

The nature of extinction

Julien Delord

Konrad Lorenz Institute for Evolution & Cognition Research, Adolf Lorenz Gasse 2, A-3422 Altenberg, Austria

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Abstract

The phenomenon of species extinction raises more and more concern among ecologists facing the actual crisis of biodiversity. Scientific investigations of the causes and effects of extinction must be completed by a philosophical analysis of the concept of extinction that aims to clarify the meanings of the term ‘extinction’ and to analyse modalities, criteria and degrees of extinction. We will focus our attention on the apparent paradox of the possible ‘resurrection’ of species in the near future with the help of genetic biotechnology and cloning techniques. The ontological background of the extinction concept is analysed in relation to the idea of species as classes. We will also show that there is no simple analogy between death and species extinction, and develop a conceptualist and dualistic system of supra-individual entities (species vs. population), supported by an instrumentalist approach to genetic manipulations which transform species into *interactive* kinds, which can go extinct and be recreated.

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1. Introduction

The extinction of species has always been the most dramatic threat to biodiversity. Consequently, in the last decades ecologists and conservationists have focused more and more attention on this phenomenon. Scientific research has produced outstanding work regarding the explanation of causes, mechanisms and consequences of extinctions of anthropic origin. Specialists in conservation biology have developed new concepts (Population Viability Analysis, for example, Minimum Viable Population) and new multi-disciplinary approaches. Thanks to such models, they can anticipate future rates of extinction with increasing certainty (Soulé 1987).

Above all, these models allow us to be aware that without human efforts, more and more species will be driven to extinction in the years to come. Hence, ecologists have formulated recommendations that are based on technical and ecological criteria and relate to species (and ecosystems) deserving special efforts to save (Myers et al. 2000). However, few previous studies have sought to define the nature of extinction precisely. Most biologists accept the following basic definition: “The end, the loss of existence, the disappearance of a species or the ending of a reproductive lineage”. It would also seem that the notion of ‘extinction’ designates both a recognised fact (e.g. ‘the extinction of the dinosaurs’) and a process in progress (e.g. ‘the extinction of populations of gorillas’). Yet, what is still missing

E-mail address: julien.delord@kli.ac.at

is an in-depth analysis of the nature of extinction, an ontological analysis, so to speak, that would enlighten us in our quest for ethical norms that would ensure the conservation of endangered species.

We would like to demonstrate here that a detailed study of the definitions, the criteria and the modalities of extinction will reveal many shortcomings in contemporary philosophy of ecology and evolution. Our analysis will be structured according to two principal concepts that are at the core of the notion of extinction: ‘death’ and ‘species’. We will then be led to present the ontological distinction that we establish between biological entities irrespective of whether they are real, abstract or virtual, and the ethical consequences of this system.

2. Extinction of species and individual death

A cursory glance at the scientific literature on extinction written since the eighteenth century reveals how difficult it is to categorize this phenomenon in clearly delimited ontological and epistemological classes. We regularly see various analogies drawn between the ideas of extinction and of individual death, ‘species death’ or ‘the ageing of the species’ being the most commonly used expressions. Denis Diderot is among the first scholars who referred to the metaphorically loaded idea of ‘death’ to talk about the disappearance of species: ‘As well as in the animal & vegetal reigns, an individual starts, so to speak, increases, lasts, wastes away & passes away; would it not be the same with entire species?’ (Denis Diderot, 1753 §58, *Questions*, 2).

From this time on, corresponding to the almost general acknowledgement of the existence of extinctions, the comparison—as it happens, strongly intuitive—between extinction and death has perpetuated itself, without ever being seriously questioned. It reappears, for instance, in a contemporary scientific survey of Pleistocene extinctions, where it is confidently written that ‘given evolutionary turnover, extinction is inevitable. Like death for the individual, nothing is more certain in the future of a species than its ultimate removal’ (Martin & Klein 1984, p. 3). In the same vein, the paleontologist David Raup (1991) does not hesitate to use shocking expressions in order to explain mass extinction to non-specialists; he speaks about species being ‘killed’! Finally, the analogy more or less insidiously pervades the actual discourse of ecologists concerned about vanishing biodiversity.

From a psychological point of view, then, we could assume that the only way to think about extinction is to compare it to death. Thus Claudine Cohen draws a parallel between the representations of extinction and death:

Today the question of extinctions is one of the most heated, and the most popular in paleontology [...] it carries a passionate, emotional, and even mythical charge. What is involved is death—our death—the possible

or probable extinction of our species. (Cohen, 2002, p. 231).

However, restricting the idea of extinction to individual death, itself without any clear-cut definition and criterion, hardly helps. Furthermore, as we will show below, the link between the ideas of death and extinction is far more complex than appears at first sight.

For the moment, we must begin by exposing the four different *modalities* of extinction that are usually distinguished in phylogeny (see Fig. 1):

1. A species can purely and simply stop existing: this is demographic or final extinction. We note straight away that this type of extinction can be divided into two ecological sub-categories: (a) extinction by serious injury to the survival capacities of the species’ individuals, and (b) extinction by injury of the species’ reproductive capacities.
2. A species can also vanish by hybridization with another, interfertile species, and thus produce a new hybridogenous daughter species from two mother species. This is for instance what happened to a fish species in Lake Geneva (the coregons) (Henry 2001).
3. The third way for a species to go extinct is to transform itself into a new species as a result of ecological or genetic modifications that produce an apomorphic trait; this kind of extinction is sometimes called ‘pseudoe-extinction’ (Van Valen 1973)—but inappropriately as we will show, because it is a ‘true’ extinction.
4. Finally, a species can disappear by giving birth to two or more daughter species in processes of allopatric speciation.

