Chapter 7
Evolutionary Explanations and the Role of Mechanisms

Gerhard Schurz

Abstract In the first section I outline the three basic theoretical assumptions of a generalized theory of evolution: the Darwinian modules of reproduction, variation, and selection. The analysis of functional traits of evolutionary systems which I give in Sect. 7.2 is grounded on these assumptions. The evolutionary explanation of the emergence of functions leads me to an abstract schema of evolutionary explanations that is based on iterations of variation and selection processes. In the final Sect. 7.3, it is shown, at hand of the problem of explaining evolutionary *macrotransformation*, that abstract evolutionary explanations are considered as inadequate by evolutionary scientists as long as not at least some *plausible* mechanism can be given, both for the production of complex variations and for their selection.

Keywords Evolutionary explanation • Macrotransformation • Evolutionary function • Evolutionary mechanism

7.1 General Evolution Theory: The Three Darwinian Modules

According to Darwinian evolution theory in its contemporary stage, evolutionary processes consist of the following "Darwinian" postulates or modules (Schurz 2011):

G. Schurz (✉)
Heinrich-Heine-Universität Düsseldorf, Institut für Philosophie,
Universitätsstraße 1 Geb.23.21, 40225 Düsseldorf, Germany
e-mail: schurz@phil.uni-duesseldorf.de

M.I. Kaiser et al. (eds.), *Explanation in the Special Sciences: The Case of Biology and History*, Synthese Library 367, DOI 10.1007/978-94-007-7563-3_7,

Module 1 – Reproduction: There are entities – organisms or more generally evolutionary systems – which again and again reproduce themselves in regard to certain significant traits; these traits are called reproduced or inherited traits, and every such reproductive process produces a new generation.

Module 2 – Variation: Reproduction brings along variants that are reproduced or inherited at the same time.

Module 3 – Selection: There is selection, because certain variants are fitter under given environmental conditions, that is, they reproduce more quickly than others, thus replacing the other variants in the long run. The selecting parameters of the environment are also called *selection parameters*.

Sober (1993, p. 9) summarizes the three modules as "inheritable variation of fitness." Thereby "fitness" is understood as the *effective* rate of reproduction, that is, the average number of reproducing offspring. Varying rates of reproduction alone lead only to a *weak* selection in the sense of a continuous decrease of the relative frequency of the less fit variants. This does not yet mean that these variants have to become extinct. Yet in all realistic examples there exist upper bounds to population size due to the environment's limitation of resources. As a result, *strong* selection occurs, that is, the frequency of the less fit variant does not only decrease, but at one point in time, these variants eventually become extinct.

We should add that in contemporary evolution theory, an "overall adaptationism" is no longer tenable. Evolutionary processes are not solely the result of selection and adaptation; a further important kind of evolutionary processes are different kinds of random drifts that are caused by selectively neutral variation mechanisms. More importantly, not every phenotypical treat which is the result of selection processes is the cause of a selective advantage and hence has a direct adaptive explanation; many traits have been selected as mere causal side effects of other traits which have an adaptive explanations (see (EE)(2.) in Sect. 7.3).

Dennett (1995, 64f.) has emphasized that the three Darwinian modules make up an *algorithmic* process, whose fundamental properties are as follows:

1. The evolutionary process can be outlined in an abstract and object-neutral manner, which is why at least in principle evolution theory can be generalized to many object areas, also outside of biology, for example, to the evolution of culture (see below).
2. The algorithmic process consists of certain basic steps: (a) the reproduction of the genes or, in general words, of the system's "reprons" (see below);

(continued)

(continued)

(b) their variation; (c) the causal creation of organisms with their phenetic traits; as well as (d) the selection of these organisms and their genes, based on varying rates of reproduction of their genes.

3. Algorithmic processes are *recursive* (or iterative), that is, *the same* sequence of simple steps is repeatedly applied to the result produced in the meantime.[1] In this way, from very many *local* steps strung together bit by bit, a *global* result of development emerges, which is in no way already discernible from the "internal nature" of the local steps and often enough cannot even be calculated mathematically in advance but only be understood and explained evolutionarily. This recursiveness is indeed the secret of all evolutionary processes. It leads to highly complex structures resulting from the iteration of astonishingly *simple* basic components, which then look as if a "superior designer" had conceived them. Recursive procedures are also the most important foundation of formal logics and computer programs.

Typical evolutionary processes are *quasi-teleological*: From their selective directedness a goal *seems* to result, which is pursued. However, a lineage owes its directedness only to the *stability* of selective forces over many generations. If the selective forces or selection criteria change strongly, the direction of evolution subsequently changes, too. On the basis of such changes of direction, evolution can be divided into stages, for example, anaerobic versus aerobic unicellular organisms. In contrast, it is no longer possible to speak of directed evolution, if the selection parameters change in a quick and irregular manner, with alteration rates of a similar magnitude than the generation rates. This can lead to strong fluctuations or even to chaotic developments. It is questionable whether in this case one can still speak of evolution at all – at least one cannot speak here of *directed* evolution anymore. As a prerequisite of directed evolution, one has to assume a *fourth* condition (in addition to the three modules mentioned above):

Condition for directed evolution – stability of selective forces: The alteration rate of the selective forces is either low compared to the generation rate, or else the changes are regular or predictable.

