Uroboros, or biology between mythology and philosophy
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THE LIMITS OF BIOLOGY

1. A QUESTIONS OF METABIOLOGY

From time to time, we run into discussions of a specific kind and into questions and answers such as following:

- In a discussion on Nessie: Can you *guarantee* that there is no dinosaur left in Loch Ness? Whereupon the answer might well be: Well, to guarantee the non-existence of an animal transcends the limits of biology.
- In a discussion on Descartes' machine theory of organisms: Do we really *know* that animals feel pain? Does such a claim not go across the limits of biology (or of natural science, of science in general)?
- In discussions on man's place in nature: The evolutionary ladder, the phylogenetic tree, the traditional *scala naturae*, or simply complexity considerations, show that man is *superior* to all other living systems (and all the more to inanimate systems). Do we, in making such *evaluative* statements, again trespass the limits of biology?
- As a final example, take the question: Are we *obliged* to preserve on Earth as many species as possible? Can such an obligatory claim be justified by biology, or does that go beyond the limits of biology?

In all these cases we seem to run into "the limits of biology", into areas where biologists are no longer competent. What are these limits?

Questions such as these, though posed by biologists are not genuinely biological questions; at least, they are not answered by way of biological methods, let's say, by outdoor observations or by experiments in a bioscientific laboratory. Questions as to the character of a discipline are rather part of *metascience*, here of philosophy of science. Hence our considerations will be less biological than metabiological.

2. WHERE THE LIMITS DON'T LIE

In trying to specify where the limits of biology do in fact lie, it might be worthwhile first to point out where they do *not* lie. The limits of biology do not lie where, for some time, they have been supposed to lie: *biology is not imperfect physics.* Philosophy of science has started mainly from physics as the paradigmatic science and was tempted to extend the standards developed there to all sciences. From this perspective, biology could indeed appear as a rather dubious discipline:

- the set of its objects and, therefore, the area of applications is markedly smaller that of physics and of physical laws
- biological laws are much more difficult to find than physical ones
- most biological laws seem to allow for exceptions, they are not universally valid even in the field of competence of biology
- explanations are less compelling, and many evolutionary facts don't admit of any explanations at all
- predictions are difficult, in some cases even completely impossible; therefore biological theories can be confirmed, but hardly refuted; according to Popper's of falsifiability
- a good empirical theory must be prone to be refuted by experience
- biology, and first of all evolutionary biology, would offer nothing but a metaphysical research programme
- biological theories are less mathematized and less axiomatized than physical ones.

If this characterization were correct and taken seriously, the limits of biology would be determined by the degree to which it meets the standards of physics. Seen from this perspective, biology would appear as a rather questionable science. This perspective, however, is not the only possible one and, above all, not the only correct one. What could prevent us from turning the table and looking at physics as "lifeless", as "dry", as poor in details, or as awfully abstract? If measured by the numerosity of its object classes, biology is even superior to physics.

By this symmetrization, I don't propose the opposite evaluation, but rather caution against such ratings in general. Only then shall we be able to see and to value the methodological autonomy of biology. And only then will we able to properly assess the *limits* of biology.

3. DIFFERENT KINDS OF LIMITS

A discipline may be limited in several ways. There might be

- theoretical-cognitive limits ("What can we know?")
- limits of curiosity ("What do we want to know?")
- practical-technical limits ("What can we do?")
- ethical-moral limits ("What are we *allowed* to do?").

These limits are not independent of each other. We may distinguish them though not separate them. What we produce, change or prevent, very much depends on our knowledge; and technical progress is, vice versa, a pacemaker for scientific progress. And very often moral limits are recognized and felt only if knowledge and power have reached a certain threshold. This entanglement notwithstanding, we shall try to treat our four questions separately.

We might also ask to what extent the limits of biology are, at the same time limits of physics, of natural science, of empirical science, of science in general, or of any rational enterprise. It would turn out that most limits of biology apply to, are even characteristic of, all science. But we won't dig too deeply into that problem.

4. DOES BIOLOGY OFFER CERTAIN KNOWLEDGE?

We might as well extend this question to the more general one whether there is certain knowledge at all. Since we shall deny this question, we need not consider biology separately.

For centuries, people were convinced that certain knowledge existed. Many pathways seemed to lead there: holy scriptures or religious dogmas, divine revelation or Platonic vision, evident axioms or valid inferences, innate ideas or synthetic a priori judgments, experience and reason, observation and experiment, induction or deduction.