This classification requires some clarification, because the term *extinction* generally refers, if it is not further specified, to complete demographic extinction (the first type I have mentioned). Yet, this type of extinction should be considered more precisely as a double disappearance: disappearance of the species, certainly, but also disappearance of the vital process borne by the species lineage, and hence of the phyletic branch whose extremity was the species. The three other types of extinction are, on the contrary, a mere disappearance: the species as a set of individuals united by hereditary links, showing specific morphological and genetic characteristics. The vital process, continuing in a new species, survives.

In order to be able to distinguish these two types of extinction, Raup & Stanley (1971) speak of *phyletic extinction* in the first instance, and of *non phyletic extinction* in the three other instances. We need now to go one step further in the study of extinction by analysing in more detail the extinction *criteria* relevant to the final extinction of the species (Type 1).

2.1. Extinction after the death of the last individual

This is the most common criterion to define an extinction, the one used by the international instances of

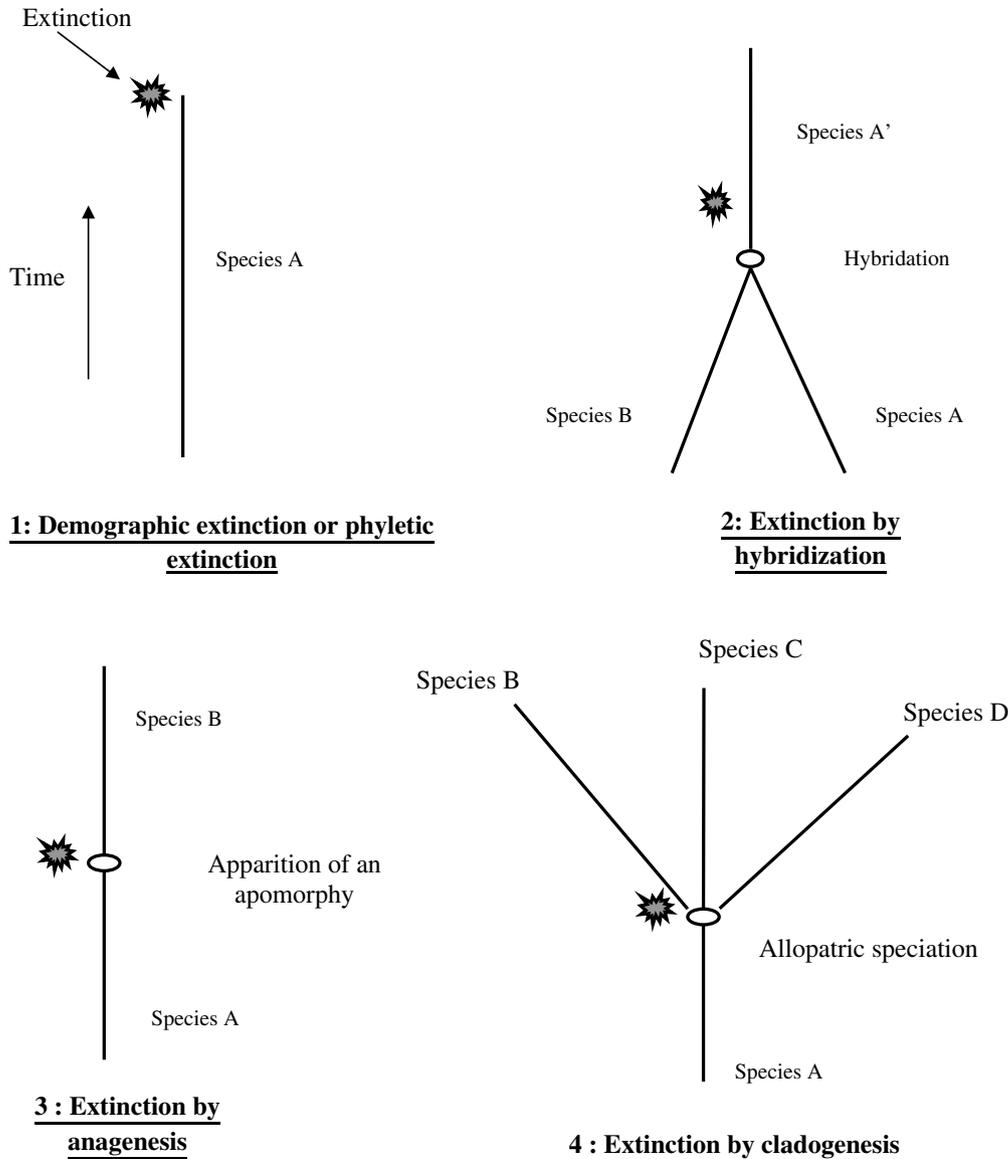


Fig. 1. Schema of the 4 different types of extinctions (Type 1: phyletic extinction; Type 2: extinction by hybridization; Type 3: extinction by anagenesis; Type 4: extinction by cladogenesis).

environmental watch and protection (UNEP, IUCN), and is used as a reference by the majority of ecologists: this is the declaration of extinction at the moment the last specimen of the species is acknowledged to have died. Here is reproduced for instance the extinction definition for the constitution of the *IUCN Red List* (1994):

EXTINCT (EX): A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Despite the false appearance of evidence of this criterion we will find complementary definitions pertaining to quite

different epistemological approaches of the concept of species.

2.2. Extinction after the ending of the reproductive process

This kind of extinction matches an idea proposed by Kevin de Queiroz according to which the species would go extinct after the disappearance of the last couple, even if individuals of the same sex are still alive.

Regarding termination, organisms sometimes end by ceasing to function as integrated wholes—that is, by death. Species can end in an analogous manner, normally termed extinction. And just as certain component cells can continue to live after their organism dies, certain component organisms continue to live after their species become extinct. The most obvious example is a

species composed of organisms with obligate sexual reproduction and separate sexes (and no sex-changing abilities) in which the only surviving organisms are all members of the same sex. (De Queiroz, 1999, p. 70).