---

[1] This condition is curiously missing in Dennett (1995); though it is the most important one (see also Boyd and Richerson 1985, 20f.).

The or-else phrasing is necessary, because organisms can adapt to changing environments very well, so long as the alterations are regular. Accordingly, species are differentiated into *specialists* and *generalists*; the latter adapt to altering conditions (Sober 1993, p. 21). A simple example is the adaptation to the times of day and year. There are also more complex examples, namely, the amphibian arrowhead, whose leaves assume a sea grass-like shape under water, one similar to the leaf of a water lily on the water, and an arrow-shaped one on land (Wilson 1998, 185f.). The most generalist living being is, without doubt, man.

Because of its abstractness and object-neutrality, evolution theory can, at least in principle, be generalized to other domains in which the three Darwinian modules are realized in some form. One example is *cultural* evolution. Let us begin with the negative demarcation of the theory of cultural evolution from sociobiology. Sociobiology (similar to evolutionary psychology) considers the cultural development of humans as being ultimately determined by their genes. In contrast, in the theory of cultural evolution, cultural development is precisely *not* reduced to the genetic-biological level and tried to explain from there. Rather, a *distinct level* of cultural (social, technical) evolution is assumed: the evolution of *memes*. The meme concept has been introduced by Dawkins (1976, Chap. 11) as the "cultural counterpart" to the genes.[2] With memes are meant human ideas and skills, which are reproduced by the mechanism of *cultural tradition*. In that regard it should be emphasized that "culture" is always understood *in a broad sense* here, as everything human made, which cannot be reduced to the human genes – cultural evolution therefore comprises not only cultural history in a narrow sense of moral and religion, art, and literature but also social, political, and legal history and in particular the evolution of science and technology.

For the evolution of memes, it is not important which position one assumes in the mind-body controversy – whether one sees memes rather as neuronal brain structures or as mental thought structures. Essential is only the presence of the three Darwinian modules. In order to be able to describe these modules sufficiently generally, we introduce a few additional object-neutral concepts of the generalized theory of evolution (GE), summarized in Table 7.1. Every kind of evolution consists first and foremost of its specific *evolutionary systems* – these are those systems that are in a direct interaction with the environment. In biological evolution (BE) these are the organisms – in cultural evolution (CE) the cultural systems created by humans. Evolutionary systems always possess certain subsystems or parts, which are more or less *directly* replicated or reproduced from each other: we call these subsystems in a generalized manner the *reprons* or repron complexes. The reprons of BE are the genes, gene complexes, and genotypes; the reprons of CE are the memes or meme complexes, that is, stored information in the human brain or mind, respectively. BE is characterized by the additional condition of sexual reproduction and genetic diploidy; this peculiarity does not occur in CE.

---

[2] On meme theory cf. Blackmore (1999), Aunger (2000, 2002), Mesoudi et al. (2006), Schurz (2011).

Table 7.1 Concepts of GE, applied at the levels of BE and CE

Generalized evolution	Biological evolution	Cultural evolution
Evolutionary systems	Organisms	Human societies
Reprons	Genes in the nucleus	Memes or acquired information
Phenetic traits	Organs, abilities	Skills, procedures, language, ideas and thought patterns
Reproduction	Replication, DNA copy	Passing on to next generation by imitation and learning
Variation	Mutation and recombination	Interpretation and variation of passed on memes
Selection	——— Higher rates of reproduction due to higher ———	
	rate of propagation	cultural attractiveness
Inheritance	Sexual (diploid)	Asexual (blending inheritance)

We call those traits and skills of an evolutionary system, which are produced by the reprons in the course of its individual development, the *phenetic* traits of the evolutionary system. In BE these are the organismic traits, in CE the cultural or technical products or the institutions, which have emerged from human memes. *Selection*, finally, comes about on all levels by certain kinds of evolutionary systems and underlying reprons reproducing more quickly under the given environmental conditions than others. Beside these fundamental similarities between BE and CE, there are of course also a number of important differences, for example, intentionally directed variations in CE, which however constitute no fundamental obstacle to the application of the three Darwinian modules. Table 7.1 compiles the fundamental concepts of GE and their counterparts at the levels of BE and CE.