All that times, however, there were also skeptics questioning the possibility of certain knowledge. More and more roads to knowledge were found uncertain, subjective, or impassable. Nowadays, the appeal to superhuman authorities appears irrational or dogmatic; intuition and evidence cannot be guaranteed to be intersubjective; and sensory illusions and mass psychoses would depreciate our sensory evidence even if it were intersubjective. Logic and mathematics are structural sciences that owe their certainty – as far as they exhibit such certainty at all – precisely to the fact that they don't even try to describe the world. Success and corroboration don't warrant truth, since occasionally even error may lead to success. Inductive inferences are not necessarily truth preserving; supposed laws of nature often prove to be false; and synthetic a priori judgments don't seem to exist.

The arguments for or against the existence, or at least the possibility, of unshakable knowledge cannot be presented here. 2500 years of epistemological critique, however, seem to teach on thing: *certain knowledge about the world doesn't exist*. Whenever we try to find definite proofs, ultimate foundations or final justifications, we find ourselves caught in the notorious Munchahsen trilemma, this triple impasse of logical circle, infinite regress and dogmatic break-off. Knowledge in the traditional sense, certain knowledge about the world, ultimate foundations are utopian ideas; all approaches to realize them have failed with sobering regularity.

Biology can't help that. As all science is fallible, preliminary, tentative, or hypothetical, biological knowledge is likewise. From this insight we should not, however, conclude, that scientific knowledge, being uncertain, is just speculative and therefore worthless. Between certainty and mere speculation there is a wide spectrum. Philosophy of science tries to specify criteria by which theories should be judged and by which rational theory choice is rendered possible. Here necessary and desirable criteria may be distinguished. Necessary features of a good theory in empirical science are non-circularity, consistency, explanatory power, testability and test success; desirable are, in addition, simplicity, visualizability, scope, depth, completeness, precision, axiomatizability, applicability and others. Though all these criteria are not sufficient to secure the certainty of scientific knowledge once dreamed of, they can nevertheless serve to mark out scientific hypotheses as admissible and successful, even as *reliable* or trustworthy.

5. WILL BIOLOGY EVER BE COMPLETED?

Certainty and completeness are different properties. Even if biology does not yield *certain* knowledge, it could still solve all its problems by *preliminary* answers. But even that will never be the case.

Objects of biology are not only plants and animals living now, but also all their phylogenetic forerunners. Therefore, a complete biology should embrace not only descriptions of what there is, but a reconstruction of phylogeny as well. How and why did those highly complex organisms which we find now, and which we represent ourselves, originate? How did every species, every organ, every tissue, every function, in short every organismic trait come into being? And why? All that would have to be asked and answered by a complete biology.

But there are two million different living species, and even they represent, according to serious estimations, only one percent of all species which ever existed on earth. To describe and to explain phylogenetically two hundred million species with so many traits and combinations of traits is evidently a task that can't ever be performed. A phylogenetic explanation not only requires a description of the evolutionary *path* following which a specific trait originated, not only all initial and all intermediate steps, it must also exhibit the prevailing *selective conditions*, the species- and gene-preserving *functions* of all such traits, including again, their respective initial and intermediate stages.

Thus, biology will never be complete in this sense. This is true even if physics should come to such a closure. This fundamental incompleteness of biology might be looked at as an advantage or as a disadvantage: as an advantage because, for biologists, the stuff from which questions are made (*der Stoff, aus dem die Fragen sind*) will never be exhausted, as a disadvantage because research in biology is a Sisyphean task. Meanwhile at least, it doesn't seem that the science of life could become boring.

6. DOES BIOLOGY PROVIDE ULTIMATE EXPLANATIONS?

One of the most important aims of science is to give explanations. Explanations of what? Explanations of all facts which seem to be in need of explanation. Now, what are explanations? Occasionally we are told, to explain something means to reduce it to something familiar. This is not always true. Sometimes – and these are just the great moments of science – scientists frame *new*, so far unheard of, hypotheses by which they then manage to explain either new facts, or facts well known but hitherto unexplained. Thus, Thomas Hunt Morgan explains many facts of inheritance by using Johannsen's *new* concept of 'gene' and, above that, by framing *new* hypotheses with regard to such genes. And Watson and Crick, by introducing the so far *unknown* or at least unidentified double helix, are able to explain the observations of X-ray diffraction and many more findings. Such explanations are then reductions to something unknown.