This concept of extinction, and the idea of species linked with it, is clearly functionalist as far as it is concerned with the determination of causes and not of properties. This point is confirmed by the definition of the category of ‘functional extinction’ proposed by CREO (*Committee on Recently Extinct Organisms*): “‘Functional extinctions’”, referring to a restricted population that can no longer reproduce under any circumstances, are inevitable extinctions’ (CREO, n.d.).

However, for De Queiroz, it is much more than an *inevitable* extinction, it is a truly *achieved* extinction. He understands life-giving process not as the life of the organisms that compound the lineage, but as the process taking place at the level of relationships between the members of the species, i.e. reproduction. Extinction, as described by De Queiroz, follows from his characterization of species as an evolutionary lineage, the process of transmission of genetic information, that is dynamic and spatio-temporally indefinite entities contrary to organic individuals. Extinction and death would thus constitute the end of two different types of processes, although both life processes.

De Queiroz claims that the meaning of ‘extinction’ should be limited accordingly: the end of the species following a *bifurcation* (cladogenesis—type 4) for instance should be called ‘distinction’ because the end of the species is associated with a fission (De Queiroz, 1999, p. 83 n. 21).

In contrast to De Queiroz, we consider for that reason that the species goes extinct, as in the classical definition, at the moment when the last specimen of the species dies, but maybe it can be considered as ‘*virtually non-extinct*’ (a category that will be explained below) as long as one possesses the information (genetic and biological in general) likely to make it live again. This will become clearer with the presentation and explanation of the last extinction criterion.

2.3. Extinction after complete disappearance of the last specimen

This type of extinction that only occurs after the last specimen, even dead, is destroyed, appears in the work of the great geologist Charles Lyell (1832). Lyell found with great excitement the documents relating the death of the dodo species, that is, the year and the precise day—8 January 1755—when the rotten remains of the last dodo specimen were thrown away from the University of Oxford. It is as if he really declared the extinction of the dodo and the other species only on the day when the form and the ana-

tomic constitution of the specimens vanished; as if the species was a synonym of type, of external appearance; or more precisely, as if the species existed above all on the cognitive level, a mere item of information which humans use to structure their comprehension of nature.

Even if this conception of extinction underlying Lyell’s remark about the disappearance of the last dodo specimen might appear isolated and anecdotal, according to us it belongs to the same category as the conception of extinction proposed by Alastair Gunn (1991). Indeed, he is troubled by the new possibility in the age of biotechnology of extinction as the erasure of a species’ genetic information.

The connection between Lyell’s and Gunn’s thought is supported by the analogy between ‘form’ and ‘information’. It is two ways to achieve the same objective: to define the identity, not to say the essence of the species. When it is a question of *form* or *information*, and not of the *life* of a species, extinction cannot be reduced to the simple death of individuals; it also has to account for the ending of the recognition process and of the transmission of information. We will show that only a non-realist conception of species can logically match such a definition of extinction.

Above all, a very unusual fact encourages us to recognize the same thought pattern among Lyell’s and Gunn’s work; these two authors are without doubt among the few thinkers to have raised the question of recreation or *resurrection* of extinct species. Lyell proposed the idea of a rebirth of the old species according to a pattern of cyclical return of ancient Earth periods.¹ It should be understood, however, as a material and plausible explanation (the notion of entropy having not yet been formulated) of Linnaeus’ theologically based belief in the non-definitive extinction of species. Gunn, for his part, is one of the very few contemporary philosophers to have taken up the problem of the recreation of extinct species, made theoretically possible by the reduction, led by geneticists, of the species’ characteristics to the genetic information that they carry.

Whatever the outcomes of their theories may be, these thinkers teach us a rather surprising lesson: the extinction of species should be considered as potentially reversible. Although ecologists claim that an extinction is forever, (and they are right as long as they talk about ‘natural’ species), it is not inconceivable to imagine having a species recreated by artificial techniques. This idea, or *fantasm*, is not recent as Daszkiewicz & Aikhenbaum (1999) reveal the existence of many projects since the end of the nineteenth century to recreate extinct races or species by backcrossing. The most famous example of this was the attempt under the Nazi regime in Germany to recreate the aurochs.

Without referring to *Jurassic Park*-like science-fiction, ancient micro-organisms such as the 1918 Spanish flu virus have already been recreated (Tumpey et al., 2005), and it will be without doubt possible in the coming years to

¹ This idea was mocked at the time by De la Beche in the famous drawing ‘Awful changes’, where Lyell is represented as Professor Ichthyosaurus. See Rudwick (1992), p. 49.

recreate a multicellular living individual from its DNA or from cells taken from an extinct animal or plant (and in a good state of conservation) thanks to advanced biotechnologies. Significant amounts of money are already invested in these kinds of projects (Vincent, 2002). Is it then possible to speak of ‘resurrection’ of species if the extinction becomes reversible? What does it imply for the ontology of species and extinctions and in particular for the debate about the links between death and extinction?

3. The ‘resurrection’ of species: a new look at the nature of extinction and species

3.1. The technics of species recreation

In order to tackle the question of species’ resurrection, we must understand how a species can be recreated and which technologies could allow a species to live again. Nowadays, we can only mention one way to proceed: genetic engineering.²

Even if the technician optimism behind genetic engineering is questionable (Ehrenfeld, 1986), we can nevertheless hope to recreate an organism from a piece of skin or of organic tissue preserved for a relatively short time in museums, or naturally by the cold or by the absence of dioxygen (in peat bog, amber, sediments, etc.) (Orlando, 2005). The critical and limiting factor is without doubt the access to enough and good quality information: in other words, DNA. This is the DNA (both nuclear and mitochondrial—and a small quantity of cytoplasm) which is transmitted from generation to generation, bearing genetic information.

