ON MANUFACTURED LIFE AND THE BIOLOGY OF THE IMPOSSIBLE

ARANTZA ETXEBERRIA
MARILA LÁZARO

ABSTRACT. This paper aims to discuss and reflect on the possible and desirable limits of natural and manufactured life. Many ideas of how fabricated life could be, as well as many decisions about it, depend upon the notion of life one adopts. We set about from a notion of life as autonomy, in which the main property of organisms is that of autopoiesis: a living being produces itself. Yet, two other forms of *poiesis* or production that affect life are *biotechnology*, able to manipulate living organisms within the limits of the possible, and *art*, which may "create" new living forms, even non-existent in nature. A consideration of the forms of life produced by biotechnology and art poses urgent problems not always solvable by the epistemic or biological approaches to life.

KEY WORDS. Autonomy, constraints, biotechnology, art, evolution, monsters.

INTRODUCTION

One of the most striking properties of life is the variability and diversity of forms it may display; its creativity appears to be open-ended [1]. Most of us would accept that many forms of life, as yet unknown to us, never produced by evolution in earth nor conceived by anyone, even the apparently impossible, may exist somewhere else (in other galaxies, for example) or may come to exist somehow (evolution, laboratory, art). However, it is also the case that we possess some sort of canon or set of rules to demarcate normal or "natural" living variants from strange or rare forms.

Very often, accounts of life's variability and diversity are related to genes, regarded as *forms* with respect to matter or material properties. When the ontology of life is reduced to the properties of genes, the formal aspect may be seen as a set of instructions specifying discrete characters. Thus, it appears that the formal properties of genes confer to life an open-ended variability, as it seems that the appropriate changes of

Department of Logic and Philosophy of Science, University of the Basque Country (UPV-EHU).
arantza.etxeberria@ehu.es / ylblaolm@sf.ehu.es

genes—produced naturally or in the laboratory—will result in the desired varieties. However, forms may be understood in a different way, so that genes are material constraints acting on the physico-chemical dynamics constructing the morphology and function of organisms that are autonomous. If gene action is considered to be more material, the variability of the living realm appears to depend on complex material dynamics, as well as on history, and then there are limits on the variability that can be obtained, since there is no simple correspondence between an alteration on a gene and a resulted modification. Thus, the apparent permissiveness in producing "new" living forms suggested by the immense variability of life may be ontologically limited if certain forms are not possible, or it may have to face ethical limits, if new forms oblige us to take into account the status and rights of altered life.

Nature and life are non-coextensive domains; there is an inanimate nature and not all life is so natural; although no living being is completely artificial, forms of altered life challenge many of our views on natural life. Living forms differing from the "normal"—extraordinary types—have often been considered "monsters [2]": some of them generate naturally (spontaneously), others are imaginary (represented by art), and still others are created after the manipulation of already existing living beings. The word monster comes from the Latin *monstrum*—that which is shown forth or revealed—and it seems to be related to the verb *monere*: to warn—in ancient times monsters were considered to be messages from the gods bringing news of special facts that were to occur. Since prehistoric times humans have imagined all sorts of monsters as possible, but not existing, forms of life. These days some humanly produced creatures recall many of the characteristics of ancient imaginary forms, specially their cross-species character, and yield to the same sort of fear.

Here we propose a reflection on the limits to the production of altered life. Our start point is a view of life as autonomy and of living beings as autonomous material systems, and then we compare how living organisms are modified in evolution—thus producing new forms —with other creations in art and in biotechnology. Although we do not intend to be exhaustive in the examples, we will raise some issues about the biology of the impossible and the status of the resulting manufactured life.

AUTONOMY, GENES AND POSSIBLE LIFE

Thinking about life does not end in biology—it has many other sources of ideas and images— but it is clear that science plays an important role. However, in biology there is still no generally accepted definition of life (Luisi 1999, Morange 2004, Ruiz-Mirazo, et al. 2004)). Along the twentieth century there have been different images of life: the intense debates

between vitalists and mechanists of the first decades were in a sense overcome by organicist proposals that tried to scientifically account for systemic properties (Etxeberria & Umerez 2006; Gilbert & Sarkar 2000). After the 50s, most disputes turned around the significance of the genetic understanding of life: whereas for some authors genes and informational mechanisms constituted its essence, other perspectives emphasized the importance of more global, systemic properties. This last view seems favored these days, given the results of the Human Genome Project. One of the main problems of the systemic perspective is how to relate the global theoretical view on organisms with detailed operational explanations of the dynamics of components. Work on autonomy constitutes an attempt to combine this double perspective.

The notion of autonomy to characterize life stems from the Kantian theory of organisms (of the *Critique of Judgment*) and subsequent work in that line (Jonas 2000, Weber & Varela 2002, Van de Vijver, et al. 2003). Autonomy is generically predicated of individuals acting in the world in a self-regulated way, without external control or authority; agents are autonomous if their actions are truly their own. The concept has undergone an interesting development in history. In Ancient Greece the term was understood in a political sense (city governed by own laws); in the Enlightenment, it referred to the self-determination of persons, both political and ethical: rational agents give themselves the laws they must follow, their autonomy means that they are only obliged to those self-given laws. In the twentieth century's biology the notion of autonomy has acquired a different character, especially after the work of Maturana and Varela (1973, 1980; Varela 1979), when it begins to be understood in terms of the self-production of the specific components constituting a living system, the control of its dynamics, and consequently of its materials, to form an individual identity:

> The individual organization can be shown to be one of self-construction through recursive production of components, and it is this specific organization, autopoiesis, which is at the base of the autonomy of living systems. The most clear paradigm of this autopoiesic organization is the cell and its metabolic net. Once the individual organization is clearly defined, one can attempt to analyze the added complexities that autopoietic systems have undergone in the history of earth, including their reproductive capacities and higher order aggregations (Varela 1981, p. 36).

