Stoller introduced the term 'gender' specifically as the social counterpart of biological sex, to account for the phenomenon of transexuality, i.e, to explain the experience of being "trapped in the wrong body". Since then, the concept of gender has spread in both scientific and philosophical literature, and today it is part of ordinary discourse. (Notice that, notwithstanding its popularity, gender too is now being questioned).

Now, biodiversity is not so different from those of race and gender, though of course there may be differences when it comes to their scientific and political use. In particular, while race was misused as a supposed biological basis for racism, the social construction of biodiversity has nourished with new life several scientific disciplines, put the environmental crisis on the top of decision makers' agenda, and raised the awareness of common people across the planet. In other words, unlike race – and more like gender – the "construction" of biodiversity appears to have had mainly positive outcomes.

That being said, at least a caveat is in order: vernacular biodiversity does not and need not correspond to scientific biodiversity. While scientists and the general public agree on the ethical aspects of the issue (both agree on attributing value to biodiversity), the main goal of

[4] The first modern occurrence of the race concept is probably in Francois Bernier's *A New Division of the Earth* (1684), where the French physician presented a division of humanity into five species or races by means of their "remarkable differences" (skin tones, hair texture, bone structure, etc.)

scientists—especially conservation biologists—is to elaborate adequate biodiversity measures to be used in biodiversity conservation. And while the common-sense concept of biodiversity is affected by aesthetic considerations (never mind bacteria; let's save the giant panda and the Siberian tigers), the scientific concept is not. Moreover, from a scientific point of view it would be more appropriate to speak of *biodiversities* in the plural, because of the different levels at which biodiversity can be considered and because of the different ways in which biodiversity gets "specialized" in the different disciplines that study it. (See below, Section 4.) In other words, while scientists aim to make the concept of biodiversity more precise—mainly by parceling it out—common-sense biodiversity remains a fundamentally imprecise and vague notion. And, paradoxically, these characteristics appear to favor the popularity of the concept among the general public:

> People respond to it, it works, because each of us can find in it what we cherish… What is it you most prize in the natural world? Yes, biodiversity is that, too. In biodiversity each of us finds a mirror for our most treasured natural images, our most environmental concerns. (Takacs 1996: 81)

3. Defining Biodiversity

Having distinguished the scientific and the vernacular meanings of biodiversity, we can focus on the first. There are, unfortunately, many different definitions of biodiversity available in the literature. Consider:

> Biological diversity means the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. (CBD 1992)

> Biodiversity is 'the variety of life', and refers collectively to variation at all levels of biological organization. (Gaston & Spicer 1998: 3)

> Biodiversity is not simply the number of genes, species, ecosystems, or any other group of things in a defined area ... More useful than a definition, perhaps, would be a characterization of biodiversity that identifies the major components at several levels of organization. (Noss 1990)

> Biodiversity is an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans. (DeLong 1996)

These are just a few examples. In his review of the relevant literature from 1976 to 1996, Don C. DeLong (1996) lists no less than 85 definitions of biodiversity. Such definitions differ primarily in their degree of inclusiveness: from those that include the present/past/future of all life on Earth to those that restrict biodiversity to the state of a specific area at a given time; from those that include processes to those that only countenance entities; from those that include human-induced biodiversity (such as alien species, or genetically modified crops) to those that exclude it from the inventory, equating biodiversity with wilderness; and so on. The table below summarizes a representative selection of DeLong's 85 definitions, in order of decreasing inclusiveness.