Confronted by the diversity of ways in which genetic information may be transmitted, Gunn asks himself about the spatiotemporal continuity of species: ‘Does it make any difference whether the genetic information on a species is stored in DNA or on a floppy disk?’ (Gunn 1991, p. 301). Gunn replies negatively to this question. Firstly, he takes the imaginary example of the cloning of a particular individual and extends this reasoning to the species: Hitler’s clone (cf. Hull, 1994), that is, an individual possessing the same genetic information as Hitler, would never be the same individual, and far less the same person, because he would not be entirely determined by his genotype, but also by epigenetic effects and by the environment. Similarly, because a recreated species’ ecological environment will be different from that of the original (especially if the lapse between the extinction and the recreation is long), the spe-

cies will become another species, that is, it will be *different* from what it would have been if it had evolved naturally. Finally, Gunn is led to reject the consequences of the informational analogy that he introduces when he becomes aware that it contradicts the spatiotemporal unity of the species that he considers as essential: ‘There is something odd about the idea that the extinction of a species could occur at the moment the disk file is erased’ (ibid.).

Gunn’s demonstration however is highly questionable as it relies on the assumption that species taxa are individual. According to this approach defended by Ghiselin and Hull (1976), species taxa are spatio-temporally limited entities, or lineages, composed of organisms (in a part-whole relation) instead of being atemporal classes instantiated by organisms (in a class-member relation). We will show that this position leads to a confusion in a counterfactual argument which has different meanings for individuals and species (*If* the species had not become extinct, it *would* have evolved differently). Moreover, there is something counter-intuitive in Gunn’s reasoning that Michael Ruse (1995) expressed humorously with a ‘T-Rex story’³ and that we could summarize by saying that Gunn’s view runs contrary to most species concepts, for instance Mayr’s biological concept of species as far as the recreated organisms are *potentially* fertile with their extinct ancestors.

In fact, Gunn plays with the ambiguity of the expression ‘different’ or ‘not the same’. In the case of an individual organism’s cloning, Hitler II for instance is ‘different’ from the original Hitler in the sense of spatiotemporally *distinct*. (It is a numerical difference or *numero differentia* to refer to the Scholastic term.) For the species, it is not a question of *numero differentia* but a question of *specie differentia*, or differences in characteristics.⁴ In the former example, different means *materially distinct*; it is a discrete, absolute difference (all or nothing). In the latter example, different means *qualitatively changed*; it is a continuous change, with a potential infinity of degrees. This remark is fundamental as it clearly differentiates species from individuals and establishes species as classes, following the founder of systematics, Aristotle, i.e. that the study of forms is the way to gain access to knowledge, when the position of matter in space and time is purely accidental.⁵

To be fair, Gunn briefly tackles the question of the recreation of the species as a class: ‘Could it be that a species was a class with members at time T_1 , and was a class without members (or null class) at a later time T_2 , and was caused to be a class with members at a still later time T_3 ?’ (Gunn, 1991, p. 298).

² By ‘genetic engineering’ we mean the process that would allow by reverse engineering the creation of a functional DNA strand out of a nucleotide sequence, the insertion of this DNA in a nucleus, and the insertion of this nucleus in a receiver denuclearised ovum or egg.

³ ‘Frankly, this kind of discussion [on extinction forever or not] rests a bit too heavily on intuitions for my taste . . . As I disappeared down the throat of a recreated tyrannosaurus, I know where my intuitions would be. If it looks like a duck, quacks like a duck, lays eggs like a duck, then . . . !’ (Ruse, 1995, p. 183).

⁴ In this phrase *species* is used in a Scholastic sense, not be confused with the contemporary biological sense of the English term ‘species’.

⁵ Some authors like de Queiroz have argued that all taxa are individuals. They are forced to recognize that such a materialist stance prevents them from creating any ‘classification’. Cf. Mahner & Bunge (1997), pp. 26–63.

Indeed, there are numerous examples of classes which become empty classes—without members—and which become non null classes afterwards. A good example is the class ‘King of France’. Moreover, Gunn accurately remarks that an extinct species is a special null class. Unlike ‘Gryphon’ or ‘Sphynx’ which denote a constantly null class, an extinct species had to be instantiated once.

Therefore, we face a case study in which two positions on the extinction of species (final and non-final) must be matched to two concepts of species (class or individual). Thus we obtain four possibilities, from which two only are logically valid: a temporally indefinite class and an individual which disappears once and for all. Indeed an individual is spatio-temporally defined by a principle of unicity—an ‘*individuum*’, an ‘*a-tomos*’—that which cannot be divided (Gayon, 1996). A class is by definition a set of things defined by the fact that these things possess one or many characteristics in common. Thus, it is a formal or abstract construction and it is atemporal—which is not contradictory with the fact that a class can possess temporally defined instances.

Unlike Gunn, we will push the informational metaphor towards its limits and we will refuse to consider a priori the strangeness of a species going extinct when a computer disk is erased.

3.2. The recreation of species: An argument for the species as a class

We will suppose that it is foreseeable—at least soon—to convert all the genome of an organism into bits, a unity of information according to the theory of Shannon (1949).

We will also suppose that this information can be stored without alteration in a digital form for instance. The notion of information is subject to a fierce debate and we recognize that what we call genetic information is different from purely theoretical physical information, though John Maynard-Smith (2000, p. 181) affirmed that there is ‘a formal isomorphism, not merely a qualitative analogy’ between both concepts. We should also be aware that the genetic information is not a perfect copy of the organism, not even of its structure or of its form. It is only the information which provides the ‘recipe’ to obtain the future ‘ingredients’ in order to make the organism (*ibid.*).