Known or not – obviously every explanation not only contains what is explained (the explanandum), but also something by which it explains (the explanans), something to which the explanandum is reduced. The explanatory part – mostly a combination of general laws and special initial and boundary conditions – may then, on its part, become the object of why-questions, hence of deeper explanations. Obviously, there may exist chains, nets, and hierarchies of explanations in which one or more elements serve the purpose of explaining others.

May such a chain, may such a net end somewhere in an natural way? An *infinite* continuation is impossible for practical reasons. And an explanatory *circle* making recourse to facts which are already found to need explanation themselves, would be logically fallacious, a typical vicious circle. An ultimate explanation, then would be one whose explanans neither needs nor allows for further why-questions. [In philosophy of nature, we could also ask for an *ultimate cause*, for a cause which doesn't have or need any further cause if, for instance, it could be its own cause (*causa sui*).]

There is, however, no fact and no factual claim where the why-question would make no sense. Ultimate explanations are therefore impossible, and biology cannot supply them either. It may be that we are not interested in a further explanation; it may be that we don't succeed in finding it although we are interested; and it may be that the explanandum is purely accidental and therefore unexplainable. For whatever reason we have no further explanation, ultimate explanations do not exist.

And yet, biologists talk about "ultimate causes"! How come? The meaning of 'ultimate' is quite different here. *Ultimate* causes in this sense are opposed to *proximate* causes. Proximate causes are, as a rule, physiological *mechanisms*, and proximate explanations make clear how – on the physiological level – a trait is realized or a function is performed. An organismic trait is an *ultimate* cause if it has survival value for the organism (or for its genes), if it enhances its fitness, if it is *functional*.

Whereas physics doesn't care for functions, biology does. Thus we may say paradoxically enough that although there are no ultimate explanations in any science, in biology there are. This is due to the ambiguity of 'ultimate'. It would be preferable to use the word 'teleonomic' and to talk about teleonomic explanations. But since Julian Huxley proposed the ultimate/proximate distinction and since Ernst Mayr made it popular, there is little hope that biologists will change their vocabulary.

7. ARE THERE FACTS UNEXPLAINABLE BY BIOLOGY?

We did stress that with respect to every fact the question "why?" is perfectly legitimate. From this pervasive legitimacy it does not follow that we always know the answer. Are there facts which are described, but not explained, by biology? Such facts do indeed exist. We may divide them into three groups.

The first group comprises facts which are explained not by biology but by another discipline. Thus, not only physicists search into the origin of stars, but likewise biologists search into the origin of living systems. However, whereas physicists give a *physical* answer to their star question, biologists don't get a biological answer to their life question. Genetics and developmental biology, it is true, explain (tentatively) how from individuals new individuals arise, and the theory of evolution explains (tentatively) how from species new species arise. But how the *first* organisms could or did arise, they don't explain. They are unable to do so because they *presuppose* the existence of living systems, of species, of life. Evidently the first living systems could not originate of living systems (because then they would not have been the first ones), but only from non-living systems. And to non-living systems the laws of biology do not, of course, apply yet. Therefore, the origin of life can and will be explained, if at all, only by physics and chemistry. In view of the usual and useful division of labor between biology and physics (on which later), this limitation of biology is easily understood and easily tolerated.

The second group of unexplained facts embraces *chance events* and their consequences. Chance events have no causes and, therefore, no explanations. (The phrase "this can only be explained by chance" must, if permitted at all, be understood metaphorically.) It is true that chance events are, as a rule, not completely lawless; they obey statistical laws. Such laws are, however, applicable only to whole classes of events. They cannot explain singular events.

In biology chance events play a constitutive role. The immensely large number of existing species, and even the totality of all living systems having once existed or existing now, is still forbiddingly small compared to the number of all the different organisms which could exist in principle. From the huge spectrum of possible living systems only a minute fraction will be realized even in the farthest future. How are the systems to be realized selected from the domain of the possible ones? We know that the selection occurs under the constitutive influence of several *chance factors*: undirected mutation, fluctuations of population size, random recombinations of genes. Thus biological systems always exhibit accidental aspects which cannot be described, explained or predicted by deterministic or probablistic laws. Therefore, the limits of repeatability, explainability and predictability are much narrower in biology than in physics. That evolutionary biology could not make testable predictions at all (as, following Popper, some people claim) is, however, not true.