Opponents of the generalized theory of evolution (GE) have often reproached it with the claim that the transfer of the theory of biological evolution (BE) to cultural evolution (CE) is a mere metaphor. Yet as we have developed GE here, it involves entities on the cultural level which are by no means merely metaphorically; they rather *literally* reproduce and in doing so are subject to processes of variation and selection. For instance, according to cultural evolution theory, the carriers of technical evolution are precisely not the technical appliances or resp. artifacts – in this traditional view evolution would indeed only be a metaphor, as technical appliances do not reproduce. Rather, the carriers of technical evolution are the culturally reproduced skills as well as manners of the production and utilization of technical appliances, and they obviously do reproduce.

7.2 Functional and Evolutionary Explanations

Evolutionary explanations in biology have predominantly been discussed in the context of the controversy about evolutionary function concepts and functional explanations (cf. Allen et al. 1998). The function concept is a philosophical problem of a long tradition, whose discussion is directly linked to the dispute between the theory of evolution and creationism or teleology. Let us consider the basic form of a functional explanation:

> (FE) Basic form of a functional explanation: Systems (or species-members) of type S possess a certain trait T in order to perform a certain function F, which has a high value for S.

For example, the vertebrates possess a heart that circulates the blood in the body, in order to provide the body with oxygen.

Functions are certain causal effects of the underlying organs or resp. traits of evolutionary systems. Cummins (1975) suggested analyzing functions as common effects of complex systems. This analysis, however, is unable to clarify what distinguishes effects performing biological purposes (like the heartbeat) from nonfunctional effects (like the falling of a stone, when I let it go). So, the central task lies in working out the difference between nonfunctional and functional causal effects. In principle there seem to be only three strategies that correspond to time-honored philosophical doctrines for this purpose:

First, one can perceive "in order to" in the sense of the intentional function concept as a creator's intention, who has purposively constructed system S with trait T in this way, so that it has the effect F. Applied to the macroperspective of evolution, this intentional function concept leads straightaway to creationism.

Second, one can perceive the "in order to" as an ontologically distinct "force" by which the future attracts the past, which can in no way be reduced to scientific causation. In this way one arrives at the Aristotelian conception of teleology.

Both creationism and teleology are hardly tenable from a contemporary scientific viewpoint. This leaves, *third*, the evolutionary analysis of functions, which makes the concept of the function compatible with a causal-naturalist analysis, neither requiring divine creators or teleological forces nor relinquishing the quasi-directedness of function. On that note, Millikan (1989, p. 13), Neander (1991, 174), Sober (1993, p. 84), Schurz (2001, §4), and others have proposed different variations of the following evolutionary analysis of the function concept:

(EFC) The evolutionary function concept: A causal effect E of a subsystem (organ) of an evolutionary system (organism) S is an evolutionary function iff (1) E is a reproduced ("heritable") trait and (2) the reprons (genes) on which E is based were selected because they have predominantly contributed to the evolutionary fitness of species S in its evolutionary history through the effect E.[3]

Addition (see below): If only condition (1) but not (2) is fulfilled, E is called a mere evolutionary side effect of (a subsystem of) S.

The concept of the evolutionary function is a special case of the so-called etiological function approach (Wright 1976), according to which a system S possesses a trait T with function F if and only if S causes F by means of T and F is in some manner valuable to S. Thereby, the prima facie normative condition of valuableness can be characterized differently (Bedau 1998); in the concept of the evolutionary function, it means as much as selective advantage and can therefore be reduced to a purely descriptive condition (Wachbroit 1994, p. 580).

Distinctive of the concept of the evolutionary function is its just-mentioned historical nature: functions are constituted by the relevant selection history of the relevant trait T of species S. Bigelow and Pargetter (1987), by contrast, have proposed a function concept that depends only on the present time, identifying an organ's function with the organ's present disposition of contributing to the fitness. Millikan (1984, p. 29) objects to this, quite rightly, that this presence-related explication can no longer distinguish between evolutionarily normal functions and dysfunctions. Accordingly, it is still the evolutionarily normal function of a damaged pancreas to produce insulin, and only for this reason we can say that the pancreas of a diabetic human, which no longer produces enough insulin, is no longer able to perform its evolutionary function, that is, it is biologically defective. Bigelow and Pargetter would have to say that in the contrary, the pancreas of a diabetic does no longer have the function to produce insulin. In short, an organ can also have an evolutionary function, without in fact performing it or even being able to perform it (likewise Laurier 1996, 27f.).

Not every evolutionary selected trait needs to have a direct evolutionarily adaptive function – many such traits are mere side effects of such functions. In Schurz (2001) the selected traits of evolutionary systems (whether they are functional or side effects) are called "prototypical" traits and are defined as in the addition to the abovementioned explication (EFC). A prototypical trait or effect E performs an evolutionary function if and only if the selection of the underlying

---

[3] The explication corresponds to Neander's short version of Millikan's concept of the *proper function*, enriched by two additions suggested in Schurz (2001), that T has to be a heritable trait and that the reprotype has to have predominantly contributed to the evolutionary fitness. The additions are meant to solve the problems explained below.

repron RE happened because of E itself; otherwise, E is merely a side effect of other functions caused by RE. For instance, it is the evolutionary function of the heart to pump blood, whereas the sound of the heartbeat only is a side effect of this function that by itself does not have any biological function (Cummins 1975; Bigelow and Pargetter 1987). The distinction between functional-adaptive traits and mere side effects forestalls an excessively adaptationist perspective.