Scope of ecological components and processes	Characterization of diversity	Definition published by:[a]
1. Species	Richness[b]	Schwarz et al. 1976, Stankey 1990, Cloudsley-Thompson 1993, Harms 1994
	Richness and evenness[c]	Art 1993, Cloudsley–Thompson 1993, Lapin and Barnes 1995
	Variety	Sandlund et al. 1992
2. Genes, species (and their activities)	Richness	Erwin 1991, Foster 1992, Spellerberg 1992, Raven 1994
	Variety	Murphy 1988, Koford et al. 1994
3. Genes, species, assemblages	Richness	States et al. 1978, Nat. Wildl. Fed. 1991
	Richness and evenness	Patton 1992
	Variety	Reid and Miller 1989, Raven et al. 1992, Thelander et al. 1994
4. Genes, species (and their activities), assemblages, biotic processes	Richness	Schwarz et al. 1976, Salwasser 1991
	Variety	Norse et al. 1986, Wilcove 1988, Landres 1992, Counc. on Environ. Qual. 1993, Henderson et al. 1993
5. Genes, species, assemblages, ecosystems	Richness	Dasmann 1991, McNeely 1992
	Richness and evenness	Off. of Techn. Assess. 1987, Cooperrider 1991, U.S. Bur. Land Manage. 1991, Spellerberg 1992
	Variety	Counc. on Environ. Qual. 1991, Probst and Crow 1991, Fiedler and Jain 1992, Harris and Silva-Lopez 1992, United Nations 1992, Wilson 1992, Scott et al. 1993, Adams 1994, Allaby 1994, Eisner and Berring 1994, Huston 1994, Meffe and Carroll 1994, Hunter 1996
6. Genes, species, assemblages, ecological processes, and their interactions	Richness	Naiman et al. 1993
	Variety	Wilcove and Samson 1987, Samson and Knopf 1994
7. Genes, species, assemblages, ecological processes, ecological components, ecosystems, and their interactions	Richness	Barker 1993
	Richness and evenness	McNeely et al. 1990, McMinn 1991, Ratliff 1993
	Variety	Keystone 1991, Spellerberg and Hardes 1992, Daniels et al. 1993, West 1993, Noss and Cooperrider 1994, Scott et al. 1995

What are we to make of the fact that there are so many definitions of biodiversity, often inconsistent with one another? As a matter of fact, using a term with different meanings can be one of the major stumbling block to reaching agreement in decision making: in order to establish effective shared strategies devoted to the conservation of biodiversity, an agreement on the definition of biodiversity, even provisional and operative, must be reached. I suggest that such agreement can be reached, since the term ‘biodiversity’ is not genuinely ambiguous.

Firstly, a distinction has to be made between a *definition* proper (which must specify the necessary and sufficient conditions for something to fall under the concept ‘biodiversity’) and the relevant *standards of application* (through which we can determine whether something does, in fact, fall under the concept). While a definition must be universal, semantically and etymologically well-founded and not biased toward any particular discipline (at least according to DeLong 1996), standards of application are discipline-relative. Every standard aims, within the scope of the relevant discipline, to say how ‘biodiversity’ applies *in that particular discipline*. Now, in the event that a term is genuinely ambiguous, there is no (non-disjunctive) definition that can capture different uses of the term in its different contexts. ‘Seal’, for instance, is a genuine ambiguous term[5], meaning sometimes the nice fish-eating

[5] The example comes from LaPorte 2007.

aquatic mammal and sometimes a kind of stamp. There is no *and there can't be* one "natural" definition of it. Compare 'seal' with 'flat'. The term 'flat' too is used differently in different contexts, for instance a *flat matrass*, a *flat voice*, or a *flat fee*. Nonetheless, different users of the term can agree on a natural definition of it, probably something very general along the following lines: "something smooth and even, without marked lumps, curves, or indentations". The same goes for 'biodiversity': the great terminological variation is not due to a genuine ambiguity of the term, but rather to the fact that concerns for biodiversity relate not only to several realms of human practice, but also to several different scientific disciplines, where the term is applied with different standards of application. Accordingly, under the umbrella of a general and universally agreed definition, the inconsistency of the standards of applications could—at least in principle, I am not saying that it would be easy—be solved, for instance making their use explicit.

4. An elusive notion

The notion of biodiversity is a deeply intuitive one but, like time for Augustine, "If no one asks me, I know what it is. If I wish to explain it to him who asks, I do not know" (*Confessions XI, 14*). The diversity and variety of the forms of life is all around us, we just need to look at a garden, a park, or a seabed to become aware of that, and when ordinary people use the word 'biodiversity', they immediately understand each other, without any need for further clarifications. In spite of its intuitiveness, however, to illustrate what biodiversity is in an exhaustive and universally accepted way threatens to be a hopeless challenge, as testified by the multitude of conceptions (first of all, vernacular vs. scientific) and the more than 80 definitions currently available. Why is it so? And what is biodiversity?