The third group of unexplained facts has been discovered only recently. This is the behavior of *chaotic systems*. A system is called chaotic if *arbitrarily small* alterations of the initial conditions may lead to completely different behavioral results. This is also possible in deterministic systems (deterministic chaos), especially if the system exhibits, as organisms usually do, feedback and hence nonlinear behavior. Since every measurement is inaccurate to a certain degree, the future of a chaotic system is not always predictable and very often not even explainable afterwards. Just as if nature wanted to compensate for that, chaotic systems open up the *chance* that, despite their fairly chaotic behavior, they might still be described or even understood, at least qualitatively, by deterministic laws. Thus, paradoxically enough, even chaos brings order to biology!

Chaotic behavior could prevail in cell-to-cell contacts, in embryogenesis and, more generally, in morphogenesis, in protein interactions, in the formation of patterns, especially of spirals (sunflower, pine cones, leaf arrangements), in the formation and perturbation of physiological rhythms, in processes in the brain and in the central nervous system, as well as in some illnesses, e.g. in cancer, and finally in whole ecosystems with their characteristic stability problems.

8. LIMITS OF UNDERSTANDING

The concept of understanding has many facets.

We may, first of all, understand linguistic expressions: words, sentences, theories. We understand a *word* if we understand its meaning. (We don't define 'meaning' here.) We understand a *sentence* if we know the words occurring in it and if we know which relations it establishes between them, hence if we know, what it claims, states, commands, asks, and so on. We understand a *theory* of empirical sentence if we know the words occurring in it and if we know which relation it establishes between them, hence if we know, what it claims, states, commands, forbids, asks, and so on. We understand a *theory* of empirical science, e.g. the theory of heredity, if we understand its main concepts and propositions and if we know which problems it solves and to what degree it solves them better, or worse, than competing theories. It is obvious that for this kind of understanding there may be limits; however, they do not particularly concern biology and will not be further discussed here.

Apart from linguistic expressions, we also try to understand real systems. For *non-living* systems, 'understanding' is essentially synonymous with 'explanation'. I understand an *object*, e.g., a carbon atom, if I know its special properties, and if I can describe and explain these properties, especially its properties and its behavior. Sometimes, however, we also want to know how a carbon atom comes into being, perhaps even how it can be manufactured. I understand a *process*, e.g., a sun eclipse, if I know and why it occurs and why it occurs by that way and not differently.

In *living* systems, we must add to these properties their *functional* traits. I understand blood circulation if I can not only explain it, but if I also know what it is good for, which function it has, how it secures or enables the organism's survival. In that sense we may also understand plants and animals. Here again, the limits of understanding coincide with the limits of explanation (functional explanations included). And *complete* understanding where nothing would be left to ask is as unattainable as are ultimate explanations.

In the interhuman area, however, we use a still more ambitious concept of understanding. To understand a *human being* obviously means more than to know and to explain his or her life-serving functions. We know about ourselves that, over and above all that, we do have ideas, memories, intentions, motives, feelings, emotions. There, we have *direct* access at most to our own mental states and processes. We are, nevertheless, ready to ascribe such "mental life" to other humans as well. Therefore, I understand a *human being* only if I also know her inner states, especially her feelings and motives. I understand his *actions* if I know his motives, that is, if I know the wishes and aims that made him act. Sometimes, we even feel that, in order to understand somebody, we should duplicate his or her feelings.

Doubtless this understanding has *limits*. Sometimes, we don't even understand ourselves. It is even more difficult to put oneself, so to speak, into the thoughts and feelings of other people to have, in a verbal sense, fellow-feeling, com-passion, or sym-pathy. Strictly speaking, we can never know for certain what another person is feeling or thinking, not even whether she feels or thinks at all. At any rate, we cannot prove it. But, as we know, I cannot even prove, to you or to me, that I existed already yesterday. Therefore, from these considerations *no specific limits* follows for interhuman understanding. It can always be increased and improved upon.