Let me explain these notions by means of a few additional examples. In the framework of cultural evolution (CE), it is an evolutionary function of matches to catch fire if struck against an ignition surface, as they have been selected in CE for this purpose. That in striking the match one occasionally burns one's fingers is a typical side effect of this, while the color of matches is not a prototypical trait at all (neither as a function nor as a side effect). Analogously, in the framework of biological evolution (BE), it is an evolutionary function of noses to be able to smell and to protrude from the face, and it is a typical side effect of this that in winter noses cool down comparably fast, while – in contrast to the claim by Voltaire's Dr. Pangloss (Gould and Lewontin 1979, p. 583) – it is not a biological-evolutionary trait of noses to be able to wear glasses. Yet, conversely, it is certainly a cultural-evolutionary trait of glasses to be able to sit on noses.

Fodor and Piatelli-Palmarini (2010) have argued that the distinction between functions, that is, selectively advantageous traits, and mere side effects would be "intensional" and thus would constitute a fundamental obstacle to the theory of selection, as selection processes are "extensional." An excellent refutation of this view is given by Block and Kitcher (2010): they point out that the distinction between functional traits and mere side effects is an obvious and harmless causal distinction, which presumes nothing more than basic assumptions of causality (directed cause-effect relations), which are almost universally accepted in the sciences. Selection process is defined in terms of causal relations, and therefore, the distinction between a trait T that is the cause of a reproductively advantageous effect E and another trait T' which is a causal side effect of T is not at all obscure or "intensional", at least not in any sense of this word in which cause-effect relations are not intensional.

In common sense, those traits of the environment of the evolutionary system, towards which the system has adapted, are often regarded as "functional traits" of the environment. For example, it is said that the function of rain and sunshine was to feed plants water and energy. But neither the Sun nor the Earth's water cycle is an evolutionary system. Conversely, it is rather the plant which is the evolutionary system, whose functionality systematically utilizes these environmental traits. Nevertheless, we can accept the common sense mode of speaking as a derived-functional mode of speaking and accommodate it through the following additional convention: An environmental trait U is evolutionary-functional in a derived sense, iff there are evolutionary systems S with evolutionary functions F, which have adapted towards U. This means that the selective advantage caused by F would not have come about, if the trait U had been predominantly absent in the history of S's environment. With this extended concept of derived-functional environmental traits, we evolutionarily grasp the entire scope of facts, on which the creationist argument from design is based, without leaving the naturalist perspective.

The condition in (EFC) that the effect E must predominantly contribute to the evolutionary fitness of species S in its evolutionary history ensures a connection between evolutionary normality and statistical normality. A number of philosophers of biology (e.g., Millikan 1984; Neander 1991; Wachbroit 1994; Laurier 1996) have argued against this by claiming that evolutionary normality would be independent from statistical normality. In contrast, Schurz (2001) attempts to show by means of a logically elaborate argument that, while evolutionary normality is not identical with statistical normality, the former implies the latter – at least, if one understands evolutionary normality in the sense of the above-defined evolutionarily prototypical traits. For, roughly speaking, there are only three possible reasons for why a selectively advantageous trait does not also become statistically dominant:

First, the trait is not predominantly a heritable or reproduced trait but its appearance strongly depends on the environmental conditions. For this reason we (unlike Millikan 1984, pp. 20, 29) restricted our explication (EFC) to reproduced traits. This restriction solves Millikan's objection (Millikan 1989, 62ff.) that many evolutionary functions of organs are only performed rarely. For instance, sexual reproduction is certainly the most important function, yet in many species it is only performed by a few individuals – namely, only by those of the numerous offspring that survive until reproductive maturity. But the genetically determined phenotypic condition that is selected here is not the actual performance of the function but the disposition to the performance of the function under suitable circumstances, and this disposition is present in almost all members of the species. In general, normic-evolutionary traits as a rule are not actual traits but dispositional traits.

Second, a trait may not become dominant if in the selection history of the trait, alongside stages of positive selection, there have also been long stages of negative selection. In these cases the formation of a normic and statistically dominant trait does not occur, but rather, a polymorphism of traits is generated. In order to rule out selectively ambivalent cases, we have required in the explication (EFC) that the reprons on which the trait is based have in the history of S predominantly contributed positively to S's evolutionary fitness.