We should note here that this information could not be sufficiently relevant to our analogy (*in vivo* and *in silico* supported information); we should also not neglect the transmission of egg cytoplasm, of the epigenetic state of DNA like methylation, of culture—socially learned behaviors—for the higher species. It reminds us that the phenotype is not strictly determined by the genotype. Moreover, as Lewontin (1992) has underlined, DNA is a chemically inert molecule, without any catalytic activity, a ‘dead’ molecule but for its informative structure. Without the complex proteic and enzymatic machinery of the nucleus and of the cytoplasm that ‘decodes’ and ‘interprets’ the information (what we call ‘life supporting system’ in Fig. 2), the DNA would be without interest.

Let us suppose that we possess the exact genetic information g_0 of an individual i_0 from species S. Let us also suppose that we know the exact epigenetic conditions (nuclear and cytoplasmic) necessary to enable the normal development of any individual with the genotype g_0 .

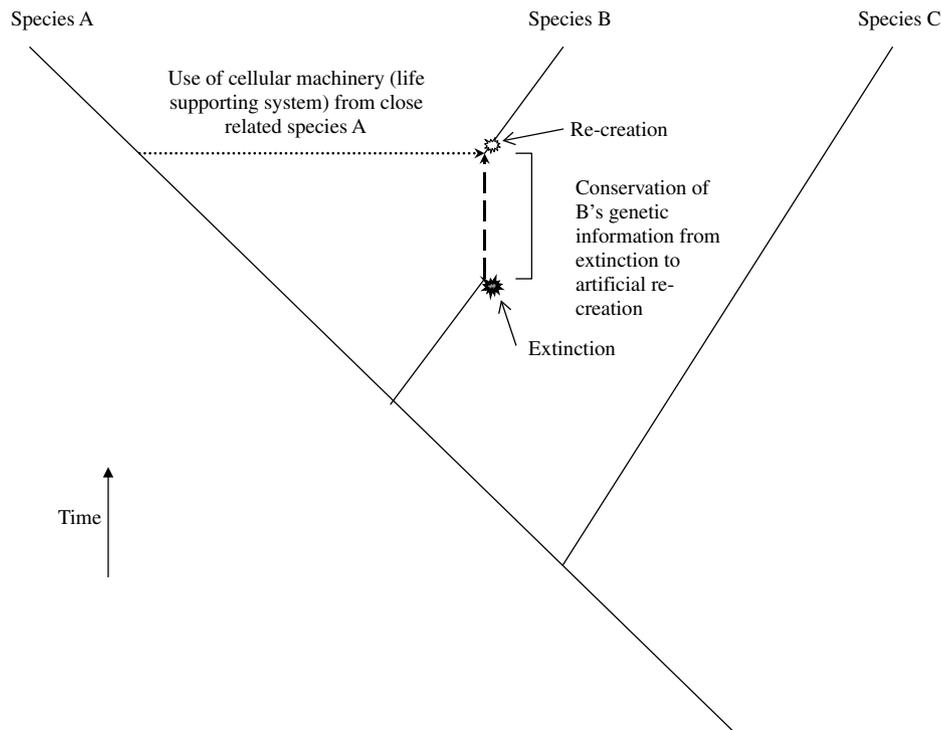


Fig. 2. Re-creation of a species by biotechnological engineering.

Under these conditions, we will suppose that a future biologist will be tempted to create one or many individuals identical to i_0 , which we should name ‘true clones’. Whatever the interference of the environment, it is clear that the new individual produced will be another individual, called i_1 for instance, even if he possess the genotype g_0 , as in the ‘Hitler II’ example. This remark is still valid if i_0 dies and if afterwards another individual i'_1 is created out of his genetic information. It is clear that i'_1 is another individual.

Henceforth we should no longer be interested in individuals, but we should speak about species to which individuals belong. Who could affirm that if we realize clones of i_0 and i_0 belonging to species S, we would obtain individuals *not* belonging to species S? Indeed, very few arguments could contradict this assumption. One could claim that a great epigenetic change during the process of cloning (understood as creating a nucleo-cytoplasmic chimera) could be interpreted as a speciation event. This kind of event seems very unlikely and, if under the global term of epigenetics we include the influence of the environment on the expression of the genotype, we will assume that ‘phenospecies’ (in contrast to ‘genospecies’) are not real species. Either way, we will assume that a clone of an individual from species S belongs also to species S, unless major genetic recombination happened, in which case we face a rare, though normal, speciation event.

Now, let us suppose that i_0 dies and that, moreover, it is the last representative of its species. How could one affirm that an individual i_1 , recreated thanks to the genetic material (g_0) of i_0 does not belong to S? It follows from this statement that a species can vanish, for as long as we want, and reappear as many times as possible; it stays always the *same* species. The evident ontological consequence of this rationale is that the species is not spatio-temporally limited but that it is an atemporal class, nothing more than a way of classifying individuals following characteristic properties.

Even better, if it happens that an error occurs during the copy of the genetic information from its storage disk, we will obtain an individual somewhat different from i_0 , both phenotypically and genotypically; yet we have many reasons to believe that it will belong to S as well. In the agronomical field for instance, despite fierce debates and controversies on many issues, the question of the species to which a given GMO belongs has never been raised. Transgenic corn *Bt*, although containing in its genome a small portion of allogeneous DNA (from *Bacillus thuringiensis*, a soil bacteria) is still named *Zea mais*; and transgenic canola is still considered as *Brassica napus*, though it slightly differs from its ‘natural’ ascendant. A species can thus be composed of organisms whose part of the genes have not been transmitted by heredity. Therefore, the genetic information of a species can escape the way of direct descent from the ancestors and have multiple and remote origins, whether human-induced or natural, as discussed Kitcher (1992).