9. DO WE UNDERSTAND ANIMALS?

The motives which induce us to other *human beings*, all lie in their behavior: in their gestures, in their facial expressions, in their nonverbal utterances, and of course in what they say. In doing that we make the obvious conjecture that if their behavior is similar to ours, similar inner states and processes are at work. This inference by analogy is, as we surely know, not conclusive; it is, nevertheless, one of the scientist's standard tools. In the case of interhuman behavior, it is so natural and subjectively inevitable that Karl Bühler and Konrad Lorenz liked to speak of a *Du Evidenz* (the evidence of a thou): we cannot help seeing in our human *vis-à-vis* another person with intentions, thoughs, and feelings.

Quite independently, this inference by analogy is strongly supported by our knowledge about our biological relatedness and about the similarity of our brains and nervous processes. Since there are – due to age, sex, race or culture – varying degrees of similarity, our understanding of fellowman and fellowwomen reaches varyingly far.

In a weaker form this arguments apply to our relation with animals. It is true, they cannot talk to us, they don't communicate with us in our language; but there are even human beings where this is not possible, and, what is more, language is not only access to others, hence not always necessary. With animals we share the environment, with the higher animals moreover a long evolutionary past. Our sense organs and central nervous systems are phylogenetically related and therefore similar to varying degrees. The longer our common history is, the latter the phylogenetic ramification has taken place, the greater are our similarities and, therefore, the chance for sympathy, for understanding.

There is no serious doubt, then, that higher animals may suffer and feel pain. In discussion about experiments with or cruelty to animal, about keeping animals in cages or hens in batteries, the problem is not whether animals may suffer; we think we know that, and as biologists we think we can show (though not prove!) and explain it. Therefore we must check how we may diminish or *prevent* such suffering. Here again the biologist, especially the neurobiologist, is qualified: (s)he can judge whether an experiment with animals will sufficiently advance our knowledge, whether a simpler organism would do, whether a living animal is really needed, whether there is a more considerate treatment, whether narcosis, local anesthesia, or nerve cutting might bring relief to animal. First of all, however, it must be clear whether and how far we are ready to *put up* with animal suffering in view of our other goals and values. This ethical or moral question cannot be answered by the methods of biology alone. Nevertheless, the biologist's knowledge and competence plays a decisive role in such a discussion.

10. LIMITS OF CURIOSITY

Curiosity and playfulness are vital drives in higher organisms, especially in man. They are essential because they make individual *learning* possible. Thus, environmental conditions and, even more important, environmental changes to which genetic programming could never prepare us, are easily mastered. Curious and playful are, first of all, the youngsters. Man, however, distinguishes himself from all animals by staying curious and open to the world up to his greatest age. Looked at from ethology, man keeps a typical juvenile trait even as an adult. (Therefore Konrad Lorenz, borrowing from zoology, liked to use the term "neoteny".) 'Homo ludens' (Huizinga) is not the only appropriate characterization of man, but nevertheless quite to the point. Even science owes its existence to human curiosity. And since there will be human beings again and again, who want not only to learn known facts, but to discover new things, human curiosity in this sense is *without limits*.

Biologists, however, are wont to think in cost-benefit relations. Even if our curiosity is unlimited, it may cost more and more to satisfy this curiosity. In fact, scientific progress becomes more and more expensive. Scientific discoveries may be likened to the treasures of the soil: nearly all raw materials which could easily be gained have been used up by now, especially those on the surface of the earth. In order to get more of them, we must dig deeper and deeper. Likewise, in science nearly all *simple* discoveries have been made such that further progress needs more and more education and more and more technical tools. Therefore it could perfectly happen that the satisfaction of our curiosity would not compensate for the respective costs. In his book "The paradoxes of progress", the molecular biologist Gunther Stent calls this effect the "principle of diminishing return". Economists know that phenomenon as "marginal utility". Even in biology with its inexhaustible wealth of unsolved problems it could happen that we stop fundamental research, not for moral reasons but for cost-benefit considerations. This crucial point is far from being reached, and it is even impossible to say exactly where it is situated. Moreover, it may be shifted by changing practical needs and by the extension of our technical abilities. But it certainly exists.

11. LIMITS DUE TO USEFUL DIVISION OF LABOR

As we have seen, biology has a *richer* spectrum of questions than physics. We could as well express this fact by saying that physics *limits* itself in its questions. That organismic structures support the survival of an individual, of its genes, or of a species, and that they are *useful* in that sense, cannot, of course, escape the physicist. Even so, physics does not use or introduce concepts like function, utility, fitness: they are reserved to biology. The reason is not that physics couldn't say anything about organisms. The physical laws are not restricted to nonliving objects. If an organism could violate the law of gravitation or the conservation of energy, then these laws would be false; they are claimed to be *universally* valid.

