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*On the Unfitness of Natural Selection to Explain Sexual
Reproduction, and the Difficulties that Remain*

Auf catechismus, auf materialismus ist ihre Lösung.[...]. Daß es einen Plato und Aristoteles, einen Locke und zumal einen Kant gegeben hat, haben sie vielleicht einmal auf der Schule gehört, jedoch diese Leute, da sie weder Tiegel und Retorte handhabten noch Affen ausstopften, keiner näheren Bekanntschaft wert gehalten; sondern die Gedankenarbeit zweier Jahrtausende gelassen zum Fenster hinauswerfend, philosophieren sie aus eigenen reichen Geistesmitteln auf Grundlage des Katechismus einerseits und der Tiegel und Retorten oder der Affenregister, andererseits, dem Publikum etwas vor.

(A. Schopenhauer, *Über den Willen in der Natur*)

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Abstract. *In its essence, the explanatory potential of the theory of natural selection is based on the iterative process of random production and variation, and subsequent non-random, directive selection. It is shown that within this explanatory framework, there is no place for the explanation of sexual reproduction. Thus in Darwinistic literature, sexual reproduction – one of nature’s most salient characteristics – is often either assumed or ignored, but not explained. This fundamental and challenging gap within a complete naturalistic understanding of living beings calls for the need of a cybernetic account for sexual reproduction, meaning an understanding of the dynamic and creative potential of living beings to continuously and autonomously produce new organisms with unique and specific constellations.*

1. SURVIVAL AND REPRODUCTION AS *EXPLANANS*

The theory of evolution by natural selection is based on certain premises about the natural world, which can be seen as conditions that, if fulfilled, automatically and necessarily lead to the process of evolution (see for example Ridley [1993], and Mayr [1991]). These conditions include the existence of heritable variation within a population causing differential reproductive success, and the struggle for survival among living beings. As Ridley puts it, if all conditions are met for any property of a species, natural selection automatically results. Mayr, essentially conveying the same message, prefers to speak about facts and inferences: the fact that populations potentially exponentially increase, and the fact that there is an observed steady-state stability of populations, combined with a limitation on resources, lead to the inference that there is a struggle for existence among individuals. Moreover, the fact that each individual is unique, and that much of the individual variation is heritable, necessarily leads to differential survival, i.e. natural selection, which subsequently leads to evolution (Mayr [1991]). Darwin himself said it in the following way:

Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring. The offspring, also, will

thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection (Darwin [1968], p. 115).

Some of these facts or premises were hardly understood in Darwin's time. For example, neither the heredity of characteristics nor the source of variations found a sound scientific understanding until after the genetic revolution within biology. Even today, however, not all premises are sufficiently explained. The struggle for survival, one of the elementary assumptions of the theory of natural selection, rests on the following pillars: (1) there is a tendency of organic beings to strive to increase their numbers to the maximum (Mayr's potential exponential increase of populations), and (2) limited resources cannot possibly support all offspring; ergo, there is a struggle for survival among organic beings. What is thus assumed in the Darwinian argument is the fact that organic beings strive to increase their numbers to the maximum, in other words, the existence of living beings with their striving for survival and reproduction. Darwin set out to explain the modifications of living beings – the transition from one life form to another – through the origin and dynamics of adaptations (traits that have evolved as a direct result of natural selection): how they arise, spread through the population, lead to divergence among populations, and eventually give rise to the origin of new species. So the *explanandum* in the theory of natural selection is evolution, the mechanism behind the origin of adaptations, as well as the general fact of adaptation, *but not* living beings with their striving towards survival and reproduction. Moreover, the latter are presupposed. Adaptations are explained, but only by presupposing living beings that, through their actions, ensure the survival of traits. Darwin set out to explain the adaptation of organisms, not organisms themselves. He focused on the *differences* among organic beings, and assumed first of all the organisms themselves, and, second of all, what is common in them, namely their striving towards survival and reproduction. Thus, in a paradoxical but undeniable sense, Darwin's theory of natural selection can be called *vitalistic*, because he presupposes living beings with their striving, and let them play an elementary

role in his explanation of evolution. His explanation of *evolution and adaptation* might be mechanical, but the explanation itself presupposes a non-mechanistic concept of life. Darwin assumes the struggle for existence (survival and reproduction) as a fact and prerequisite for natural selection. But for Darwin to provide an exhaustive explanation for life, he would have to explain the struggle for existence by means of natural selection, and not natural selection by means of the struggle for existence.