Consequently, in this last sense autonomy does not refer to *praxis*, but to *poiesis*, autonomy as (self)production. Instead of a necessary condition for the rational actions of an agent, it is concerned with the material and organizational conditions for the identity of the agent itself, thus: its conditions of possibility.

In this way, the theory of autopoiesis (Maturana & Varela 1973, 1980) affirms biological autonomy as a central notion to scientifically and philosophically explain life (and even, eventually, to artificially create it). At the same time, this theory also denies that the genetic materials have a primary role in the constitution of this organization [3], because in that case organisms would be the product of something else—the genes [4]. From the perspective of autonomy, living processes are spontaneous self-organizing processes whose result is the constitution of the system itself.

Although Maturana and Varela are reluctant to consider genes as different from other cellular components [5], other approaches to autonomy [6] are satisfied with an account of the role of genes that is compatible with the autonomy of organisms. The vision of genes as primitives from which the organism emerges is incompatible with autonomy, since organisms appear then to be determined by some components. However, we think that autonomy is compatible with a view of genes as material records or memories from which the cell constructs the components which exert a material causation in the system (Pattee 1977, Etxeberria 2004). In this view, autonomous organization is not generated by genes [7].

The two different views of genes have consequences on the way we understand possible life; that is to say, the possibility of generating new forms of life. If all variation in the organic realm stems from genes, the variability of living forms seems to be infinite, as it appears to depend mainly on the combinatorial properties of the genetic encodings of the phenotype. If, on the contrary, multicellular organisms are material self-organizing systems maintaining a dynamic stability within their environment, they are not "designed" by a genetic program. Genes are then material elements preserving and amplifying variation at different levels (molecular, morphological, etc.), but they are not the only source of variation; genetic variation is different from biological variation (morphological, behavioral, etc.). Genetic sequences cannot generate, by themselves, a desired output.

LIFE AND THE NATURAL/ARTIFICIAL DISTINCTION

The notion of the autonomy of organisms has some consequences with respect to the naturalness of life. The natural/artificial distinction is very elusive: although it has an intuitive component (for example, the artificial as human-made), the distinction may dissolve under sharper scrutiny. Nonetheless, it is widely used in debates about the moral or epistemological adequacy of technological novelties.

Classically, the notion of nature only applied to the inanimate realm, to the vast domains of open lands and seas, and mountains, life being a different matter (perhaps because the concept of life that encompasses all

living creatures is relatively new in history). The question of whether life is natural or artificial deserves some consideration. In principle, life is natural if we consider that it originated spontaneously under certain material conditions and it was modified in evolution, of which biodiversity would be a product. But from certain perspectives, living systems can also be considered to be "artificial". Of course, the biblical image makes them artificial, but this is not very relevant, as that would be the case of all the creation. Life may have some artificial element if manipulated by human intervention beyond spontaneous forces. The artificial element is introduced by selective breeding, by agriculture, or by more precise biotechnological interventions. Is this artificial activity different from the natural spontaneous forces acting at any time? If the kind of action considered is artificial selection, it implies a weaker action on organisms than actual hands-on manipulation: organisms organize themselves before selection; selection cannot produce a new form of life, it can only select among possibilities that are defined by other material conditions (i.e., dynamical and/or developmental). Laboratory manipulation—for example, genetic—goes a long way further than traditional artificial selection.

Nevertheless, we may discuss what "natural" means. The concept of "nature" has many senses; here we find three different ones:

> In a very wide first sense, nature is the ensemble of all existing things, because all of them are subject to the same laws or regularities studied by physics, biology and other so called "natural" sciences; in a second place, nature is the set of things which exist or usually exist without human intervention, with a non deliberate spontaneity (although there are many which are difficult to classify, such as fruits and grains cultivated by humans or racing horses, in which natural spontaneity and human deliberation are mixed); in a third place, nature is the origin and cause of all existing things, their ultimate explanation, their reason to be (Savater 1995, p. 256 [8]).

The first two senses, the one that encompasses all existing things and that of spontaneous existence and transformation, are considered to be "neutral", merely descriptive. Yet, Savater—closely following Rosset (1973)—strongly criticizes the third one, in which certain things or actions are preferred because of their naturalness, as he considers that this implies to confer them with a transcendence non suitable to proper materialist thinking:

> A major feature of the materialist perspective (...) consists to establish certain continuity between human artifice and the rest of the natural production of the cosmos. Human creations are not different from the rest of the universal furniture neither in their origins (they originate in the needs and desires of beings as naturally immanent as the rest) nor in the mechanism that selects

> among them the ones to perish or to endure: as in other cases, those which are more *convenient* in a given conjunction of circumstances carry on to exist (Savater 1995, p. 259).

Although this view may be correct for inanimate things, when "human creations" are forms of life, the argument has some problems related to the special characteristics of life.

One of them concerns *materialism*. If the defense of materialism makes all beings equal by reducing them to the same atoms, it cannot distinguish between the living and the lifeless. Living systems are not different in their ultimate materiality, but in the relations among components. Then, if we want that distinction to be made, we must appeal to higher level organizational properties of life which, although perfectly material, do not reside in the atoms: the living state is a systemic property, which has not been emulated artificially yet [9]. Precisely this systemic property is what makes possible that living beings are self-produced or autopoietic. Thus, as a natural phenomenon life may deserve a special consideration because of its systemic properties. In this sense, reductive materialism may be of too short scope to understand life, as it appeals to an ultimate reduction of all material life to atoms and their dynamics. A form of materialism able to account for living properties needs to be non-reductive. This problem was already pointed out by Riechmann (2000), who considers that a fourth sense of nature should be taken into account, meaning nature as biosphere, that is, as an organized system of ecosystems.