This, then, is the decisive difference between physics and biology: physics investigates *all* real systems, nonliving and living ones, and it searches for laws which apply for *all* these systems. Those phenomena, however, which are found only with organisms, and those laws which apply only to them, are traditionally reserved for biology. One limit of biology which is historically conditioned lies in the fact that it does just not care for nonliving systems.

This limit, however, is not fixed once for all. For, which systems are alive, or even better, which systems are *said* to be alive, is itself dependent on new discoveries and useful conventions. When it was found out recently that RNA molecules may replicate, biochemists were still free to regard these molecules either as *living* (because they can replicate) or as *nonliving* (because they don't evolve to higher systems). Language and intuition cannot anticipate such a decision because they are not "tailored" for such borderline cases.

A similar division of labor as that between physics and biology (or more precisely: between chemistry and biology) obtains between biology and psychology. Again it is impossible to draw a sharp line between these two disciplines: when comparative ethology was still in its beginnings, it was, tellingly enough, called 'animal psychology', operating precisely in the open area between biology and psychology, hence in the former no man's land between the natural sciences and the humanities. It is, however, usual and *suitable* that biology *restricts* itself to scientific methods and, thereby, to such traits which are common to all or many organisms, traits, which can be objectified and which can be investigated without introspection (although the latter might be useful even there). Just as physics investigates and applies to living systems, biology also investigates organisms with consciousness (including man), but no mental phenomena as such. Yet again, such concepts as conditioned reaction, learning, aggression, or the existence of a discipline like psychobiology, show that a rigorous borderline between biology and psychology does simply not exist.

12. LIMITS DUE TO WISE SELF-LIMITATION

Obviously, biology as a natural science – and even more general: as an empirical science – excludes certain questions which are asked elsewhere. Questions as to the purpose of the universe, to the goal of being, to the meaning of life, to a creator or ruler of the world, to the roots of validity, or to moral justifications, are not only not answered in biology: they are not even posed there. Inside empirical science, questions are legitimate only if they concern *facts* and if they have at least a *chance* to be answered in the framework of the methods of empirical science.

Again, the borderline is not sharp. In fact, the methods of empirical science, its material and mental tools, its aims and claims, its domains of competence and of application, have drastically changed in the course of time. Isaac Newton (1643-1727), the creator of physics as a science, was still convinced that from time to time God must fix the planetary system in order to preserve it from instability and collapse. The French physicist Maupertuis (1698-1759) interprets the newly discovered extremal principles of mechanics as scientific evidence for the activity of a wisely planning creator and as a physical instantiation of Leibniz' thesis that this world is the best of all possible worlds. And far into the 19th century, the stunning adaptation of organismic structures is looked upon as a visible sign of an ordering hand. Not until Charles Darwin (1809-1882) is this "teleological proof for the existence of God" dismantled, the observed adaptation of organisms now being explained from inside biology, first of all by natural selection.

Thus, whereas the borderlines between biology and the neighboring sciences – physics, chemistry, and psychology – are blurred more and more, the borderlines between biology and metaphysics, biology and theology, biology and ethics, have become even sharper. It was finally recognized that the relations supposed or at least hoped for did just not exist and that the empirical sciences owe their success to this very self-limitation.

Thus, the claim appears reasonable that the empirical sciences have been successful by fine-tuning both the admissible *questions* and the *methods* permitted in answering those questions. All this does not mean, of course, that the disciplines characterized here as different and separable, had nothing to do with each other. To the peculiar relation between biology and ethics we shall come back.

13. LIMITS OF FEASIBILITY

There is no doubt that the quest for power is – besides pure curiosity – the main motive for the scientists. Often enough, practical needs, possible applications, technical progress, "social relevance", determine the interests of scientists and, first of all, of their financiers.

Nevertheless, man can obviously not do all he wants to do (quite independently of the question whether he can *desire* what he wants to). Where are the limits of feasibility, where do they lie in biology?