A *prima facie* difficulty comes from the fact that both words that form the term 'biodiversity' are poorly defined and intrinsically problematic. Even leaving aside the endless debate on the meaning of *bio* (there is no unanimous agreement among biologists on what life is, and we cannot—at least, not yet—rely on an uncontroversial criterion to distinguish what is living and what is not), the notion of *diversity* is a problematic one, mainly because of its vagueness. How diverse is diverse *enough*? And under which respects? It is for that reason that, for instance, Quine (1969) suggested that abandoning the notion of *similarity* (on which *diversity* is constructed by opposition) would be a mark of the maturity of science, given the impossibility to transform the intuitive notion of similarity into a scientific respectable one "where the animal vestige is wholly absorbed into the theory" (p. 55). Nonetheless, Quine himself recognizes its profound rooting in common sense along with its probable indispensability in science because of its role in induction.

> The dubiousness of this notion is itself a remarkable fact. For surely there is nothing more basic to thought and language than our sense of similarity; our sorting of things into kinds … The notion of a kind and the notion of similarity or resemblance seem to be variants or adaptations of a single notion. Similarity is immediately definable in terms of kind; for things are similar when they are two of a kind … We cannot easily imagine a more familiar or fundamental notion than this, or a notion more ubiquitous in its applications. On this score it is like the notions of logic: like identity, negation, alternation, and the rest. And yet, strangely, there is something logically repugnant about it. For we are baffled when we try to relate the general notion of similarity significantly to logical terms. (pp. 42-3)

If Quine is right, similarity and the cognate notion of diversity are at the same time unavoidable and scientifically unrespectable notions. Hence, biodiversity would seem to be a scientifically dubious notion in its very core. Yet, all of us (and the other animals, too) have a sort of innate sense of similarity and diversity, either as a product of evolution (if we accept the evolutionary epistemological hypothesis[6]) or as the result of cultural transmission (see Maffie 1998). Moreover, similarity and diversity are someway tightly bound to a notion that in the philosophy of science plays a central role, namely that of *natural kind.*

Natural kinds are supposed to be the referents of words like ‘tiger’, ‘lemon’, and ‘human being’, roughly corresponding to naïve or phenomenological species, and they are supposed to be those groupings that we would find “ready-made” in the world, independently of our cognitive practices, theories and language; they are supposed to be those articulations, to use a well known metaphor[7], according to which the world would be in itself structured and which our scientific classifications have always sought to reflect, at first imprecisely and then more and more faithfully thanks to the progressive refinement of our scientific knowledge.

While natural kinds traditionally conceived—i.e., understood as classes whose members share one or more essential properties—are considered a dead issue in evolutionary biology, phenomenological species continue to be the basis of taxonomic practice (which is probably why phenomenological species are found both in the vernacular and in the scientific concepts of biodiversity). The first step in building a biological classification is indeed to collect samples of a certain kind, as the following anecdote from Darwin’s autobiography (1958: 62) exemplifies:

> But no pursuit at Cambridge was followed with nearly so much eagerness or gave me so much pleasure as collecting beetles. It was the mere passion for collecting, for I did not dissect them and rarely compared their external characters with published descriptions, but got them named anyhow. I will give a proof of my zeal: one day, on tearing off some old bark, I saw two rare beetles and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one which I held in my right hand into my mouth. Alas it ejected some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost, as well as the third one.

This presupposes a (built-in or acquired) disposition to perceive things as similar or diverse. After this first step, a taxonomist must go further, and check whether those phenomenological differences are in some way connected to evolutionary processes or, to put it differently, whether a supposed phenomenological species correspond to a genuine evolutionary one (in most controversial cases, molecular biological technologies are used, e.g., DNA barcoding).