Perhaps systemic properties alone do not provide enough ground to defend a special naturalness for life: some systemic properties can be produced by human technologies, but there is also a difference in *origins*. This argument has been acknowledged since Aristotle: whereas artificial things are "made", living beings are "born". In fact, this distinction states a difference in *agency*: all things that can be made by an agent are artificial, whereas those that are born are natural. Sometimes this idea has lead to confusion: a consequence of it may be that all agencies are equal in what concerns the natural/artificial distinction, in other words, that the products of non-human agents (for example, bees) may not be more natural than those of humans [10], that is, that they are similarly artificial. We have nothing against this (although it may be rather counterintuitive at times). However, in our view it is not correct to conclude the reverse, to state that human agency is natural because it is not different in kind from the agency of other beings considered natural. This idea has been often held, for example Sober (1995) says:

> *If we are part of nature, then everything we do is part of nature, and is natural in that primary sense*. When we domesticate organisms and bring them into a state of

> dependence on us, this is simply an example of one species exerting a selection pressure on another. If one calls this 'unnatural', one might just as well say the same of parasitism or symbiosis (p. 234) (emphasis in the original).

Ortega y Gasset (1982) considered that the human being is an ontological centaur, natural and artificial, but this double character should not mean that humans can make "natural" things, it only means that they are naturally born or produced, autonomous in their origins. Their products are artificial without a doubt. Although we could say that things like honey are artificial, as far as we consider bees "agents", living beings are natural according to origins because they cannot be made by any other agent. Life is autonomous, and this property has been very important to ground classical claims for free will and moral autonomy in the case of humans (autonomy of praxis). In fact, even the most critical voices of the natural/artificial distinction claim in its favor.

Nevertheless, these days the distinction between *being born* and *being made* or fabricated is starting to break down for many living organisms whose birth is altered by reproductive technologies, genetic modification or cloning, even producing cross-species organisms such as hybrids and chimeras. Before, living beings acquired some of their characteristics at random, whereas now external design seems to be increasing. Within this line of thinking, Habermas (2002) revisits this Aristotelian distinction between what has been "grown" and what has been "done" (or fabricated) to warn of the dangers of genetically "designing" human babies. This argument of the naturalness of origins alleges that if humans are generated by a process in which parents induce certain characteristics of children through genetic design, then these creatures will not be able to freely "make themselves". Parental design would affect the self-conscience of fabricated creatures in an unprecedented way. Habermas's argument has the problem of considering that artificial living beings can be made by modifying their genetic endowment, but this criticism to genetic modification technologies is very problematic as it considers that the genetic endowment constitutes some sort of "essence" of the organism, and that genetically modified organisms loose their autonomy, as far as they are fabricated. Yet, neither the autonomy of praxis nor that of poiesis depends on genes. Most traits being interactive, the autonomy at the level of the praxis cannot be modified only at the level of genes, whereas *poietic* autonomy cannot be generated at the genetic level either. This is a limit that shows that in what concerns the natural/artificial distinction life is different from non-living beings. The reason why Savater and many others want to maintain this distinction is to preserve human free will, that is to say, autonomy of *praxis*. Moreover, as we tried to argue in the previous

section, the autonomy of living systems goes further than that, it is autonomy of *poiesis*, this is: self-production

Finally, let's recapitulate on *autonomy*. An artificial organism is not artificial in the same degree in which an inanimate material is (for example, plastic). In fact, science has not been able so far to produce a living system starting from material inanimate components. Artificial organisms are only partly artificial: artificially modified, but not artificially fabricated; no existing life is completely artificial. This issue, which is in part empirical (science has not been so far able to produce life in the laboratory) may also be a statement in principle if we understand autonomy as self-production: even if life emerges in the laboratory, it will not be "made" by anyone, as a being can only be alive if self-made.

One of the reasons many authors have to reject the natural/artificial distinction is the intuition that no ethical commandments should derive from it. The idea is that something is not better because its origins are natural: value is independent of origins. For them, ethical considerations based on values emerging from the natural/artificial distinction are unclear, as they seem to be falling in a naturalistic fallacy. Yet it is important to notice that the argument has two faces: it is as fallacious to consider that artificially produced beings are less valuable because of their origins (for example, biotechnological), as to maintain that some human interventions are good because they operate in a way similar to natural evolution. Nevertheless, and although moral reasoning were independent of facts, if autonomy of *poiesis* (and *praxis* in the case of humans) is the main property of life in the sense we have explained (systemic property, self-produced), then moral reasoning about living beings and their modification must take this into account, and probably there will be actions performed on things which are wrong to be done to living beings.

In the next section we reflect on the possible creativity with respect to life with the aim of discussing more on what should not be done with life.

DIFFERENT ACTS OF CREATIVE *POIESIS*: LIFE, ART, BIOTECHNOLOGY

Any form of life is intrinsically creative. "Natural" life produces itself in overwhelming diversity. Can this creativity be pushed further? In the field of artificial life the attempt to produce forms of life different from those existing in the earth has been named the "biology of the impossible" (Emmeche 1992). There are at least two other forms of creative *poiesis* or production of life. One is the life created (or, at least, represented somehow) by *art*, which may generate new living forms, even non-existent in nature, in a wider range, moving between the existing and the conceivable. The other is that produced by *biotechnology*, the ability to manipulate

living organisms within the limits of the possible variability. Perhaps the main difference between them is that the second is "instrumental", that is, the produced diversity responds to some human need, either practical (to produce some concrete form of organism) or theoretical (to learn more about living organization by inducing certain changes).

EVOLUTIONARY CREATIVITY

The two different conceptions of genes mentioned above bring about different views on the creativity intrinsic to living systems, and, in general, they are associated with different views on the power of natural selection to produce living forms by exerting an adequate selection pressure. Those who think that diversity and variability ultimately depend on genes that may trigger the construction of any kind of living variant, believe that there are no "natural" limits to the possible forms, and that the variability of life on earth has been constrained only by history (certain variants had simply no chance to appear) or by material tradeoffs. Others, however, consider that the development of multicellular organisms constitutes a self-organizing process governed by morphogenetic "rules" that make it very difficult to introduce new variants.