Third, it may be that, while a trait E had been predominantly positively selected in the history of S, the evolutionary history of S was interrupted by an externally triggered catastrophe, so that the time was too short for E to become statistically dominant. Catastrophes admittedly occur repeatedly in evolution, but for evolution to be able to take place at all, they have to be sufficiently rare. For this reason we restrict the claimed connection between evolutionary and statistical normality to the "major part" of evolution and permit exceptions caused by catastrophes.

By means of this analysis, all objections against the connection between evolutionary and statistical normality that are known to me are no longer applicable (for further elaborations cf. Schurz 2011, 2012)

7.3 Evolutionary Explanation and Mechanism

The preceding evolutionary explication of functions can be turned into the following explication of evolutionary explanations:

(EE) Evolutionary Explanations:

Explanandum: An evolutionary species (organism) S possesses a certain subsystem (organ) with a certain effect E that S's ancestor species (S′) did not possess.

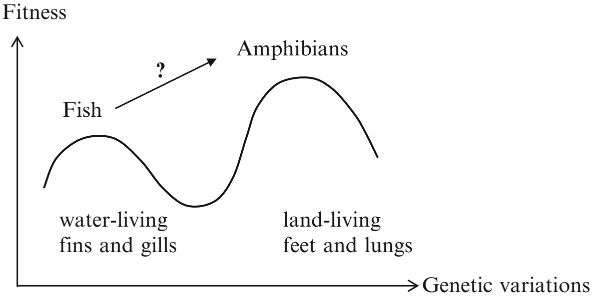
Explanans: (1.) Certain combinations of variations (mutations) in the ancestor species led to the appearance of a new complex of reprons (genes) R_E that produced the effect E in the normal environment of the ancestor species, leading to a new variant S*.

(2.) In the subsequent history of the ancestor species, the causal effect E was selected because it had predominantly contributed to the evolutionary fitness of the new variant S*, which by successive reproductive isolation evolved into the new species S* (while the ancestor species S′ either died out or transformed into a distinct species S**).

A remarkable feature of this explication of evolutionary explanations is that it does not inform us about *causal mechanisms*. This lack of mechanisms arises at two places:

Mechanism of variation: We are not informed about the mechanisms by which a series of variations lead to the new genes or reprons R_E which produce the new phenotype E. This is not a problem in the case of so-called microtransformations, in which the new phenotype differs only a little from the old one, because mechanisms for microvariations (such as mutation in biology) are well known. Examples are leg length of hoofed animals, or beak sizes of birds, etc. However, in the case of so-called macrotransformations, where an entire new type of organism appears, such as the transition from water-living to land-living animals or from nonflying into flying animals, the lack of causal explanations indeed constitutes a problem. Many critics of Darwinian evolution have objected that the combination of *independent* improbable mutations which are necessary

Fig. 7.1 Passage through a fitness valley



to produce the required new macrotrait seems to be far too improbable to be possible without creationist assumptions.

Mechanisms of Selection: Also, abstract evolutionary explanations do not inform us about the mechanisms of selection, that is, *how* the new phenotypic effect E leads to the selective advantage. This may be no problem for fully developed macrotraits whose function is clear; but it is much more unclear for intermediate forerunners of these traits. For example, the wings of present birds enable them to fly, and this is a clear selective advantage, but what was the selective advantage of vestigial wings in bird-forerunners who were too small to enable their possessors to fly?

The remainder of this section contains an analysis of the evolutionary explanations of *macrotransformations*. The analysis will show that, in fact, evolutionary explanations are not considered as adequate by evolutionary scientists as long as not at least some *plausible* mechanism can be given, both for the production of complex variations and for their selection. The "plausible" mechanism need not be empirically confirmed to a high degree, but it must not be *too* improbable in the given background knowledge. In this respect, the mechanisms cited in evolutionary explanations often may generate only a *how-possible* explanation rather than a full causal explanation (see Schurz 1999, 110f.).

The fundamental problem of the origin of new macrostructures by successive mutations is the apparent necessity of the passage through a *fitness valley*. One example is the transition of water-living fish to land-living amphibians and reptiles. Of course, fishes who occasionally rob with their fins in shallow water and subsequently on land suffer drastically in their fitness. So how could those fishes who supposedly evolved into amphibians have survived their first steps without God's help? The problem is illustrated in Fig. 7.1.

If the origin of a new macrotrait every time requires the passage through a fitness valley that is life threatening for the evolving species, why then have so many new macrotraits originated in the evolution, without all species having become extinct in the process? For this there is an explanatory solution, which at least in most cases, has subsequently delivered the missing explanation and thereby increased the probability of the process. It consists in the existence of specific transition forms during a macrotransformation, possessing a rudimentary antecedent of the new macrotrait, which in the given environment performs some function *other* than the later one, so to speak a *proto-function*, due to which the antecedent was already able to prove fitness-increasing.