3.3. The ‘resurrection’ of species: neither a paradox nor a false problem

One of the first objections to our demonstration could be a nihilist-like affirmation: assuming that the concept of species has been devoid of its substance since the emergence of evolutionary thinking, one could object that our rationale amounts only to playing with empty words. Although we refute this position which leads to ‘getting rid of species’ (Mishler 1999), this debate will not be open here; we think it is worth keeping the concept of species for the sake of coherence even if it has to be adapted to the recent transformations of taxonomy (Ereshefsky, 2001). Like the concept of ‘gene’, it has still a strong pragmatic efficiency based on cognitive reasons (Hey, 2001), even if its epistemological validity is questioned.

In this context, we draw again on the list of conditions and the contexts under which a species can become extinct and appear again. This process can also be represented by a simple diagram (Fig. 2).

- It is necessary to have a significant part of the genome of at least an individual from species S and the biotechnologies allowing for the expression of this genome in an appropriate cellular machinery, comparable to which of extinct species S.
- Genetic information should be stored and transmitted without alteration.
- The artificial or biotechnological transmission of genetic information is equivalent to natural transmission.

Some epistemological and metaphysical consequences about the relations between genes and species follow from these points:

- The implication that a genome belongs to one and only one species.
- But a species *is not* reducible to only one genome (the equivalent of the type) in general, and is defined by a genetic and allelic diversity, which could be resumed by the notion of ‘genomic cluster’.
- A species *is not* reducible to genetic information as the notion of species only makes sense as a set of something (individual organisms). Without individuals a species is equivalent to the null class. For individual organisms to exist and survive, a minimum of cellular machinery and a propitious environment are necessary.
- The genetic information contained in a genome (nuclear and cytoplasmic) is *necessary and sufficient* to determine the species to which an individual organism belongs.

The last statement is maybe the most important and also the most controversial so far. We should therefore warn the reader against some misinterpretations: it does not mean that we defend genetic determinism in the sense that the genome would entirely explain the biological characters of an organism. Indeed, the interactions between genes

and the environment might be highly variable and we don't assume that there exists a necessary link between some individual traits and the affiliation to a species. This statement does not mean either that there is a 'natural' rule at the genetic level which allows us clearly to attribute a genome to a species. We have to take additional information into consideration (genealogical, ecological, etc.) to make a decision. In this sense, the identification of a species taxon does not escape arbitrary decisions. The genome is not an essence. Eventually, this statement makes sense in the perspective of recreation of species insofar as the genetic information is the material which allows us to manipulate and even transform species with the help of biotechnology. This definition of species should be called 'interactive' or 'normative' instead of 'descriptive' like traditional definitions (phylogenetic, evolutionary, phenetic, etc.). This point will be discussed further below.

We affirm that with the previous assumptions we end up with a 'conceptualist' notion of species. The class species is here defined by a property, a *logos* in aristotelian terms, the information being borne by the DNA—what Ereshefsky (2001) calls a 'cluster analysis' class based on genetic similarity. But this affirmation of a class-species needs more refinement.

One could detect a logical paradox in our demonstration. We wanted to demonstrate that one could reply positively to Gunn's question, whether a species could go extinct at the moment where a magnetic disk is erased, if one considers species as classes and not as individuals. This would mean that as long as the genetic information is available, the species would still exist. Thus although we said that a species can disappear and appear again as many times as we want, one could say that in fact the species never really vanishes and that the argument of the recreation *de novo* of species is flawed.

The paradox comes from a fuzzy conception of what belongs to a species. Therefore, we should ask the question: is the genetic information of a species an instance of the species? The answer is clearly no! It is only a criterion (even if the most important today) that helps us determine if an organism belongs to a certain species. Contrary to zealots of the 'species as individual' theory, who inscribe the species in a mereological (part-whole) relation with all the inferior levels and, for this reason, would say that the genome is a part of the cell, which is a part of the organism, which is a part of the species, we say that if we agree that the genome is a part of the organism, it is only a criterion of the species' nature.

Thus, I can say that the species S *becomes extinct* and *reappears* without committing any fallacy, as when I say 'species S' I don't make any assumption about its existence. I only take the expression 'species S' as a name denoting an *abstract* or *conceptual* way of classifying things according

to certain properties. When there are no more instances of class S (e.g. *Mammuthus primigenus*), it becomes extinct because it becomes a *null class*, which has nothing to do with its *existence* as a class. Finally, no species 'really' disappears when a given genetic information stored on a floppy disk is erased!

Eventually, we hope to have demonstrated that 'extinction' is not equivalent to 'individual death'! When we speak about species, we don't speak about functional properties that support a life process, but only of the instantiation of a class. There is though 'something' which dies when a species disappears, beyond the death of the last organism. This is the disruption of the population. We give an account below of the biological system and the epistemological basis upon which our concepts of species and population rests.

3.4. A dualist-conceptualist ontology of species and extinctions

We acknowledge that our position is quite opposite to Hull's, Ghiselin's and the positions of most of today's life scientists and epistemologists (Brogaard, 2004), which are realist (in relation to entities) and individualist. Instead, we endorse almost all the hypotheses and epistemological assumptions of Mahner & Bunge (1997) in Chapter 7 ('Systematics') of *Foundations of biophilosophy*. Their theory, called 'conceptualism', rests on an ontological split between two kinds of entities, individual organisms and species. 'Only individual organisms are real, i.e., are concrete individuals and exist independently of the knowing subject ... Species and the other taxa are concepts, though not arbitrary and useless ones ... They are natural kinds' (ibid, p. 214).