One important limit is set by the laws of nature. Laws of nature are (or describe) regularities in the behavior of real systems. They tell us what, under specified conditions, will happen. Other kinds of behavior are then, given the same conditions, impossible. Therefore, we may as well interpret the laws of nature as impossibility statements: the law of energy conservation implies the impossibility of a perpetuum mobile; from the law of entropy increase it follows that heat cannot "of itself" pass over from cold to warm; and according to Nernst's heat theorem (the third law of thermodynamics), it is impossible to reach the absolute zero of temperature. Similarly it is, according to Hardy-Weinberg's law, impossible to eliminate a recessive hereditary disease by removing all pure disease carriers. Since, however, all knowledge is preliminary and fallible, we cannot exclude such possibilities with absolute certainty. Even a law such as the conservation of energy, well-tried, never refuted and intimately interwoven with all empirical science, could in principle turn out to be false. Thus, even claims to the impossible are endowed with the proviso of possible errors.

On top of that, many claims to the impossible have turned out to be erroneous in the history of science. Thus it was claimed that men could not live above 3000 meters (Cauchy), that the chemical composition of stars could never be found out (Comte), that aeroplanes should be impossible (Siemens), that rockets could not accelerate in empty space ("New York Times"), that organic substances could not be synthesized from inorganic ones (vitalism), and so on. All these assertions on supposed impossibilities, on supposed limits of feasibility, were found to be erroneous.

This negative score should warn us. We may confidently declare impossible whatever contradicts the laws of nature; what is, however, possible or impossible inside the framework of natural laws, is quite difficult to determine. Will it be possible to clone human beings? To grow a mammal completely outside a placenta? To synthesize a whole organism from inanimate matter? To decode completely the human genome and to modify it deliberately? To cure hereditary diseases, to eradicate AIDS, to prevent cancer? There are no laws of nature which would exclude in principle such possibilities. Our knowledge is limited, especially our knowledge about the future of our knowledge – and of our abilities.

In the long run, however, the decisive question will not be what we are able to do, but what we are allowed to do.

14. BIOLOGY AS A "SCIENCE OF THE CENTURY"

"Die Jahrhundertwissenschaft" ("The science of the century") is the title of a book by the German historian of science Armin Hermann. As we might expect he presents *physics* as the most important science of our century. Physics was indeed decisive for the *first* half of our century. In 1900, Max Planck laid the foundations for quantum theory, possibly the greatest revolution physics has ever seen. The first half of our century ends with the use of nuclear reactors on the one side, of nuclear weapons on the other.

For the *second* half of our century, however, *biology* seems to be the dominant science. In 1953, Watson and Crick find the double helix, and molecular biology has made unforeseen progress since. And again we feel that the second half of our century also ends with rather ambivalent progresses, this time of applied biology.

In 1978, another German author, Jost Herbig, opens a book on genetic engineering with the following words: "Biology has reached the critical stage of a science: it is constructing nature. The age of synthetic biology has now begun". Perhaps it is this what makes a science a 'science of the century': it constructs nature. Then we could even predict the sciences of the next, of the 21st century: the neurosciences. Will they also construct nature, will they change human beings, will they create brains, will they become synthetic sciences? And will there then ensue another bad awakening? Sciences of the century seem to distinguish themselves by being highly celebrated at the beginning and deeply damned at the end. How come?

The answer is, I suppose, very simple. For thousands of years, man could not do much more than was allowed. In the last centuries, however, the natural sciences developed very fast, even explosively in our century. Along with human knowledge human power increased; whereas what was permitted did not change essentially. Thus, human power by far outgrew what was allowed, and this is a *qualitatively new situation*.

For centuries, it seemed quite unobjectionable for a researcher to satisfy without restraint his or her thirst for knowledge. The purity of science virtually consisted in ranking truth above all and not caring for applications. Indeed, as long as there were no dangers combined with it, truth rightly could be seen as the upmost good. Warning hints as the biblical tree of knowledge, the magician's apprentice in Goethe's poem, or Mary Shelley's Frankenstein, could be attributed to a far future.

This has now changed. The knowledge of mankind has opened new possibilities which go far beyond the satisfaction of urgent needs. We create means and tools that can be used for the weal and woe of mankind. (S)he who nowadays strives just for truth, is looked at as irresponsible. Thus, science meets with *limits* which formerly were knows but not felt. What should we do about that?