5. The Inventory of Life: from Natural Kinds to the Phylogenetic Tree

It is a rather uncontroversial stance that “biodiversity both as a vernacular and a scientific concept is about the classification of perceptible things and phenomena, especially species” (Oksanen 2004: 2). More precisely, biodiversity has to do with taxonomy, namely the

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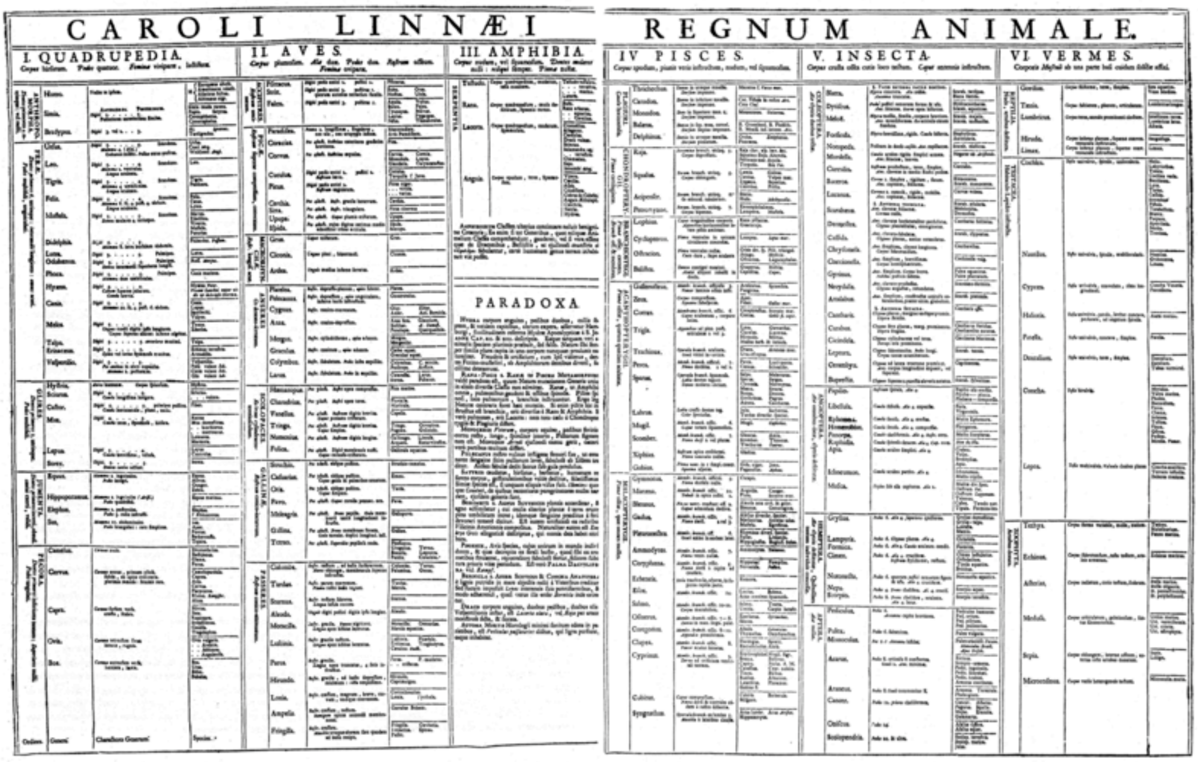
[6] According to a hypothesis coming from evolutionary epistemology (see Oksanen & Pietarinen 2004: 2), human minds have evolved so as to be receptive to nature’s diversity. (Note that this already presupposes a realistic stance towards natural diversity that cannot be taken for granted, as we will see.) To put it briefly, in order to survive, primitive men and women had to be able to distinguish edible from non-edible fruits, dangerous from harmless animals, toxic from non-toxic plants, etc. Accordingly, the ability of perceiving nature’s diversity would be a sort of adaptive trait.