Other authors have made similar claims. Both James Barham and Abner Shimony have stressed that the theory of natural selection presupposes certain elementary characteristic of living beings. In this sense, so they claim, the theory resembles Boyle's law: just as Darwin presupposes these features instead of explaining them, so too, in his gas theory, Boyle presupposes the existence of the forces underlying the matter constituting gasses, and he does not attempt to explain them. Thus, natural selection is a sort of statistical mechanics of organisms, where the probability theory is applied to biological phenomena (Barham [2002], Shimony [1989]). And one of these assumptions is, as argued, the striving for survival and reproduction of organisms.

The use of the word 'fitness', a central concept within the theory of natural selection, reflects this theory's nature. Although fitness is an ambiguous term (Dawkins [1982]), it predominantly refers to the potential of living beings to survive and reproduce. The process of adaptation, then, is the evolutionary modification of a character under selection for a fitness-enhancing functioning in a particular context or set of contexts (West-Eberhard [1998]). In other words, traits, or adaptations, the *explanandum* in the theory of natural selection, are explained through their fitness-enhancing effects, which thus serve as explanatory ground. To give an example (derived from the *Origin of Species*): an accidental deviation in the size and form of a body of an insect might profit a bee or other insect, so that an individual so characterized would be able to obtain its food more quickly, and so have a better chance of living and leaving descendants (Darwin [1968], p. 141). So, the deviation in size and form of the bee (*explanandum*) is explained by its fitness-increasing effect (it obtains its food more quickly,

and thus has a better chance of living and leaving descendants). Explaining traits, like longer legs, better eyesight or more colorful flowers, is done through the already-existing living being that already strives to survive and to reproduce: the only effect of an enhanced trait is that the individual does this a bit better, which consequently results in the spreading of this trait throughout the population (adaptation, evolution).

In light of this analysis, it is also important to mark the difference between the *preservation of traits* and the *survival of organisms*. Whereas preservation relates to traits or adaptations, and thus to entities that are preserved over the generations and during the course of evolution, survival relates to organisms, and only concerns the survival within a lifespan. An organism has no evolutionary continuity: in the Darwinian context, an organism survives if it lives long enough to reproduce; destruction is in any case unavoidable (the use of the term survival in the context of organisms is therefore confusing and misleading). Traits, on the other hand, are potentially immortal, as they can spread through the population, and can endlessly be passed from generation to generation. Moreover, traits, or adaptations are *explananda*; the very thing Darwin set out to explain. The survival of organisms, on the other hand, serves as *explanans*, one of the premises of the theory of natural selection, one of the conditions for evolution to take place. These two phenomena – survival of organisms and preservation of traits – are thus obviously different phenomena, with different places within the theory of natural selection. In this light, it is highly remarkable that even Darwin did not clearly make this distinction, or at least did not consistently apply the terminology. In some passages of the *Origin of Species*, preservation and survival refer to modifications of qualities (traits), and in other passages to individuals, or even races. In some passages we find “that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind” (Darwin [1968], pp. 130-131), and “this preservation of favourable variations and the rejection of injurious variations, I call Natural Selection” (Darwin [1968], p. 131). But then a little farther on we read:

I can under such circumstances see no reason to doubt that the swiftest and slimmest wolves would have the best chance of surviving, and so be preserved or selected [...] (Darwin [1968], p. 138) – and – Natural selection can act only by the preservation and accumulation of infinitesimally small inherited modifications, each profitable to the preserved being [...] (Darwin [1968], p. 142).

Here, Darwin uses the term preservation for both organisms and modifications, despite their profoundly different role within the theory. Paradoxically enough, we find the most unusual subject of preservation within the subtitle of the *Origin of Species*, “the preservation of favoured races in the struggle for life”, a reference which does not reappear in the work. Still, a close analysis of the theory of natural selection forces us to clearly differentiate these phenomena, and allocate them different roles within the Darwinian explanatory scheme.

If we further investigate the possible explanation of the sexual reproducing organism, we see that the traditional Darwinian explanation, i.e. the explanation of traits based on the fitness they cause, cannot help us further. We have seen that traits are explained through the fitness they produce. Better eyesight is selected because it enhances the chance that an organism possessing it can survive and reproduce. Thus, the trait causing better eyesight has a higher probability to spread through the population than the original trait leading to less good eyesight, so leading to evolution. If we wanted to fit the question of the existence of reproduction within this explanatory framework, we would have to talk about the origin of the traits that cause this behaviour and processes: let us say the genitals, the hormone system, and the relevant parts of the brain. If we apply the explanatory scheme as described above, the answer would have to be that these structures and organs exist because they increase fitness, the ability to survive and reproduce. So the ground for the existence of reproductive organs is the possibility of organisms to reproduce. Now, here we are obviously begging the question concerning the origin of reproduction, and it is clear that we cannot explain reproduction in this way. If we try to explain reproduction with fitness, we mix the

explanans with the *explanandum*, and consequently end up with a *petitio principii*.