However they recognize immediately that the old concept of natural kinds, as objective commonalities among organisms, is weakened by the fact of evolution, and they replace it by the looser concept of 'biological kind'. This concept remains, however, too realist for us; henceforth, we shall defend a conceptualism which insists more on the *arbitrariness* of the taxa defined, linked to an instrumentalist conception of science whose essential features are exposed in the following paragraph. This position which finds its roots in Hacking's (1983) realism about experimental entities is defended by the Belgian philosopher Gilbert Hottois who criticizes 'the notion of natural genus or species [that] is quite inadequate to describe the objects of an interventionist, operative, artificial science producing its own objects' (Hottois, 2004, p. 64).

Thus he calls *interactive* those kinds that can be modified artificially.⁶ In this sense, he reminds us that the most important aspect of today's sciences are maybe not the theories and the structure of their language, but the

⁶ This notion of interactive kinds should not be confused with Hacking's definition in *The social construction of what?* (1999), which concerns peoples or group of peoples aware of their own categorization by the society and able to act (or not to act) accordingly—that is, symbolic and retroactive interactions. Hottois insists more on the technoscientific dimension of interaction, following Hacking's *Representing and intervening* (1983).

epistemological significance of technology, which is far more than an ‘incarnated’ theory. It is the factor that allows us to go beyond *natural, spontaneous* phenomena and thus to question the world in greater depth. Instrumentalism underlines the fact that scientific propositions should not be judged true or false, but should be judged on their effects (e.g. heuristic) and by the possibility they offer to the scientist to manipulate the world (knowledge is also power).

We shall in the following paragraphs present the philosophical significance of this interactive ‘conceptualism’ for our subject. The fundamental aspect of this view is for us the strict ontological distinction between the concept of *species* and the concept of *population*. As Mahner & Bunge (1997, p. 230) remind us, ‘the relation between taxa is the relation of set inclusion (\subset)’. Membership (\in) is only for organisms to the first category taxa (species). Populations instead are mereologically *composed of* organisms. We can thus distinguish two kinds of nested hierarchies; one is a systematic hierarchy, grouping all taxa, that is abstract entities, from species to all living organisms, and the other one, the ecological-evolutionary hierarchy, is composed of real, material entities, individuals so to speak (cells, organisms, biopopulations, communities, biosphere) (Eldredge 1985).

This conceptual distinction is supported by other than logical arguments. Mishler & Donoghue argue for instance that ‘evolutionary processes . . . occur primarily on a small scale (even when extrapolated over many generations) relative to the traditional species level. In such groups, the units in nature that are more like individuals are actually interbreeding local populations’ (Mishler & Donoghue, 1992, p. 128). Another example is provided by Mary Williams (1989), who demonstrates that the real evolutionary unit is the population for certain types of selection.

Despite these examples, a brief analysis of the discourses of eminent evolutionary thinkers shows that they easily confuse the terms ‘population’ and ‘species’, taking the former as a less extensive and less definite entity than the latter. In contrast to this position, we think that there exists an ontological fundamental difference between populations and species, although they can be numerically coextensive in certain circumstances, as when there is only one population left of a species on the brink of extinction.

A population (or ‘biopopulation’ according to Mahner & Bunge) is a group of organisms with specific observable interactions, mainly reproductive and sexual, but also peculiar behavioral traits, common feeding strategies, defense against predators, mutual aid and altruism, spatial cohesiveness. We can view populations as spatio-temporally limited individuals in the sense of Hull (1976), although we acknowledge that in many cases the clear identification of a population (even worse, of a metapopulation) and its limits can be tricky and subject to debate (cf. Gannett, 2003).

A species is a class, and a class is a ‘set whose membership is determined by a predicate or a conjunction of predicate’ (Mahner & Bunge, 1997, p. 226). Thus, for these two philosophers, a species should have a nomological value, as

far as the identification of a species requires one or many underlying theories. Moreover, they add that ‘the only necessary and sufficient property for belonging in any taxon is “stemming from the same common ancestor”’ (ibid., p. 228).

‘Stemming from the same common ancestor’ is roughly true in nature, though not exactly, but it is clear that it becomes more and more questionable as we deal with species containing organisms that are biotechnologically modified. As a matter of fact, the laws of nature (understood as technology-free or ‘natural’ processes) helping define a species blur when considering the genetic manipulations made by humans. It follows from this observation that we should have lower theoretical expectations about the ‘naturalness’ or the ‘reality’ of species.

Because the identification of species relies, above all, on the classification of *organisms*, a taxonomist should ‘work with any properties, whether morphological, physiological, genetic, developmental, behavioral, or what have you’ (ibid., p. 233). However, because in our instrumentalist metaphysics the genetic criteria are by far the most important as being the *sole operative* factor, a species can be related to a ‘genetic space’ containing all actual and potential genes and alleles of the collection of individuals (past, present and future) belonging to the species. This kind of empirical ‘function’, that links a species to the ‘genetic space’ of its member organisms should not be confused at all with a reduction. A species is not a ‘genetic space’, even if the idea that a genetic sequence could give an instant biological identification of a species (what are also called genetic ‘barcodes’) could allow us think so (Hebert, Cywinska, & Ball, 2003). Actually, this sequence has been chosen *because* its degree of variation corresponds contingently to the level of divergence conventionally ascribed to species in the systematic hierarchy.