From this perspective, "hopeful monsters" are not to be expected. Pere Alberch (1989) considered that the rules of development impose a "logic" to the construction of organisms, furthermore, this logic will be visible even among those deviations of "normality" that constitute monsters or natural teratologies. The analysis of teratologic forms revealed that not all conceivable forms can be generated. Teratologies do not only appear in an ordered and discrete mode, they also exhibit general transformation rules. These properties are not exclusive of teratologies but of all developmental systems, although they manifest more clearly in pathological systems. Therefore, the rules of organic development "constrain" the possibilities of evolution. For example, monsters with two heads are relatively common in all vertebrates, whereas three headed ones are extremely rare. Alberch argued that if even the morphology of these non-adapted creatures follows rules, then it is plausible to think that something similar occurs with normal organisms [11].

The debate on developmental constraints is a key piece in the criticism of developmentalists to the ideas of the Modern Synthesis in evolutionary biology. For Alberch the logic of monsters is the logic of nature, emerging out of material biological processes. In that sense, not everything is possible.

ART: THE CREATIVITY OF THE IMAGINATION

The relation between organic and artistic forms has been a subject dear to many developmental biologists. Is our imagination constrained at the time of producing life forms? For example, Alberch (1998) was interested in

studying the mental morphogenetic process, considering that imagination and creativity generated from brain activity may be restricted, in the sense of marked by past experience and by the functionality of the brain.

The imagery behind mythology, popular stories, contemporary science-fiction or even artistic forms reveals the mind's capacities to generate its own morphologies. Mythological fauna seems to be assembled following general principles also acting in science-fiction and folklore. Its outcome appears to derive from one or several of the following processes: distortion of size and/or form, multiplication, suppression or recombination of existing parts. The mythical new form is constituted by parts chosen by their emotional power so that their deformation or combination reinforces certain moral characteristics. For example, a dragon is pictured as living under the earth (perhaps suggesting hell), as ferocious (as it has teeth), or as exhaling fire (it may be dangerous). They depart from reality, but they reflect the structure of the mind and the way we perceive the world; it seems to be difficult to conceive an imaginary form in which no part evokes at least some form existing in nature.

Even so, some artists have aimed to create forms without natural references. An example is Miró's work, whose paintings present biomorphic creatures without a correspondence with reality, generated through automatic creation techniques, like in surrealism, and referring to dreams in the creation of its abstract details. The produced forms conserve references to archetypes present in children drawings, and as they do not pursue to imitate reality, they turn out to be "pure" signs. According to Alberch, Miró seeks purity of forms, so as to connect with those entrenched in some kind of archetypical structure or mental organization; he contends that the emotions transmitted by his work would not be achievable if there were no internal references of this type. In his words: "At the end, I got free from the natural, and now my landscapes have nothing to do with external reality" (Miró, cited by Alberch 1998, p. 22).

Even if Miró's forms are the result of an internal process and they do not derive from external observation, they are limited by human specific signs. It constitutes a "naturalized" view of artistic creation in relation to the limits imposed by the biological constitution of the artist herself/himself. That is why Alberch concludes that there is no universe of nameless objects in the brain. This means that, even in art, not everything is possible.

BIOTECHNOLOGICALLY MODIFIED CREATURES

It has been noticed that biotechnology constitutes some form of "biology of the impossible" because it breaks constraints and trespasses barriers that nature has established in a systematic way, but perhaps not universal. In effect, those barriers can be sometimes overcome in the laboratory. The status of constraints as a source of normativity above that of natural laws

has been a matter of intense debate at least since the 70s [12]. It may be the case that nature's regularity even in the production of monsters may be not maintained with human intervention: natural constraints guiding natural evolution may be overcome with deliberate intervention.

Biotechnology sometimes acts with a view of life based on the idea that life is pure variability, and that the optimal variants can be produced with the advancement of science. That is why bioengineering sometimes does not take into account the species specific forms and other properties, and acts blurring interspecies barriers as a way to explore the domain of the possible beyond what exists.

All of them are produced following a kind of logic of human reason (or of the sleep of reason [13]), that is to say, in what they have of manufactured, they have no logic of themselves. Rifkin (1998) has called *algeny* to the view that life is pure variability. The term algeny was coined in analogy to alchemy (the thought that there are no barriers to transform elements) to express that species are seen as continuous, without barriers, in which changes may be introduced.

As Rheinberger has noticed (1995), the relation between the external and the internal intervention in nature and experiments changes with biotechnology; now the organism itself becomes a locus for experiments. One of its results is the production of biotechnologically altered organisms, such as chimaeras and other transgenic creatures.

Some critics (for example Midgley) consider that developments in biotechnology do not stem from clear scientific principles, but constitute a new ideology about nature, created in concordance with the interests of the biotechnological industry. The main change brought about by it would be an image of nature and natural life that considers that no natural limits exist (for example, no barriers among species) and where anything can be modified according to external design:

> What is really worrying the objectors is not, I think, the detail of any particular proposal. It is the hype, the scale of the proposed project, the weight of the economic forces now backing it, and the sweeping change of the attitude that is being demanded. Biotechnology on the scale that many people are currently proposing appears not to be compatible with our existing concepts of nature and species—concepts that are part of our current science as well as every day thought. And a new ideology is being proposed that would remodel those concepts to fit the new technologies, envisaging species as unreal and nature as infinitely malleable (Midgley 2000, p. 8).

However, Franklin (2003), whose work turns around the definition of kin relations in contemporary societies, considers that both the positions against or in favor of some biotechnological activities may be motivated by considerations to our kin. For example, experiments with embryos may

be rejected in the name of the right of these nearly human beings, but they may also be defended in the name of the possible lives that may be saved thanks to them.