When we consider the Darwinian explanatory scheme in a broader context, we see that it encourages us to see biological phenomena, not as the work of a supernatural creator or the result of an immanent tendency in nature, but simply as entities that by chance persist. The theory of natural selection tells us to see nature not as a specific *production* – the theory adds nothing, and couldn't possibly add anything, to the known (blind and undirected) forces of nature and completely adheres to the natural sciences – but rather as a specific *selection*. And the entities that are selected are simply those that are left over after the less fit are eliminated. Mayr accordingly described natural selection as a two-step process: the first step is the production of random variation, the second step is the actual process of non-random selection or elimination (Mayr [1988]). This statement is correct, but still incomplete: by just focusing on variation, Mayr presupposes the existence of living beings where this random variation can occur. A complete account would state that natural selection works on entities that by chance are produced (origin of life) and subsequently modified through random mutations. Thus natural selection works as a sieve on entities that themselves are created and altered by undirected, blind forces.

In this sense, the Darwinian explanation is well adapted to deal with the explanation of traits. Traits find their origin in random mutations, where only those variants are preserved that increase the fitness of their bearers, and therefore bring about their own preservation. However, this explanation is not well adapted to deal with sexually reproducing organisms.

To illustrate this, let's imagine two individual organisms that compete for food. One of them is able to obtain it because of, say, better muscular development, while the other dies of starvation. Now it is quite legitimate to say that the stronger organism is selected, that natural selection favours the stronger animal above the other one, but this interpretation of selection does not provide an explanation for the existence of these organisms themselves. We have seen that selection in the form of random production and

modification and non-random selection is proposed, as a process that can account for the existence of biological entities, where what is selected is simply that which persists. But sexually reproducing animals do not fit this concept: their existence simply cannot be seen as the persistence of something that is blindly created or altered. An organism finds its origin through the ingenious processes and behaviour of reproduction of their parents, not through blind and uncontrolled physical forces. Organisms are not merely entities that persist, much less does this persistence explain their very existence¹. Organisms might be *subject to* natural selection, but they cannot be seen as the *product of* natural selection as random production and non-random, directive selection. And this distinction between *subject to* and *product of* selection is of pivotal importance: some organisms might be naturally selected over others, but this does not take away the fact that their existence cannot be explained by natural selection.

2. THE UNITS OF SELECTION AND GENIC SELECTIONISM

The units of selection problem in evolutionary biology can be defined as the problem of identifying the entities adaptations exist

¹ Mayr acknowledged that not everything can be explained through random variation and non-random selection, and thus spoke about another kind of selection: "There is, however, also a second kind of selection, which Darwin appreciated far better than any of his contemporaries and which he called sexual selection. [...] For Darwin sexual selection consisted of the preference of females (female choice) for particular males as well as in polygamous species the battles of males for the greatest possible harem. Since Darwin's days it has become clear that this kind of selection includes a far wider realm of phenomena, and instead of sexual selection it is better referred to as 'selection for reproductive success.' It includes such phenomena as parent – offspring conflict, sib-rivalry, unequal parental investment, unequal rates of division of prokaryotes, and many of the phenomena studied by sociobiology. In all these cases, genuine selection, not elimination, is involved, unlike survival selection" (Mayr [1997], p. 2091). But the elementary difference between survival selection and sexual selection (or whatever we choose to call it) is that the former is exhaustive, and relies on nothing else but the natural forces that create and alter, while the former is again something that in itself demands an explanation. Mayr placed the process of sexual reproduction to the site of the *explanans*, while sexual reproduction was exactly what we tried to explain. Our goal was not to acknowledge that sexual reproduction is an elementary process in biology; our goal was to explain it, something which natural selection (Mayr's survival selection), the only genuine and exhaustive naturalistic explanatory principle, was unable to do.

for the good of. We have seen that the traditional Darwinian explanation – proposed by Darwin and still maintained by the majority of Darwinists (Mayr [1997]) – restricts the unit of selection to the organism, and thus proposes that adaptations exist for the good (fitness) of the organism.