We recapitulate now the important points of our approach aimed at giving a global and coherent view of species extinction and recreation. Homogenous populations and organisms (individuals) living in a given niche and a given spatio-temporal framework belong to a species or subspecies (class). Ecology allows us to *describe* a species in depth, not to *define* it. For the latter we need taxonomic criteria : phylogenetic, evolutionary, interfecundity, similarity, etc. To quote Lherminier & Solignac (2005, p. 417) who appeal to Kant, ‘the ecological relation is not *determining* regarding diagnosis, only *reflexive*’. Though there exists no unequivocal relationship between ecological or organismic features and genes we can, at least temporarily, attribute to this species an ‘interior’ or hard criterion of membership—its genetic constitution. If a species which becomes extinct is judged to be worth conserving, and at least an entire genome is preserved, thanks to biotechnology (DNA processing, cellular engineering, cloning, etc.) we can hope to have the species recreated. In this case, the technology *makes* the genome the *essence* of the species in an Aristotelian sense due to the genetic determinism postulated at the species level. Or we could say that the

species takes the nature of a pure *essence*, intemporal and absolute, during its temporal suspension. It is human technology that creates a pure virtuality similar to Aristotelian *dunamis*. Instrumentalism is also a philosophy of that what happens. But as soon as the species reappears, with individual and live organisms, the essence disappears, and we enter again the domain of life, fuzziness, dynamics, continuity. These new organisms and populations regain their place in the ecological world, evolving until a biological change justifies the identification of a new species.

Before we conclude, we will complete our study by the exposition of what we call ‘degrees’ of extinction, which constitute another layer of philosophical analysis of the phenomenon of extinction.

3.5. Discussion on the ‘degrees’ of extinction

We must first discuss the extinction of populations and make clear the sharp contrast with the notion of species’ extinction. What is the extinction or disruption of a population? Because we said that a population is an individual, we should try to understand a population’s extinction in comparison with individual death. This will be done with the help of the examples and discussion on death presented by Jack Wilson (1999) in *Biological individuality*.

- A population could go extinct with the death of all its members. Here, the extinction *is* the ‘death’ of the population, understood as the final death of an individual.
- A population could go extinct with the cessation of all effective relations between the members of the population (as when the organisms of one population are dispatched in many other populations).

We are clearly in the situation described by De Queiroz (1999), of a functional extinction. But, is the population ‘dead’? Yes, but in the sense that its life has been ‘suspended’ as Van Inwagen (1990) writes. This situation is the analog for populations as cryptobiosis for organisms (Wilson 1999). The individual remains numerically and materially the same, however without relations. The population can live again if the relations are recreated between the same individuals.

A population can thus go extinct in dying by disruption on two levels (intra-organismic and inter-organismic) and can, in the latter case, be brought again to life as long as it still exists numerically. But a population cannot be recreated after the extinction due to the ‘disruptive’ death of its members as in the first case. Clones recreated from the genomes of the last members of the population would be other organisms and thus the population of clones would be *another* population. Thus we end up with two different ‘degrees’ of populations’ ‘death’.

Concerning species, we have already described four modalities of extinction at the beginning of this article,

and yet we present below what we call three ‘degrees’ of conceptual extinction.

The first is the ‘objective’ extinction degree when the species becomes a null class (whether by phyletic or non-phyletic extinction).

The second degree of extinction, made possible by the artificial creation of clones from entire genomes, concerns the extinction of genetic information coming from the members of the species. As long as we can expect for technical reasons that a member of an extinct species can be recreated, we can say that the species is ‘*virtually* non-extinct’ or ‘*potentially* non-extinct’ to refer to the Aristotelian vocabulary. Here the natural *telos* is of course replaced by a human and technical finality.

The third and last degree of extinction is related to the extinction of the meaning of the species. More than organisms or genomes waiting to be saved to alleviate human shame, species have their own signification and existence as primary members of our perceptive, cognitive and symbolic universe. A species would thus go extinct (for us) in the sense that it existed as an abstract category (‘good to think with’, as Lévi-Strauss, 1962, demonstrated) and disappeared from our understanding with the loss of information and representation about this species. This is probably the kind of extinction to which Lyell was sensitive when he spoke of the dodo, like Strickland, Lyell’s contemporary, a great ornithologist who was the first to write an entire book on the dodo and who sought consolation in this view of the naturalist’s duty: ‘It is, therefore, the duty of the naturalist to preserve to the stores of science the knowledge of these extinct or expiring organisms, when he is unable to preserve their lives; so that our acquaintance with the marvels of animal and vegetable existence may suffer no detriment by the losses which the organic creation seems destined to sustain’ (Strickland & Melville, 1848, p. 5).

To fight against this kind of extinction, the disappearance of a species as an abstract or a virtual category, is also a way to protect traditional cultures as their interpretation of the world and their means of maintaining memory of the past are supported by the natural categories (Caillon, Quero-harica, & Guarino 2004).

4. Conclusion

We hope that our instrumentalist–conceptualist ontology of extinction, and the dualist (real/abstract) view of biological entities it supports, will help us think, at the level of the species, about the challenges presented by the increasing success of biotechnology as well as biodiversity conservation. This system distinguishes on the one hand, real entities that can be understood by science in terms of explanation and causality (individuals), and on the other, abstract entities which form our representation of the living world (class). We recognize that the ontological commitment of this system fails in a Quinean sense as we ask too much ontologically of the world (that both classes and individuals exist). Nonetheless, we were able to show

in the first section that the four modalities of extinction are true species extinctions, that the functional criterion of extinction is relevant to the disappearance of populations and not species, and that we have a representation of taxonomic entities which allows us to think about the recreation and the artificial transformation of species without philosophical dead-ends.

The communication between the worlds of class and entities is ensured by the concept of ‘virtuality’, which stems from an instrumentalist and technological approach to life, subordinated to human will and finality, and which allows for the existence of what we called the ‘second degree of extinction’. The species, this node at the conjunction of representation and action, becomes an *interactive* kind thanks to biotechnology and genetics, and shows that ethical questions concerning the environment are no longer centered around fixed and archaic categories like nature and artifice, as nature and artifice blend into each other, but should be oriented toward the definition of a common world in which human and non-human species could live together without abnormal species extinctions.

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