In any case we should reflect on the fact that, for the moment, none of those beings owe their living state to a laboratory manipulation: all of them retain their original autonomy as living beings This must be taken into account in order to evaluate their status. If not everything is possible in the spheres of life and evolution, then it is possible to question whether there are limits for biotechnology.

BLURRING BOUNDARIES BETWEEN NATURE, SCIENCE AND ART

We have claimed that in all the domains considered—life, art and biotechnology—not every living form is possible. Nevertheless, life is being manipulated and we still do not know how far the produced changes can go.

Probably art is the case where creativity in relation to living forms can be freer. An exhaustive study of the creativity of art goes too far beyond the scope of our interests in this article. In what follows we will present some examples of how nature, science and art are entangled to generate or create forms of life.

Many sources, including classical thought, consider that nature is the canon for, and the main source of, form and beauty. Thus, some numeric relations, such as the "golden number", found in the disposition of sunflower seeds, in the growing pattern of some mollusks, or in the development and geometric disposition of branches and leaves of plants, or the body measurements of the human, are considered to originate in nature. They have to do with optimal plans of development (to use space and permit growth) and have been repeated and sought in the artistic forms since classical times.

Similarly, artist Karl Blossfeldt (1865-1932), looking for inspiration in nature, tried to reveal the basic structure of the natural world and its relation to artistic forms. He was influenced by the view of nature as an organic whole evolving and tending to perfection, of the *Naturphilosophie*. The photographs of his *Herbarium* transmit the idea that art imitates life, it is understood as a mimetic *creation*.

A different character is that of art understood as a form of *reflection*. For example, Joan Fontcuberta [14] proposes an ironic homage to Blossfeldt with the aim of scrutinizing formal appearances, scientific representation and the authoritarian discourse of science. His own *Herbarium* also deals apparently with the details of the natural forms of plants, but it is fashioned as artificial constructions realized with recycling materials. This work aims to question the very possibility of true representation or imitation of

nature, and to make explicit possible political, ideological and epistemological artifices which produce a mistake of illusion and reality. Several of the artistic projects of Fontcuberta are based in the fabrication of a reality not so alien to the real, in which he tries to awaken the critical sense of observers in order to evaluate the information offered to them, the relation between artifice, the discourse, and evidence from nature.

A step further from nature and its imitation is constituted by art pretending to create or produce living forms such as the proposal of *transgenic art*. In this line artist Eduardo Kac [15] has conceived transgenic art as a "new form of art based on the use of genetic information techniques to transfer synthetic genes to an organism, or natural genetic material from a given species to another in order to create singular living organisms" (Kac 1998).

He intends the public to buy his transgenic art works with a commitment and responsibility towards the created new form of life (2003). One of his very controversial projects was the creation in 2000 of the green-fluorescent-protein bunny (whose name is *Alba*), a transgenic rabbit containing a gene synthesized from a green fluorescent protein extracted from a jelly fish, which makes its white (albino) skin shine in green under certain forms of light. This work comprises "the creation of a green florescent bunny, the generated public debate and the social integration of the animal" (Kac 2003) and was accomplished with the complicity of French scientists from a biotechnological laboratory. In his writings Kac emphasizes the old relationship between humans and rabbits, which includes their domestication and selective breeding starting in the sixth century, as part of the argument he uses to justify the manipulation realized. Even if it tries to be a reflection on the scientific events sometimes not visible for society, and on its right to be well informed to take decisions and critical stands, his "work" is contradictory and disturbing in relation to the questions posed here. The author has signaled the advantage and convenience of genetic manipulation with medical goals and also the political and social problems related to the access to these new goods. He also believes that *Alba* serves to unmask the popular belief in that the DNA is the master molecule, emphasizing on the organism, but this goal does not sound precisely very compatible with the creation of improbable monsters such as *Alba* through genetic manipulation techniques. Kac also keeps the patent of the "created" green bunny, and intends to grow it as a member of the family.

In sum, we have appealed to these examples to show that we can find at least three levels of complexity in the relation of the artistic work with nature (art as creation, art as reflection and art as manipulation).

SOME CONCLUSIONS

One question to consider is *how biology supports manipulation*, that is to say, how plausible are claims to produce organisms by design. Biotechnology's creation trespasses natural limits, in the sense of spontaneously occurring, but it moves within the limits of the possible. Life can be manipulated in the laboratory, but it is not clear whether human laboratory action on life will be the same as that of natural selection. Furthermore, even if it is possible to manipulate an organism, the consequences are not simple to foresee or to guide. The morphologies of living beings have not been molded exclusively in contact with the environment, but as a consequence of internal self-organizing processes involving many interrelated factors, including the interaction with the environment. That is why it is not clear that the outcome of genetic manipulation will respond to the pursued goals.

Another question is to consider the *pertinence of manipulating life*. It is common among neo-Darwinians to justify transgenic practices by considering that it only implies to act as nature did. Kac himself, even if he introduces in his reflection the intention of valuing the organism and its relationship with its environment, justifies his art by saying that "we do what we have been doing since thousands of years ago, selecting life" (Kac 2003). This is a naturalistic fallacy. Furthermore, it does not follows that it is safe to change the genetic endowment of organisms, especially if we consider them to be self-organizing autonomies in which self-maintenance needs the correct interaction among components (organism as a complex assembling of parts). As Newman says:

> A bit player who forgets his lines can ruin a play, and a set on interacting genes, even with merely stabilizing functions can, if perturbed, derail the organism's development, composition, or functional integrity (Newman 2003, p. 493).

In what respects the pertinence of generating life by violating natural limits of forms, the main justification for it has been the needs of medical research or the hope of eradicating hunger. However, from the point of view of the development of the organism it appears that a precautionary principle will be more advisable. This has the scientific support of systems biology, these days more accepted than in previous decades.