Dawkins proposed a fundamentally different interpretation of the unit of selection. For him, adaptations do not exist for the good of the organism, but for the good of the gene:

It is legitimate to speak of adaptations as being ‘for the benefit of something, but that something is best not seen as the individual organism. It is a smaller unit which I call the active, germ-like replicator. The most important kind of replicator is the ‘gene’ or small genetic fragment (Dawkins [1982], p. 4).

The gene survives because of the active phenotypic effects it exerts towards its own survival and replication, and it is these phenotypic effects that we see as adaptations to survival (Dawkins [1982], p. 84).

Dawkins’ analysis of this level and the objection to the organism as unit of selection can be seen as an implicit attempt to overcome the earlier described inadequacy of traditional Darwinism to provide a complete explanation of biological phenomena. The unit of selection is the level adaptations exist for the good of, which means, as we have seen, that this unit is *explanans* for the adaptation – the ‘for the good of the unit’ explains the existence and frequency of traits. Now if the sexually reproducing organism is the unit, this means that the sexually reproducing organism is *explanans* in the explanation of traits. However, Dawkins disqualified the sexually reproducing organism as unit of selection because it does not fit his conceptual description of what the unit of selection foremost is: an active, germ-like replicator with a sufficient amount of fecundity, copying fidelity and longevity. But this is exactly a description of an entity that can be seen as the *product* of natural selection, entities that can be explained by it! Earlier I have focused the analysis of Darwinism on random production and non-random selection, but it actually takes more to be a product of selection, as Dawkins rightly pointed out. The entity must allow for evolution, the gradual accumulation of beneficial muta-

tions, thus the product of selection must be a fecund replicator to allow the possibility of creating sufficient copies of itself. Moreover, these copies must be good, although not too perfect to allow for the possibility of mutations (copying fidelity), even though the replicator must have enough coherence and permanence – as we have seen earlier – to still serve as something that persists in the course of evolution. The replicator must be active (have influence on his own survival and replication) and germ-like, which means that the replicator in principle can make endless copies of itself. So what Dawkins tries to ensure is that the unit of selection can itself be seen as the *product of* natural selection, that it can be explained by it, because if the unit of selection itself cannot be explained by natural selection, life cannot. The unit of selection plays by definition an important role within the Darwinian explanatory scheme, and if this unit cannot be seen as the production of natural selection, the entire Darwinian explanation is incomplete. And as the organism might be *subject* to selection, but cannot be seen as the *product of* selection, two things we learned to distinguish earlier, the acceptance of the organism as unit of selection explains the existence of adaptations as well as the general fact of adaptations through something that itself does not make sense in the light of natural selection².

As indicated earlier, Dawkins' solution to the units of selection problem was the appointment of the gene as unit. Thus, the ques-

² Accordingly, the nature of the controversy between those that support genic selectionism and those that consider the organism the unit of selection to a large extent relates to the different interpretation of the unit of selection: for both the unit of selection is the level adaptations exist for the good of, but while the latter consider it necessary if the unit of selection is subject to selection, the former deem it additionally required that the unit is also the product of, which means that it can be explained by, natural selection. Thus those that support the organismic view of natural selection (such as Mayr and Gould) criticize genic selectionism because genes cannot be *subject* to selection (cannot be selected) as for example genes are not directly visible to selection, or that the selective value of a gene depends on the genetic background in which it operates (Sober [1984]). On the other hand, Dawkins and other adherents of genic selectionism will stress on the fact that organisms must be disqualified as units of selection as they are no replicators, which implies that their existence cannot be explained by natural selection. Thus adherents of each standpoint attack the other side with arguments that are particular to their own interpretation of the unit of selection.

tion that needs to be answered is whether Dawkins' interpretation of the theory of natural selection brings us further towards a complete understanding of biological phenomena. As seen, the gene survives because of the active phenotypic effects it exerts towards its own survival and replication, and these phenotypic effects we interpret as adaptations to survival. Dawkins' explanation at first sight does not contain the gaps of the traditional Darwinian explanation. The explanatory scheme seems to be self-contained, in the sense that it does not rely on another, unexplained element such as the sexually reproducing organism in the traditional explanation. There the phenotypic trait (or adaptation) was the *explanandum*, and the organism with its behaviour towards survival and reproduction the *explanans*. For Dawkins, the gene is the *explanandum*, and its phenotypic effects towards its own survival and replication *explanans*. But although Dawkins seems to have repaired the Darwinian explanation by making it complete and not dependent on another, unexplained element, it still will not satisfy us. The reason for this is twofold. First of all, although Dawkins might have eliminated the organism out of the Darwinian explanatory scheme, genes still exist within the reproducing organisms, and their existence fully depends on them. Theoretically, genes might exist outside of the organism, but actual genes do not, and can only survive within the context of other genes within the organism. Thus, the elimination of the organism out of the explanatory scheme is not justified, as it does not correspond to biological reality.