We at first illustrate the process in the example of the evolutionary transition of fishes to amphibians. How could the transition from the fishes to the amphibians run its course, if, on the one hand, the amphibians' new macrotraits, that is, feet and lungs, would only be disadvantageous in fishes and, on the other hand, fishes without feet or lungs would die very rapidly on land?

Absolute all terrestrial vertebrates (the tetrapods or quadrupeds) descend from the ancestors of the tetrapodic bony fishes, that is, the coelacanths (of that time). In contrast to (almost) all other fishes – summarized as ray-finned fishes – these do not have vertically attached fins but similar to the feet of a vertebrate have laterally-horizontally attached front and back fins. It is assumed that the coelacanths were the ancestors of the first amphibians and "waddled" with their fins in shallow waters on the bottom of the water and close to the shore. They were able to procure food there, which other fishes were unable to reach. In doing so, they occasionally also waddled out of the water and deposited their eggs in the wet sludge outside of the water. This constituted an enormous selective advantage because there were not any predators there. During a transition period of millions of years, fins more and more similar to feet were selected as well as lung-like respiratory organs (next to the gills) for respiration outside of the water. In principle, the skin and specifically the mucous membrane are able to absorb oxygen from the atmosphere, and it is assumed that antecedents of lungs developed from an enlargement of the oral mucous membrane turned to the inside. As soon as the modified proto-amphibians were able to stay on land for a longer time, an explosion-like multiplication and diversification of the new beings on land was the consequence, as this region had so far been unoccupied and accommodated huge quantities of novel ecological niches, giving space to new life forms.

From the perspective of the early form, or the antecedent, this process is called *exadaptation*: a trait that has once been selected for other purposes assumes a different function. From the perspective of the later function, one also speaks of *preadaptation*: the trait performing the proto-function was "created in order to" fulfill a different and completely novel function later – whereby "created in order to" must not be misunderstood in the teleological or creationist sense, as if this had been planned at a higher level (cf. also Ridley 1993, 329f.). In this sense, the tetrapodically arranged fins of the coelacanths were a preadaptation for the amphibians' feet, or the latter were an exadaptation of the former. The process of preadaptation or exadaptation is ostensively displayed in Fig. 7.2. The fitness landscape is transformed by it from a roller coaster to a smooth climb.

In an analogous manner a number of additional macrotransformations could be explained:

1. *The transition from the saurians to the birds*: How did the birds develop their feathered wings? Birds originate from certain saurians. In some saurians a plumage developed with the proto-function of thermoregulation (Millikan 1989, p. 44). Meanwhile, fossils of feathered saurians of the size of contemporary

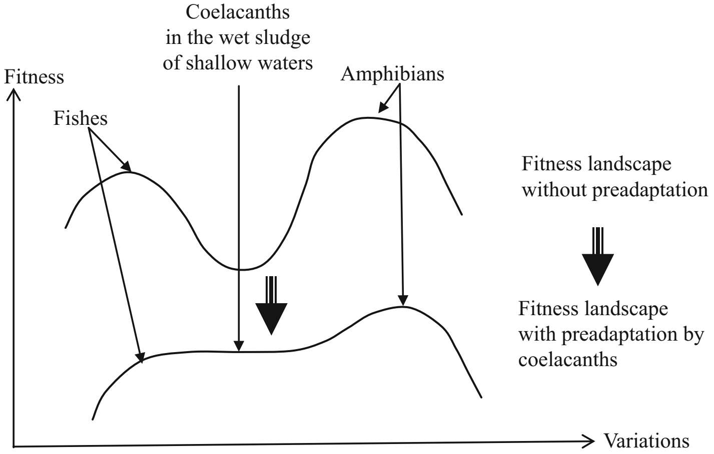


Fig. 7.2 Transformation of the fitness landscape by preadaptation (or exaptation). Transition from the fishes to the amphibians via the coelacanths

flightless birds have been found. To be sure, birds, like mammals, are warm-blooded animals and so are able to keep their body temperature high even in a cold environment, which reptiles cannot – in the case of cold, they fall into a state of motionlessness, which has possibly also been responsible for the extinction of the saurians in a cold period after the comet impact. The light skeletal structure likewise had already developed in saurians, as these due to their size are not able to move without extremely light bones. Wings could have developed from feathered flying membranes. Spreads of skin between finger or toe bones and also between body and extremities have indeed developed several times in evolution: in aquatic mammals and birds to fins and in tree-living reptiles and mammals to means of gliding from tree to tree.

2. *The origin of warm-blooded mammals*: The first mammals during the reign of the saurians have predominantly evolved to be nocturnal. With respect to the requirement of the upkeep of the necessary body temperature during the cold night, they were therefore subject to strong selection. By means of their warm-bloodedness, they were able to adapt much better to the global ice ages than the saurians.
3. *The transition from land mammals to aquatic mammals*: Whales (and later other aquatic mammals) have evolved about 50 million years ago from hippopotamus-like hoofed animals from Pakistan. During a transition period of several million years, their feet have again transformed to fin-like extremities; fossil transition forms, like the Pakicetus, are known.[4] Gills did not form again; instead, aquatic

---

[4] See en.wikipedia.org/wiki/Evolution_of_cetaceans.

mammals can hold their breath (breathed via nostrils) for a long time, but they have to surface regularly in order to breathe.