[7] In the *Phaedrus*, Plato’s Socrates claims that we should “cut it [the speech] up in accordance with its forms at the natural joints, and not try to break up any part like a bad butcher” (265e). This statement has become an influential metaphor in discussions of natural kinds to indicate the idea that natural kinds carve reality “at its joints”.

practice and the theory of classifying living things. As a matter of fact, the idea lying beyond the social construction of biodiversity was—as we have seen—to handle the decline of the biodiversity itself. In order to *practically* proceed with the achievement of this goal, we need to describe, evaluate, and assess the diversity of biological systems (an ecosystem, a forest, a lake, a biota…) at a given time. To do so, what is needed in the first place is, at large, the counting of the elements of the system and the assessment of the degree of differentiation among them. In other words, when we know what to count and how to compare what we are counting, we are making our way towards an understanding of what must be saved (and, at least partially, of what biodiversity is).

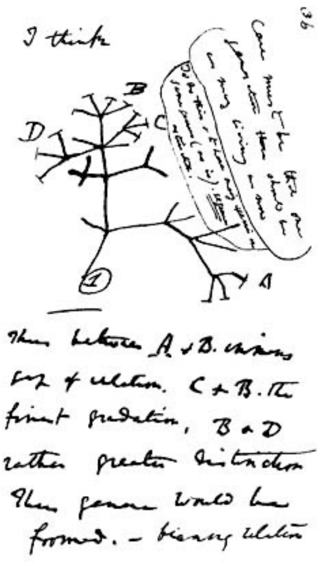
But taxonomy is not a uniform field; it rather includes several schools giving different, and sometimes incompatible, classifications of the natural world.


CAROLI LINNÆI REGNUM ANIMALE.

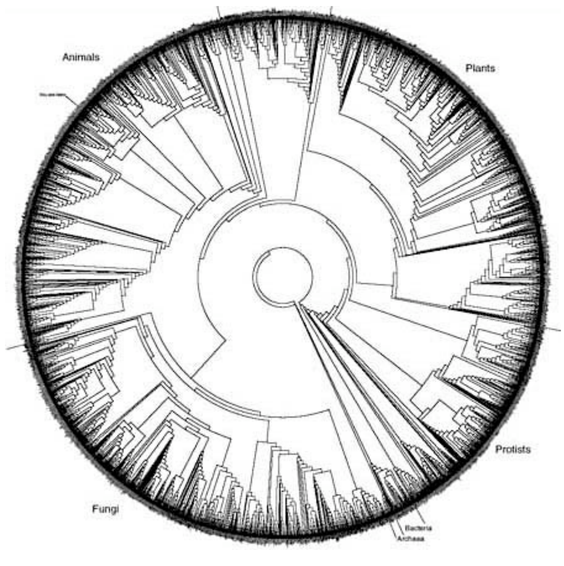
I. QUADRUPEDIA. II. AVES. III. AMPHIBIA. IV. PISCES. V. INSECTA. VI. VERMES.

PARADOXA

The father of modern taxonomy is unanimously considered Carl Linnaeus. His *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis* (title of the 10th edition, 1758; first ed. 1735) established the nomenclature rules and the hierarchical structure as we all know them. Obviously, however, it does not take into account the theory of evolution. Linnaeus's natural world, understood as the product of God's creation, was a static one. Species were thought of as the atoms of the system by virtue of their having essences coming directly from God, so *all* species were already existent; no new species could ever appear because it would have meant that something was missing in the universe, hence that creation, and God himself as creator, were not perfect. While essentialism and creationism are no longer taken seriously in biology, Linnaeus's system is still in use in spite of its static conception of the diversity of life. Indeed, it is the system referred to in the contemporary international codes that regulate zoological and botanical nomenclature.



Darwin's first diagram of an evolutionary tree. From the first of his *Notebooks on Transmutation of Species* (1837), the diagram is on view at the American Museum of Natural History in NYC.