The existence of political and economical market interests make the biotechnology decisions even more difficult (we have already seen a loss of local variants in favor of transgenic ones). Newman (2006) tried to obtain the patent of several chimeras involving humans and other animals (chimpanzee, mouse, armadillo) to show the different interests in play in biotechnology management, and as a reflexive process. We may envisage new projects of the Fontcubertas type to bring into being false biotech-

nologically produced creatures and their functions. If *Alba* would not be so real, it could be one of those false beings of his collections.

Finally, it is necessary to consider *the status of manufactured life.* As it was stated before, manipulated life has not (so far) acquired its autonomy in the laboratory; it is alive because the original living being has been manipulated within the limits of its viability. In fact, to this moment, no existing life has been artificially generated. All existing organisms, however manipulated (genetically modified, hybrids, chimaeras), come from systems already alive; they have not been brought to life from scratch. Their autonomy has not been artificially produced. Sometimes it is considered that a genetically modified organism is not the product of evolution, but of human intervention. We think that this acceptance of external design does not recognize the fact that originally there is an autonomous organism. Artificial intervention externally changes certain functionalities, and this should be acknowledged, but there is no production of a new organism. The natural forms had been manipulated, from Kac's selective breeding of bunnies to biotechnological chimeras, in different degrees of artificiality produced by human intervention.

It seems that we need a new ethics that could work with these new problems. This ethics needs to regard problems of genetic engineering and in general those stemming from the manipulation of organisms in the light of systemic notions about the nature of life.

ACKNOWLEDGEMENTS

Both authors benefit from funding through research projects 9/UPV00003.230-15840/2004 (University of the Basque Country) and HUM2005-02449 (Ministry of Education and Science). ML has a grant from the AlBan Program (EU).

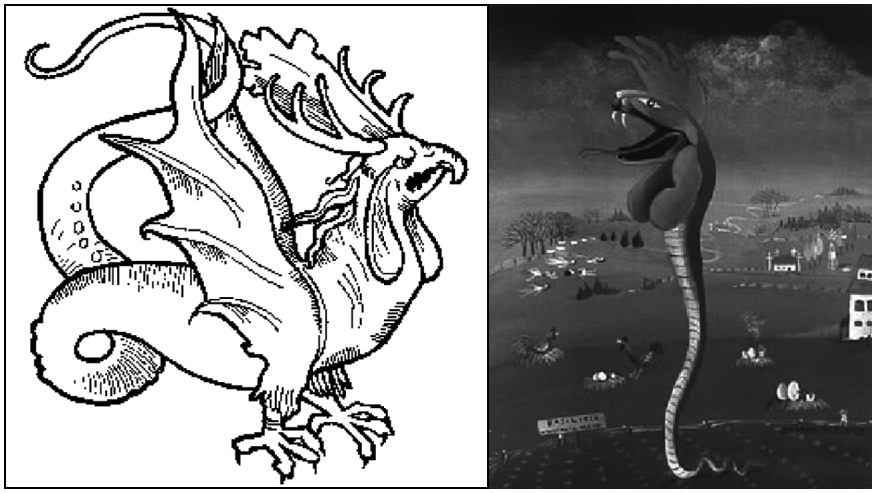

FIGURE 1
Two examples of the *basilisk* as a model of a mythological creature created by the combination and distortion of elements of living species.

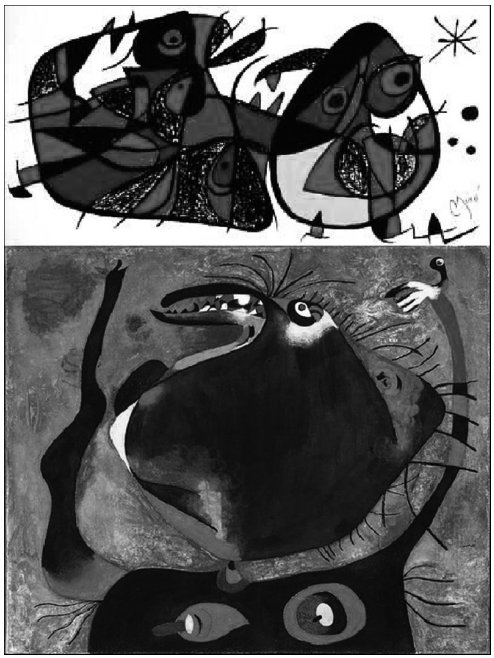

FIGURE 2
Two biomorphic creatures imagined by Miró.

FIGURE 3
Picture of a *geep,* a chimaera generated from a goat and a sheep.

FIGURE 4
Some examples taken from the two herbariums. Blossfeldt's at the top and Fontcuberta's at the bottom.

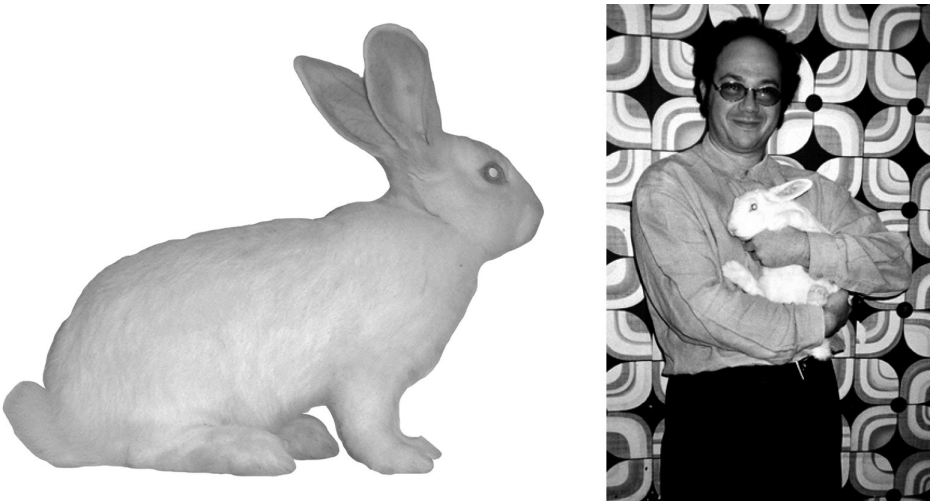

FIGURE 5
Bunny *Alba* and its "creator."