Secondly, organisms simply do exist, and for Darwinism to give an exhaustive explanation of life, organisms have to be incorporated into this explanation. But by transferring the Darwinian explanatory scheme to the level of the gene, the organism, which Dawkins defined as vehicle, is a hard thing to account for, as Dawkins himself admitted:

Given that life can be viewed as consisting of replicators with their extended phenotypic tools of survival, why in practise have replicators chosen to group themselves together by the hundreds of thousands in cells, and why have they influenced those cells to clone themselves by the millions of billions in organisms? (Dawkins [1982], p. 251).

In his work *The Extended Phenotype*, Dawkins dedicates a chapter to the organisms, but surprisingly does not show the ambition to provide a complete explanation:

I have not aspired [...] to give a completely satisfying answer to the question of why there are large multicellular organisms. I will be content if I can arouse new curiosity about the question (Dawkins [1982], p. 263).

What Dawkins provides is a discussion of how imaginable alternative life forms would be less stable or would provide fewer opportunities for evolution, but this is not an explanation and does not provide the *raison d'être* of individual organisms in light of their benefits for replicators.

The value of a theory can be seriously questioned when it cannot even provide an account for the most salient and fundamental unit of life. But (like with Darwin) this is precisely what happens in the case of Dawkins' theory: when confronted with the most intricate, complex and astonishing phenomenon in the biosphere, the biological entity *per excellence* – the organism – Dawkins remains silent. The concept of genic selectionism – like the traditional Darwinian theory – is unable to provide an account for sexually reproducing organisms, their origin as well as their processes and behaviour. This means that with Dawkins we remain where Darwin left us, namely at the question for the ground for the existence of organisms with their behaviour towards survival and reproduction: Darwin assumed it, Dawkins tried to ignore it, but neither of them explained it.

3. GROUP OR SPECIES?

The theory of natural selection that considers adaptations for the good of groups or species has greatly lost popularity after the criticism it received from prominent biologists such as Williams [1966] and Dawkins [1976]. These objections include the fact that groups or species do not sufficiently exist in the form of copies (thus do not allow for the gradual accumulation of beneficial mutations), and the high chance that selfish organisms would in-

fect and undermine the groups or species. The consensus among contemporary biologists is that group selection can at most be seen as a weak force in evolution as the conditions for it to occur are quite stringent (Hull and Ruse [1998]).

The goal of this paper is not to focus on these aspects of group or species selection, but to see to what extent this Darwinian explanatory scheme, given that it would exist and the objections against it would proven to be false, would be able to provide an exhaustive account of biological phenomena.

If the group or species is the unit of selection, adaptations exist for the good of this level. Now adaptations are about the lowest level in the hierarchy of life, while groups or species comprise the highest. An elementary level between these two is again formed by the individual organism that ensures the preservation of this group or species. Individual organisms are indispensable in the maintaining of the group or species, but the two ends of the theory, the adaptations with its explanatory ground, the preservation of the group or species, are in no way able to provide a possibility to explain the existence of individual organisms, while their existence and preservation are fully dependent on it. Thus, in case of group or species selection we can be very short, as this interpretation of the theory of natural selection in no way provides a tool for explaining the existence of reproducing organisms.

4. CONSEQUENCES OF THE INABILITY OF DARWINISM TO ACCOUNT FOR THE SEXUALLY REPRODUCING ORGANISM

The theory of natural selection gives a mechanism how organisms have evolved to the way they are, how the possibility of random variation allows for natural selection to work as a sieve to preserve certain changes. Natural selection, however, does not directly deal with the workings of living beings themselves, how they grow, physiologically function, reproduce, etc. The theory proposes a mechanism of how organisms have *become* the way they are, but its sphere does not encompass the biological processes of living beings when they *are* the way they are. Mayr [1988] introduced the distinction between proximate and ultimate explana-

tions to describe the difference between causal explanations and explanations by natural selection. Proximate causes relate to physico-chemical explanations. Ultimate causes, on the other hand, relate to historical causes for the existing adaptations and particular adaptations of organisms. In his paper *Chasing Shadows*, Walsh [2000] claims the two are in fact related: for an insight in the causes of adaptive change, one has to abandon the statistical dynamical model of evolution, and foremost has to understand the nature of organisms. The main question that lies at the core of the understanding of adaptive complexity is what kind of things organisms are, such that selection of, and mutation within them eventuates in adaptive evolution. Natural selection exists by virtue of the fact that the individual organisms it operates over are complex, self-organizing systems, the understanding of which thus forms a crucial factor in the understanding of evolution.