4. *The development of an adaptive brain in Homo sapiens*: The steadily growing brain of the hominids requires an increasingly longer and more risky gestation period of the embryo. A solution could have been to allow the brain to continue growing after gestation. The plasticity of the child's brain originating from this proto-function could in the following have been the basis of the development of the systematic learning ability of the brain of *Homo sapiens*.
5. *The transition from the prokaryotes to the eukaryotes*: The first one-cellular organism in evolution, the prokaryotes (bacteria, algae), consisted (basically) only of a cell membrane with RNA in it. The cell membrane of the prokaryotes was not as permeable as that of today's eukaryotes (which are cells with organelles such as nucleus, plastids, and mitochondria). The prokaryotic cell membrane rather contains *murein* as a solid supporting layer that is much more rigid than the eukaryotic cell membrane and which, in contrast to the latter, can only let through smaller molecules, but no macromolecules or even small prokaryotes. For prokaryotic cells to become eukaryotic cells being able to perform phagocytosis, that is, to swallow entire prokaryotes, the prokaryotes first had to abandon the rigid cell wall. But the rigid cell wall *protected* the prokaryotes from diverse harmful influences, while the eukaryotes' more complex protection mechanisms, like primitive perception and locomotion, were not available to the prokaryotes. The prokaryotes consequently had to first pass through a *fitness valley*, that is, become more vulnerable, in order to travel from their previous fitness peak to a still higher fitness peak, that of the eukaryotes (Maynard-Smith and Szathmáry 1995, pp. 122–126). This necessity of the passing of fitness valleys explains the long period of stagnation of almost 200 billions of years, before the level of eukaryotes could be reached and a new stage of evolutionary explosion could begin. How can the transition through this fitness valley be explained? Even today, this question is not answered. A clue is provided by the fact that there is a special group of bacteria, the archaebacteria, which were previously taken for an especially old bacterial stem species, but which according to more recent findings have more in common with the eukaryotes than with the remaining bacteria (the eubacteria), for which reason they are today considered as a sister species of the eukaryotes.[5] Archaebacteria, as opposed to eubacteria, do not possess a rigid supporting cell wall made of murein, so that their predecessors might have been the point of origin of the eukaryote evolution according to the endosymbiotic theory.

The preceding examples of evolutionary explanations of macrotransformations can be summarized as follows: evolutionary explanations are not considered as adequate unless they do not contain *plausible* (though not necessarily empirically

---

[5] Cf. Maynard-Smith and Szathmáry (1995, 125f.), Cavalier-Smith (2002), Szathmáry and Wolpert (2003, p. 272), as well as en.wikipedia.org/wiki/Evolution

confirmed) mechanism, both for the variations that are necessary to produce of new phenotypic traits or functions and the selective advantage that they conferred to the new variant. Typically this is done as follows: the macrotransformation from species S to S* are decomposed into a sequence of plausible microvariations V_1, $V_2, \ldots$, such that for every of these microvariations V_i, a plausible mechanism M_i (being based on mutation and recombination in BE) can be provided, by which the corresponding intermediate species variant acquires a selective advantage to its immediate predecessor. In conclusion, our explication (EE) of evolutionary explanation in the beginning of this section is incomplete and has to be complemented by the following third condition:

(EE)(3.) The required variations in (1.) are produced by a sequence of microvariations V_1, $V_2, \ldots$ each of which possesses a selective advantage as required in (EE)(2.) by way of mechanism M_1, $M_2, \ldots$

Let us finally ask why the problem of macrotransformations has been so intensively discussed as a problem for the theory of biological evolution, but not in the domain of cultural evolution. There is a simple answer to that. The mechanisms of variations in cultural evolution (CE) are way different from the mechanisms of variation at the biological level. Cultural variants do not appear "blindly" like biological mutations but are usually goal intended and rationally planned (cf. Boyd and Richerson 1985, p. 9). This difference does not constitute any real objection to the applicability of the Darwinian modules to cultural evolution. While technical inventions, for example, are not blind mutations, they are in a multifarious way *flawed* and *imperfect*. Thus, they are capable of a systematically optimizing selection, and this is all that Darwinian evolution requires. However, the directedness of cultural variations makes an important difference concerning the possibility of macrotransformations. In CE it often happens that a human individual *simultaneously* varies several connected but different ideas or skills in a directed manner. If this is the case, then something like a cultural "macromutation" results. For instance, with the invention of cooking on the fire, cooking stoves, cooking containers, etc., were invented at the same time. The inventors of the wagon wheel at the same time invented axles, the chassis, and roads. When Einstein postulated the speed of light as the maximum velocity of propagation, for the sake of consistency, he simultaneously replaced the Galilean transformations of velocity with the Lorentz transformations. In this way, spontaneously successful memetic macromutations, paradigm shifts, or mental subversions can indeed oftentimes occur in CE, which in BE they are very improbable. The probabilistic reason why coordinated macrovariations in CE are no longer improbable is simple: *given* the *intentions* of the intentional subjects who produce these variations, they are no longer probabilistically independent from each other (as mutations) but are positively probabilistically dependent.