15. BIOLOGY DOES NOT SUPPLY MORAL NORMS

It would certainly be wrong to forbid all research whose results could *possibly* be misused. We can say quite clearly and shortly what then would remain of science: nothing. Even mathematics can be applied, and even the prime numbers, innocent as they seem to be, are of practical and even military use in modern coding systems.

It would also be misguided to look for values and for norms in the empirical sciences themselves or to try to derive them from scientific findings. Pure norms cannot be gained from pure facts. If you try to do it anyway, you commit the naturalistic fallacy. From the fact alone that a specific behaviour has come out from and has been *successful* in evolution. It does not allow, for instance, that it were *good* or *right*. What is *natural* is not automatically *right*.

That descriptive statements alone are not sufficient to yield normative ones, has been thoroughly investigated by logicians and has been shown with sufficient rigor. As we have stressed already, biology, and science in general, owe their success to their self-restriction to the factual and to the fine-tuning of their questions to what is methodically attainable. Being an empirical science, biology is not able to investigate or to yield moral norms; they simply don't lie in its task domain nor in its competence.

Even those norms scientists normally adhere to in their research activity are not sufficient for a general ethical orientation. It is true that the "ethos of science" is exemplary in several respects: it asks you to aim at truth, at objectivity, at precision, it requires symmetrical argumentation, criticizability, internationality, and so on. It is, however, only a *partial* ethos which is not sufficient for the regulation of personal or political relations. That's no wonder: the upmost value of the ethos of science is knowledge; for this it is suitable, and here it is successful. Other values like justice, liberty, or love, are just irrelevant to the ethics of science. Thus moral norms can be gained neither from the results nor from the normative behavior of the natural scientist. Having stressed this, and having thereby identified another limit of biology, we could stop right here. But we want to go step further.

Man as a social being is absolutely dependent on social norms. Where can, where should he take them from? Should they be supplied or even prescribed to him by others? Should he listen to the priest, to the philosopher, to the lawyer, to the politician? Can someone outside tell the gene technologist what (s)he should or should not do?

This way is sometimes comfortable, but not advisable. The slogan of enlightenment is *self-thinking*. It is all right to listen to the arguments of others; but decisions are everyone's own matter. Yet a responsible decision needs both factual knowledge and moral orientation. Where do they come from and how do they interact?

16. FACTS AND NORMS

From facts alone no norms can follow. Therefore a biologist, searching for practical directives will not get along with biology alone. *Without* factual knowledge, however, things don't work either; it is for this very reason that normative approaches starting from "purely" philosophical positions tend to be far from the mark, being too general, too abstract, too ivory-towered.

What we need are, first of all, one or several *basic norms*. They are, on their part, not justified; ultimate justifications (of norms) are no more feasible than ultimate explanations (of facts). We may hope, however, to meet with unanimous approval for such basic norms. This assent cannot be extorted by way of argument; it can only be stated. From these basic norms more norms are derived *by adding factual knowledge*.

An example might illustrate that point. Suppose we had come to commonly accept the following norm as basic: "We should take care that future generations are not worse off than we are!" (This may be debated; but we must start somewhere.) This norm alone does not prescribe any specific action. Now factual knowledge will inform us that the world population is increasing and that with growing world population the living conditions will deteriorate. (This may again be debated; our issue here is, however, not the *correctness* of factual claims, but rather their *role* in the gaining of moral norms.) Combining now our basic norm with our pertinent factual knowledge, we may derive the norm that we should not multiply further. In combination with additional knowledge about the possibilities of birth control (especially about contraception) more, and more concrete, norms can be derived.

Both parts – basic norms and facts – are indispensable here for the derivation of norms. Therefore the interplay of facts and norms should not be seen *additively*, such as if every term of the sum could already offer something. It should rather be interpreted *multiplicatively*: if one of the two factors is nil, the product is also nil – we have nothing then. Only if both elements are combined in an adequate manner, can the result be "positive". Of course, there are more possibilities to combine elements constructively: we may multiply matrices, or cross-breed animals. Multiplication is, however, the simplest model for the co-operation of facts and norms and for their being dependent on each other.

This consideration should make clear what the scientist's genuine contribution to the establishing of norms consists in: (s)he provides the factual knowledge necessary for the derivation of more norms from basic ones. Both this knowledge and these basic norms are *indispensable*. And only our insight into the moral limits of biology enables us to see in its true light the constitutive role of biology even for ethical-moral norms.