Thus, a complete explanation of life consists of two separate albeit interrelated elements: the explanation of changes through the process of natural selection, and the 'causal' explanation of biological entities themselves through a systematic understanding of living beings as complex systems, founded on the laws of physics and chemistry.

The causal explanation of life concerns a myriad of processes and phenomena of a breathtaking complexity. Living beings, as often claimed, are by far the most complex systems in the universe, and it can be doubted that it will ever be explained in all its detail. However, there are some fundamental concepts within the study of life, elementary principles founded on naturalistic, physical principles that are of key importance in the understanding of living beings. These include the extensively dealt with notions of the genetic program, the process of replication, and concepts derived from system science such as causal feedback loops and self-organization.

The process of replication, one of those essential notions, does not only play a fundamental role within the causal functioning of living beings, but also in the evolutionary theory of genic selectionism. As we have seen, replicators that make copies of themselves with a sufficient degree of longevity-fecundity-copying fidelity create the possibility of evolution, leading to the development in time

of complex and varied replicators. In light of the mentioned two aspects of the explanation of life, it is important to stress that the workings of the replicators themselves are not explained by natural selection. The *evolution* of replicators and how they are shaped the way they are can be explained by natural selection, but the explanation of the mechanisms of their workings, on the other hand, is the realm of the causal explanation of how replicators survive and replicate. Natural selection explains *why* replicators are the way they are, by providing a mechanism for their origin, but it assumes that replicators do replicate, and does not provide an explanation *how* this process of replication works. This causal explanation has been the subject of elaborate scientific and philosophical analysis over the past decades.

But the process of replication is not the only process that demands such a causal explanation. Many organisms reproduce sexually. The sexually reproducing species can be seen as a device that permutes a discrete set of mutually accustomed genes in different combination, continuously shuffling combinations of genes that meet each other within the species (Dawkins [1986]). And this continuous flow of combinations, from the one unique constellation of genes to the other, should also be purely causally explained, as this sexual reproduction is not the realm of natural selection since it does not concern the change in biological entities through random mutations and subsequent selection. Organisms might be subject to selection, but cannot be seen as the product of natural selection, as we have seen before. The process of reproduction is a process of change, but it is not the process of change that relates to random variation and subsequent selection: physiological processes are responsible for sexual reproduction, not mutations or other sorts of random alterations. Thus, natural selection assumes the workings of replicators and leaves this explanation untouched, and likewise neither accounts for the process of sexual reproduction.

It is important to mark the fundamental difference between the process of replication and reproduction. The replicator has been defined as an entity that passes on its structure (largely intact, to allow for variation on which natural selection can do its work) in

successive replications (Nanay [2002]). The process of replication is the repeated reproduction of the same structure: the specific structure contained in the replicator is copied to external material, which in its turn imposes its structure on again other material. Natural selection provides a mechanism of how the structure of the replicator is shaped, but the laws of physics and chemistry explain the fact that this structure is time and time again imposed on different material through the process of replication. Thus natural selection deals with the selection of different *forms*, not with matter itself³. A specific form or constellation is naturally selected, and physico-chemical processes lead to the process of replication, in which different matter is shaped in the form of the replicator. Moreover, it is very well conceivable that this replication can go on *ad infinitum*: the structure contained in the first replicator is identical to and causally determines the structure of a future replicator, whether it is 1, 10, or 1 million generation further.

Furthermore, the process of replication can in essence be understood causally in chemical terms. The fundamental feature underlying the possibility of replication is constituted by the *existence of chemical affinities between molecules*. In principle, the core of replication is the existence of the affinity of DNA molecule Adenine for molecule Thymine (and vice versa), and the affinity of molecule Guanine for molecule Cytosine. It is this affinity that essentially underlies replication, and this phenomenon should therefore be explained by it, as well as the unlimited potential of this process.