FIGURE 6
In *The Farm*, artist Alexis Rockman (www.genomicart.org) represents a pig showing its internal organs which will be used in humans, a cow endlessly producing milk, tomatos that are huge.

NOTES

1 Open in evolution, although constrained and almost deterministic in ontogenetic development. Ruiz-Mirazo, et al. (forthcoming) elaborate further the notion of open-ended evolution.

2 The first three senses of *monster* appearing in the Oxford English Dictionary are: 1. "Something extraordinary or unnatural; a prodigy, a marvel." 2. "An animal or plant deviating in one or more of its parts from the normal type; an animal afflicted with some congenital malformation; a misshapen birth, an abortion." 3. "An imaginary animal (such as the centaur, sphinx, minotaur, or the heraldic griffin, wyvern, etc.), having a form either partly brute and partly human or compounded of elements from two or more animal forms." Our "natural monsters" follow definition 2, whereas our "monsters of reason" and "monsters of imagination" concord with definition 3.

3 As one of us has written somewhere else: "(A)utopoiesis is defined both in positive terms (autopoiesis *is* the organization defined by a recursive network of component production), and in negative ones (autopoiesis *is not* a result of the properties of certain cellular components, such as genetic materials). The negative presentation of the theory involves a criticism to the role played by biological concepts such as genetic information, reproduction and evolution in the explanation of life." Etxeberria (2004), pp. 347-8.

4 "(M)echanistic systems in which the product of their operation is different from themselves we call allopoietic" (Varela, et al 1974, pp. 188-9).

5 In this, they are precursors of the Parity Thesis affirmed by Developmental Systems Theorists, according to which "any sense in which genes code for phenotypic traits or program development or contain developmental information can be equally well applied to other factors required for development" (Griffiths & Gray 1994, p. 195).

6 Others who have worked on the notion of autonomy are Kauffman 2000, Collier 2000, Ruiz-Mirazo & Moreno 2001.

7 A problem faced by Maturana and Varela is that they aimed to define the autonomous organization without history, and genes are intrinsically historical. Although autonomy as autopoiesis is challenged by genes, because not all the components are readily produced by the organization, we think that as far as it is the organization that uses genes to produce the components required—and not genes which define the organization—autonomy is preserved.

8 All citations from sources originally in Spanish were translated by the authors.

9 Research aiming to produce artificial life both in the computer and in the laboratory is working at least in two directions: the bottom up strategy tries to emulate global living properties starting from raw materials, whereas the top down one intends to get a minimal form of life by reducing the complexity of actual life.

10 Something similar can be said of Barbieri's argument for the artificiality of life (Barbieri 2005). Barbieri's biosemiotic approach to life focuses on some of the characteristics of organic molecules such as DNA, which he endows with agent capacities. Then, life is artificial because it is made possible by those very special molecules. In our view, although those molecules are special, the autonomous being of a system is previous in the case of life.

11 This point was also studied experimentally, and the result was that by perturbing developmental paths (by means of an experimental manipula-

tion) only a limited set of transformations was obtained (Alberch & Gale 1983, 1985).

12 See (Pattee 1973) for the role of constraints in living organizations, and (Gould and Lewontin 1979) for their role in evolution.

13 As it is well known, for Goya "The sleep of reason produces monsters."

14 See several comments on the ironic Homage of Fontcuberta to Blossfeldt in Fontcuberta (1998). In the exhibit *Fauna secreta* J. Fontcuberta and P. Formiguera make a very interesting parody of the verisimilitude of scientific method presenting a fantastic bestiary together with some apparent proofs of existence.

15 www.ekac.org

REFERENCES

Alberch P. (1982), "Developmental constraints in Evolutionary Processes", in J. T. Bonner (ed.) *Evolution and Development*. Berlin: Springer Verlag, pp. 313-332

Alberch, P. (1989), "The logic of monsters: evidence for internal constraint in development and evolution", *Geobios* 12: 21-57.

Alberch, P. (1998), "El ingeniero, el artista y los monstruos", *Mundo Científico* 188: 18-23.

Alberch, P. & Gale, E. A. (1983), "Size dependence during the development of the amphibian foot. Colchicine-induced digital loss and reduction", *J. Embryol. Exp. Morph*. 76: 177-197.

Alberch, P. & Gale, E. A. (1985), "A developmental analysis of an evolutionary trend: digital reduction in amphibians", *Evolution* 39(1): 8-23.

Barbieri, M. (2005). "Life is 'artefact-making'", *Journal of Biosemiotics* 1: 107-134.

Collier, J. (2000), "Autonomy and process closure as the basis for functionality", *Annals of the New York Academy of Sciences* 901: 280-290.

Emmeche, C. (1992), *The Garden in the Machine: The Emerging Science of Artificial Life*. Princeton: Princeton University Press.

Etxeberria, A. (2004), "Autopoiesis and natural drift: genetic information, reproduction, and evolution revisited", *Artificial Life* 10: 347-360.

Etxeberria, A. & Umerez, J. (2006) "Organización y organismo en la biología teórica ¿Vuelta al organicismo?" *Ludus Vitalis* XIV(26): 3-38.

Fontcuberta, J. (1998), *Ciencia y fricción: fotografía, naturaleza, artificio*. Murcia: Mestizo.

Franklin, S. (2003), "Drawing the line at not-fully-human: What we already know", *American Journal of Bioethics* 3 (3): 25-27.

Gilbert, S. F. and Sarkar, S. (2000), "Embracing complexity: Organicism for the XXIst century," *Developmental Dynamics* 219: 1-9.