References

Allen, C., Bekoff, M., & Lauder, G. (Eds.). (1998). *Nature's purposes*. Cambridge, MA: MIT Press.

Aunger, R. (Ed.). (2000). *Darwinizing culture: The status of memetics as a science*. Oxford: Oxford University Press.

Aunger, R. (Ed.). (2002). *The electric meme: A new theory of how we think*. New York: Simon & Schuster, Free Press.

Bedau, M. (1998). Where's the good in teleology? In C. Allen, M. Bekoff, & G. V. Lauder (Eds.), *Nature's purposes* (pp. 261–291). Cambridge: MIT Press.

Bigelow, J., & Pargetter, R. (1987). Function. *Journal of Philosophy, 84*(4), 181–196.

Blackmore, S. (1999). *The meme machine*. Oxford: Oxford Paperbacks.

Block, N., & Kitcher, P. (2010). Misunderstanding Darwin. *Boston Review*, Mar/Apr 2010. bostonreview.net/BR35.2/block_kitcher.php

Boyd, R., & Richerson, P. J. (1985). *Culture and the evolutionary process*. Chicago: University of Chicago Press.

Cavalier-Smith, T. (2002). The neomuran origin of archaebacteria, the negibacterial root of the universal tree, and megaclassification. *International Journal of Systematic and Evolutionary Microbiology, 52*, 7–76.

Cummins, R. (1975). Functional analysis. *Journal of Philosophy, 72*(20), 741–765.

Dawkins, R. (1976). *The selfish gene*. Oxford: Oxford University Press.

Dennett, D. C. (1995). *Darwin's dangerous idea*. New York: Simon & Schuster.

Fodor, J., & Piatelli-Palmarini, M. (2010). *What Darwin got wrong*. London: Profile Books.

Gould, S. J., & Lewontin, R. C. (1979). The Spandrels of San Marco and the Panglossian paradigm. *Proceedings of the Royal Society of London B, 205*(1161), 581–598.

Laurier, D. (1996). Function, normality, and temporality. In M. Marion & R. S. Cohen (Eds.), *Québec studies in the philosophy of science* (pp. 25–52). Dordrecht: Kluwer.

Maynard Smith, J., & Szathmáry, E. (1995). *Evolution*. New York: Oxford University Press.

Mesoudi, A., Whiten, A., & Laland, K. N. (2006). Towards a unified science of cultural evolution. *Behavioral and Brain Science, 29*, 329–347.

Millikan, R. G. (1984). *Language, thought, and other biological categories*. Cambridge, MA: MIT Press.

Millikan, R. G. (1989). In defence of proper functions. *Philosophy of Science, 56*, 288–302.

Neander, K. (1991). Functions as selected effects: The conceptual analyst's defense. *Philosophy of Science, 58*(2), 168–184.

Ridley, M. (1993). *Evolution*. Oxford: Blackwell Scientific.

Schurz, G. (1999). Explanation as unification. *Synthese, 120*(1), 95–114.

Schurz, G. (2001). What is "normal"? An evolution-theoretic foundation of normic laws and their relation to statistical normality. *Philosophy of Science, 68*(4), 476–497.

Schurz, G. (2011). *Evolution in Natur und Kultur. Eine Einführung in die verallgemeinerte Evolutionstheorie*. Heidelberg: Spektrum Akademischer Verlag.

Schurz, G. (2012). Prototypes and their composition from an evolutionary point of view. In W. Hinzen, E. Machery, & M. Werning (Eds.), *The Oxford handbook of compositionality* (pp. 530–553). New York: Oxford University Press.

Sober, E. (1993). *Philosophy of biology*. Boulder: Westview Press.

Szathmáry, E., & Wolpert, L. (2003). The transition from single cells to multicellularity. In P. Hammerstein (Ed.), *Genetic and cultural evolution of cooperation* (pp. 271–290). Cambridge: MIT Press.

Wachbroit, R. (1994). Normality as a biological concept. *Philosophy of Science, 61*, 579–591.

Wilson, E. O. (1998). *Consilience. The unity of knowledge*. New York: Knopf.

Wright, L. (1976). *Teleological explanations*. Berkeley: University of California Press.