However, the process of sexual reproduction is fundamentally different: a reproducer is not *copying* an existing structure shaped by natural selection, but creating a *new* structure or constellation, the former nor the latter directly being formed by natural selection. Thus reproducers cause the creation of new reproducers with

³ This notion is too little highlighted in Darwinistic literature. In living beings, matter changes in a constant flux, and the element constant in life is always the form, but never its matter. Consequently, natural selection always refers to the selection of certain forms, never to the matter within this form itself. Thus when we conclude that the replicator can be seen as a product of natural selection, it always refers to the specific form of the replicator, not to its material content.

a different structure, which is something fundamentally different and scientifically more challenging to account for than the replication of the same structure. Where in the case of replicators a form is retained and matter is changing, in the case of reproducers neither the form nor the matter are retained, the only thing that is permanent – and natural selection can give an account for – is the building blocks of the genetic material, genes. Moreover, while replication only needs the existence of one replicator for the process to take place, reproduction requires the existence of a group of mutually co-adapted reproducers, the existence of which, therefore, causally also needs to be accounted for. Szathmáry and Maynard Smith [1997] introduced the term reproducer next to the replicator, and so also suggesting a similar role for sexual reproduction within the theory of natural selection as replication. Despite this, its explanation has not received the level of attention as the replicator has.

A challenge within such an explanation will be illustrated through the ideas of Jacques Monod set forth in his classic *Chance and Necessity* [1972]. In this work, Monod describes the most salient characteristics of living beings: the fact that they are self-constructing machines (they owe nothing to the action of outside forces, but everything from interactions within the object itself), their teleonomic characteristics (organisms are objects that are seemingly endowed with a purpose or project), and their ability to reproduce and to transmit unaltered the information corresponding to their own structure, or self-reproduction. Moreover, Monod claims that the fact that these characteristics – especially teleonomy and reproductive invariance – are interconnected, solves the epistemological paradox connected to living beings, their ‘strangeness’ in light of the naturalistic premises of modern science, namely their teleonomic character. Invariant reproduction is the ability of living beings to reproduce and to transmit unaltered the information corresponding to their own structure. The information that stands at the basis of all teleological processes and behaviour by serving as a blueprint for the organizational scheme of the individual, is preserved intact from one generation to the next one (see also Van Rossum [2003]). Moreover, Monod claims that the con-

nection between teleonomy and invariant or self-reproduction is the only way in which living beings can be brought into a naturalistic understanding.

But associating teleonomy with self-reproduction – causing the fact that “source of the information expressed in the structure of a living being is *always* (italics from author) another, structurally identical object” (Monod [1972], p. 12) – is making sense of certain biological phenomena (replication), but neglecting others (sexual reproduction). It should be clear that in sexual reproduction, the source of the information expressed in the structure of a living being is *never* another, structurally identical object. Explaining self-reproduction (replication) is a comfortable undertaking for a naturalist – as we have seen, its essence can be understood through the existence of chemical affinities. But explaining sexual reproduction is of an entire different nature, and remains, also in case of Monod, unexplored.

If we stay in line with Monod’s terminology, it is our task to connect teleonomy (seemingly goal directed processes) with reproductive *variance*, and it is exactly here where a difficulty lies. Sexual reproduction, as seen over the generations, is continuously creating *new* combinations of genes, ever again shuffling genetic material into *unique* constellations. Moreover, these constellations are teleonomically (vs. randomly) created, as sexual reproduction is (most clearly in higher animals) aimed at *specific* entities. Mating partners are not randomly chosen, but the process of sexual reproduction is targeted at specific entities with certain characteristics.

Sexual reproduction as this dynamic, teleonomic process is difficult to understand since it cannot be just chemically explained like replicators, but demands a cybernetic account. If we take a group of organisms in a certain point of time, these organisms carry within them, through their structure and genetic constitution, the potential for creating endlessly new organisms, each unique in their genetic make-up. It is therefore the task of science, and cybernetics in particular, to give an account for this possibility – the science of systems constantly creating new systems, systems with this autonomous, creative, and teleonomic potential. It is in that light that sexually reproducing organisms have to be seen and explained, as it forms an essential ingredient in the naturalistic

understanding of living beings.