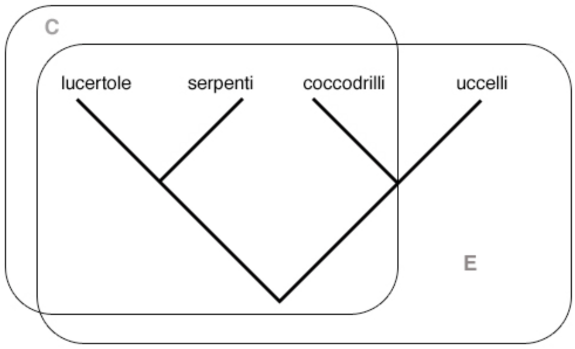
A phylogenetic tree of life, created by David Hillis, Derreck Zwickil and Robin Gutell. http://www.zo.utexas.edu/faculty/antisense/Download.html

From Darwin on, the whole picture changed drastically. Life evolves. It continuously produces (and loses) diversity. Species are significant atoms of this diversity, not because they have essences, but because they speciate, i.e., they originate new species by means of divergence processes (caused by different type of factors, from geographic isolation to hybridization), becoming extinct or transforming themselves through those processes. To account for the evolutionary world, *Evolutionary Taxonomy* intends to provide the Linnaean system with an historical reinterpretation in terms of phylogenesis, the historical ramification of lineages. In theory, if not in actual taxonomic practice, the similarity criterion is replaced by a causal-historical criterion. Briefly, species are now grouped in genera (and genera in more inclusive taxonomic categories), not according to their similarity but rather on the basis of their most recent common ancestor. Put differently, a genus is a group of species that has a fairly recent common ancestor and that, generally but not necessarily, exhibit similar inherited characters. Higher taxa are groups whose common ancestor lived in a more remote time; hence the evolutionary divergence among them is bigger, as is the corresponding phenotypical diversity.

In spite of its attractiveness, evolutionary taxonomy is grounded on an unproved theoretical assumption, namely that phenotypic diversity and genetic relation covariate. It also suffers from the practical difficulty of individuating which characters[8] must be considered as homologies, i.e., characters from whose presence it is possible to infer phylogenetic relationships. For example, heart and kidneys, which are found both in human beings and in chimps, are homologous organs, and witness a common evolutionary history. Likewise, it might be thought that vision—shared by insects and mammals—is the mark of a common evolutionary history. But it isn't. Mammals and insects do not have any eyes-endowed common ancestor (see MacLaurin & Sterelny 2008, chap. 1). A further difficulty for

[8] A character is a biological distinguishing feature that is characteristic for a particular, individual organism and can be used to classify, or identify it as a member of a particular taxon.

evolutionary taxonomy is that although it is based on evolutionary relations, it doesn't make exclusive reference to them.



An example is the famous case of Reptilia taxon (Figure above). If we look at the ancestor-descendent relations only, birds should be included in the same taxon (Reptilia) that includes lizards, snakes, and crocodiles. But according to evolutionary taxonomists, birds are *too different* from those other animals; hence birds should be included in a different taxon. By contrast, *Cladistic Taxonomists*—even though they proceed from the very same theoretical presuppositions as evolutionary taxonomists, namely, the idea that the main goal of a taxonomic system is to reconstruct the tree of life as it has been shaped by evolutionary forces—adopt a criterion that is thoroughly historical. No matter how diverse birds are from crocodiles, insofar as they originate from the same historical event of branching, they belong to the same κλάδος of the tree. It is rather clear that the choice does not depend on empirical matter only (we already know what we need to now about Reptilia's members). How to choose then between the two classifications?

6. The Species Problem

Puzzles of the same kind are even more frequent when species are at issue, to the point that in the literature the difficulties tied to the concept of species have been codified under the label "Species Problem". And Species Problem, as we are going to see, can seriously affect the description, assessment, and hence conservation of biodiversity.

Both in taxonomy and in biodiversity species occupy a privileged place. In taxonomy, while higher ranks such as families or orders are often considered just arbitrary groupings, species enjoy a sort of ontological primacy: they are "more real", so to speak, insofar as they are among the units of natural selection (at least according several biologists). In biodiversity, species diversity is almost unanimously thought as one of the main levels that have to be taken into account (along with genetic diversity and ecosystem diversity) when biodiversity is described, and species are generally the target of conservation policies. Moreover, species are of peculiar importance in the common-sense conception of biodiversity.