Griffiths, P. E. & Gray, R.D. (1994) "Developmental systems and evolutionary explanation", *Journal of Philosophy* 91: 277-304.

Gould, S. J. & Lewontin, R. C. (1979) "The spandrels of San Marco and the Panglossian paradigm: A critique of the adaptationists programme", *Proc. R. Soc. London* 205, 581-598.

Habermas, J. (2002), *El futuro de la naturaleza humana. ¿Hacia una eugenesia liberal?* Barcelona: Paidós. (English version in Polity Press, 2003)

Jonas, H. (2000), *El principio vida. Hacia una biología filosófica*. Madrid: Trotta.

Kac, E. (1998), "Transgenic art", *Leonardo Electronic Almanac* 6 (11): http://mitpress.mit.edu/e-journals/LEA

Kac, E. (2003), "GFP Bunny", *Leonardo* 36 (2): 97-102.

Kauffman, S.A. (2000), *Investigations*. Oxford: Oxford University Press.

Luisi, P. L. (1998), "About various definitions of life", *Origins of life and Evolution of the Biosphere* 28: 613-622.

Maturana, H. R. & Varela, F. J. (1973), *De máquinas y seres vivos: una teoría sobre la organización biológica*, Santiago: Editorial Universitaria (3rd edition in 1994 with a new preface by each author).

Maturana, H. R, and Varela, F. J. (1980), *Autopoiesis and Cognition. The Realization of the Living*. Boston: Reidel.

Maynard Smith, J., Burian, R., Kauffman, S. Alberch, P., Campbell, J, Goodwin, B., Laude, R., Raup, D. & Wolpert, L. (1985), "Developmental constraints and evolution: A perspective from the Mountain Lake Conference on development and evolution", *Quaterly Reviews of Biology* 60: 265-287.

Midgley, M. (2000), "Biotechnology and monstrosity. Why we should pay attention to the 'Yuk factor'". *Hastings Center Report* 30 (5): 7-15.

Morange, M. (2003), *La vie expliquée: 50 ans après la double hélice.* Paris: Odile Jacob.

Newman, S. A. (2003), "Nature, progress and Stephen Jay Goulds biopolitics", *Rethinking Marxism* 15 (4): 479-496.

Newman, S. A. (2006), "My attempt to patent a human-animal chimera", *L'Observatoire de la Génétique* **27** (April-May).
Ortega y Gasset, J. (1982) *Meditación de la técnica y otros ensayos sobre ciencia y filosofía*. Madrid: Alianza Editorial.
Oyama, S., Griffiths, P.E. & Gray, R.D. (eds.) (2001), *Cycles of Contingency. Developmental Systems and Evolution.* Cambridge MA: MIT Press.
Pattee, H.H. (1973), "The physical basis and origin of hierarchical control", in H.H. Pattee (Ed.) *Hierarchy Theory. The Challenge of Complex Systems.* New York: G. Braziller, pp. 73-108.
Pattee, H. H. (1977), "Dynamic and linguistic modes of complex systems", *Int. J. General Systems* 3: 259-266.
Rheinberger, H-J. (1995), "Beyond nature and culture: A note on medicine in the age of molecular biology", *Science in Context* 8: 249-263.
Riechmann, J. (2000), "La industria de las manos y la nueva naturaleza", en J. Riechmann, *Un mundo vulnerable. Ensayos sobre ecología, ética y tecnociencia*, Madrid: Los Libros de la Catarata, pp. 95-130.
Rifkin, J. (1998) *The Biotech Century: Harnessing the Gene and Remaking the World*, New York: Jeremy P. Tarcher/Putnam.
Robert, J. S. & Baylis, F. (2003), "Crossing species boundaries", *American Journal of Bioethics* 3 (3): 1-13.
Rosset, C. (1973), *L'Anti-nature*, Paris: PUF.
Ruiz-Mirazo, K. and Moreno, A. (2001), "Searching for the roots of autonomy: The natural and artificial paradigms revisited", *CCAI: Communication and Cognition- Artificial Intelligence* 17 (3-4), 209-228.
Ruiz-Mirazo, K, Pereto, J. & Moreno, A. (2004), "A universal definition of life: autonomy and open-ended evolution", *Origins of Life and Evolution of the Biosphere* 34(3): 323-346.
Ruiz-Mirazo, K., Umerez, J. & Moreno, A. (forthcoming), "Enabling conditions for 'open-ended evolution'", *Biology and Philosophy*.
Savater, F. (1995), "Naturaleza", en F. Savater: *Diccionario Filosófico*, Barcelona: Planeta, pp. 254-275.
Sarkar, S. (1997), "Form and function in the molecularization of biology," in Alfred Tauber (ed.) *The Elusive Synthesis: Aesthetics and Science*. Dordrecht: Kluwer, pp. 153-168
Sober, E. (1995), "Philosophical problems for environmentalism", in R. Elliott (ed.) *Environmental Ethics*, Oxford University Press, pp. 226- 247.
Van de Vijver, G., Van Speybroeck, L. & Vandevyvere, W. (2003), "Reflecting on complexity of Biological Systems: Kant and Beyond?" *Acta Biotheoretica* 51(2): 101-140.
Varela, F. (1979), *Principles of Biological Autonomy*. New York: Elsevier North Holland.
Varela, F. (1981), "Describing the logic of the living. The adecuacy and limitations of the idea of autopoiesis", in M. Zeleny (ed.) *Autopoiesis: A Theory of Living Organization*. New York: Elsevier North Holland, pp. 36-48.
Varela, F., Maturana, H. and Uribe, R. (1974), "Autopoiesis: the organization of living systems, its characterization and a model", *Biosystems 5*, 187-196.
Weber, A. & Varela F.J. (2002), "Life after Kant: natural purposes and the autopoietic foundations of biological individuality", *Phenomenology and the Cognitive Sciences* 1, 97-125.