Pointing out the problematic position of sex within the theory of natural selection is, of course, far from original. The question *why* sex exists, its *raison d'être* in light of the theory of natural selection, has inspired a still ongoing discussion within biology, as was also seen in the remarks Dawkins made in *The Extended Phenotype*. But this paper attempts to do more. Besides to the question of *why* sex exists (for a fundamental aspect of life certainly a justifiable query), comes the question on *how* it works. By stripping the theory of natural selection to its essence – the explanation of the gradual accumulation of features by the iterative process of random production and variation, and subsequent non-random, directive selection – it becomes clear that this explanatory framework is not fit to explain sexual reproduction. The immediate consequence of that observation is that a proximate, causal explanation of the phenomenon should be given instead.

Now also here one can argue that the proximate explanation of sex has received a lot of attention within biological literature. But although the extensively dealt with behavioural and physiological aspects of sexual behaviour concern a causal, proximate explanation of sex, it does not cover the explanation as identified in this paper. One might understand the physiology of fertilization, or understand the courting behaviour of ducks, but this does not explain how systems – living beings – carry within them the potential of infinitely creating new, specific and unique systems (organisms) through sexual reproduction. Again, what is needed is a *complex theory of sex*, how we can understand the principles of organisms as reproducing systems, or the dynamical and creative potential of living beings to continuously and autonomously produce new and specific organisms with unique constellations. In order to abandon the statistical dynamics point of view to get a full understanding of life as Walsh [2000] encourages us to do, one does not have to consider the individual organism, but organisms as complex systems that infinitely produce new organisms, each with its own unique constitution. By clearly marking the boundaries of the theory of natural selection (what this paper attempted to do), we see that the unit within life that requires a causal explanation is not the isolated organism, but a *community of organisms tied to-*

gether in space and time through sexual reproduction. Once moulded by natural selection, this group of organisms is endlessly producing new organisms, shuffling the genetic content of the species in ever new constellations. By scrutinizing the theory of natural selection and clearly analysing its nature and the limits of its explanatory potential, sexual reproduction is found insufficiently explained, revealed as a gap within the naturalistic understanding of life. Instead of being assumed or ignored, this fundamental characteristic of living beings needs to be accounted for within the naturalistic paradigm of science in a causal, cybernetic way.

5. CONCLUSION

Living beings have long posed a problem for naturalistic, materialistic philosophers who attempted to explain the world through physical, mechanistic laws. Rejecting all finalistic, dualistic and vitalistic explanations on natural phenomena, naturalism is still left with the question how the world ends up filled with objects that seem to falsify the claim that everything in the world is the result of the free play of physical forces to which no goal, purpose or specific direction can be attributed. The ideas laid down in Darwin's *Origin of Species* are considered to be the key to the mystery, the remedy from all vitalistic, dualistic and finalistic claims of the natural world as they provide a framework to explain the existence of biological phenomena in a naturalistic context (Montalenti [1974]).

I have attempted to show limitations of Darwin's theory of natural selection in relation to sexual reproduction. Sexual reproduction, defined as the dynamical and creative potential of living beings to continuously and autonomously produce new organisms with unique and specific constellations, has been assumed by the traditional interpretation of natural selection, and removed from the elementary explanatory scheme of the theory of genic selectionism. I have also shown that sexual reproduction couldn't possibly be explained by natural selection, whose creative potential consists of the iterative process of non-random selection on random production and variation. This brings another dimension to

the science of sex: next to the explanation of why sex exists (its *raison d'être* in light of sexual reproduction), a close and detailed examination on the nature of the theory of sexual reproduction reveals the need for a mechanistic, cybernetic explanation of sexual reproduction as well. For a complete naturalistic account of living beings, science should give an account for the dynamical and creative potential of living beings to continuously and autonomously produce new organisms with unique constellations. This conclusion brings sexual reproduction into new light: as a fundamental and – through the essential teleonomic, dynamic and creative characteristic of sexual reproduction – challenging gap in the understanding of life in a naturalistic explanatory framework.

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SULLA INIDONEITÀ DELLA SELEZIONE NATURALE
A SPIEGARE LA RIPRODUZIONE SESSUALE,
E LE DIFFICOLTÀ CHE RIMANGONO

Riassunto

Essenzialmente, il potere esplicativo della teoria della selezione naturale fa riferimento ad un processo iterativo di produzione casuale e successiva selezione non-casuale. Viene qui mostrato come in questa cornice esplicativa non ci sia spazio per la riproduzione sessuale. In effetti, nella letteratura darwinista, la riproduzione sessuale – una delle caratteristiche più salienti della natura – è spesso assunta o ignorata, ma non spiegata. Per arrivare ad una completa comprensione naturalistica degli esseri viventi è necessario che la biologia riesca a dar conto del potenziale dinamico e creativo della riproduzione sessuale.