Unfortunately, even though laws like the Endangered Species Act[9] take for granted that we know exactly what species are (and how to count them univocally), identifying and counting

[9] The Endangered Species Act of 1973 claims that "Species are objective entities that are easily recognized" (National Research Council 1995: ix) and defines them in a circular way as follows (notice also that the definition is applicable exclusively to organisms that reproduce sexually): "The term 'species' includes any

species is far less easy than it might seem at a first glance. Apart from disparities due to the fact that every taxonomic practice involve a certain amount of arbitrary choices by taxonomists, the disagreement about species delimitation and count is due to the fact that different researchers often use different species definitions (at least twenty concepts—i.e. families of definitions), depending on the field in which they work and on the type of organisms under consideration. For instance, a paleontologist will make use of a species concept based on morphological characters, whereas a zoologist will probably opt for an interbreeding-population concept. On the other hand, a species concept based on interbreeding will be fairly unserviceable to a bacteriologist, and so on. Disparities coming from this type of disagreement are a serious obstacle to the assessment of biodiversity and to the application of the policies devoted to species preservation. Consider the case of the red wolf, reported in an article in *Scientific American* by Zimmer (2008). The red wolf (*Canis rufus*) is considered a separate species, living in the southeastern U.S. Recently, this wolf has been the subject of a massive project to save it from extinction. But now the Canadian scientists argue that it is just an isolated population of *C. lycaon* and, luckily, thousand of exemplars of *C. lycaon* are still thriving in Canada. Or think about the Birds of Paradise: starting from the very same data, according to the phylogenetic concept such birds come in about 90 species, whereas according to the interbreeding-based species concept they come in 40/42 species (see Cracraft 1992). How can we account for these disparities? And how can we handle them with an eye to the biodiversity preservation policies?

The problem of delimiting and counting species is part and parcel of a more general issue that has become known in the literature under the name of "Species Problem". It occasioned a very large amount of literature (see Stamos 2003 and Richards 2010 for an overview) and every author tends to identify it with a different issue. In the formulation by Stamos, for instance,

> In a sense, the species problem is really quite simple. Are biological species real, and, if real, what is the nature of their reality? Are species words merely operational conveniences made for the purpose of conveying various information and theories, or do species words refer to entities in the objective world with a real existence independent of science?" (Stamos 2003: 1)

The question about the ontological status of species as stated by Stamos is divided in two parts: (i) Are species genuine denizens of reality, as a realist would claim, or are they just cognitive constructs, linguistic devices by means of which biologists dissect the external world, as a nominalist would rather contend? And (ii) If species are among the things that exist, what are they? Question (ii), in turn, can be understood in two different ways: How are species defined? And: What type of entity are they? As far as species definition is concerned, as said, different subgroups of biologists advocate different—and often incompatible—accounts. Confronted with the multiplicity of species concepts, a monist, will claim that there is one and only one "right" species concept: perhaps it is among the species concepts currently proposed, or perhaps we need to trust biological progress and wait for the discovery of the right one, but the natural world has a structure of its own, and our taxonomy must mirror it. Several authors (Kitcher 1984, Mishler and Brandon 1987, Dupré 1993) are instead promoting a pluralistic approach, according to which there is no single correct species concept, one of the main reasons being that evolutionary mechanisms make it in principle impossible to pinpoint the essential property (or a cluster of such properties) that is needed in

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subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature". (Def. 16, section 2.) <http://www.nmfs.noaa.gov/pr/pdfs/laws/esa.pdf>.

order to talk of an unambiguous carving of species. Consequently, different partitions of the natural world are equally legitimate. As for the nature of species, on the traditional view species are construed as sets whose members are individual organisms sharing an essential property or a cluster of properties. Some authors (notably Ghiselin 1974 and Hull 1976) have argued instead that species are individuals, for species evolve whereas sets (which are abstract entities) are necessarily static.

It should be clear that biodiversity and taxonomy are intrinsically intertwined: no description, assessment, conservation of biodiversity can do without taxonomy. But, along with the powerful instruments and articulate framework of taxonomy, biodiversity's issue—in particular when species diversity is at stake—inherits also its troubles.

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