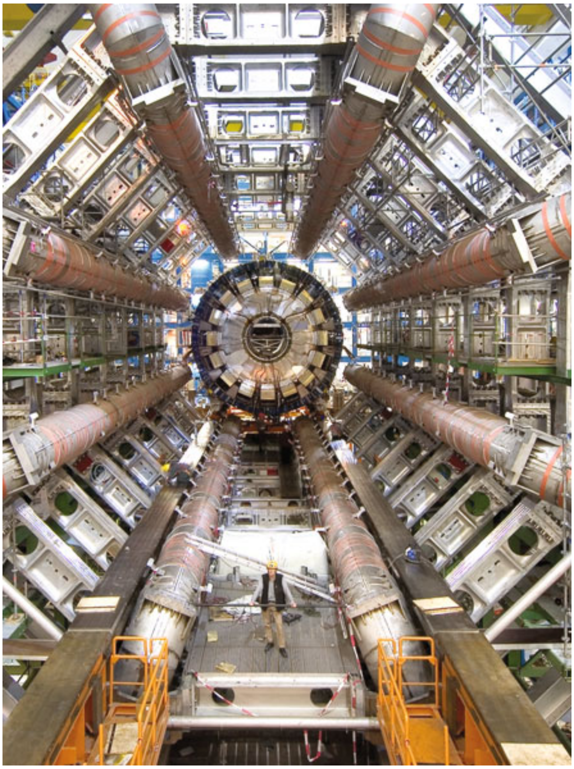
Chapter 2
Are There Unsolvable World Enigmas?



With the help of huge machines, science endeavours to wrest the last secrets from Nature. The photograph shows the large accelerator at the European nuclear research centre CERN, which is designed to simulate processes that presumably took place at the origin of the universe. Can we hope to understand some day the existence of the world, or does the origin of all things confront us with an unsolvable problem?

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2.1 The "Ignorabimus" Controversy

The physiologist Emil Du Bois-Reymond was one of the great scientific personalities of the 19th century. He is best known to specialists for his electrophysiological studies of muscle and nerve excitation. Beyond that, he was also passionately involved in debating the broad social and philosophical questions of his time.

In conformity with the scientific *Zeitgeist* of the late 19th century, Du Bois-Reymond was a committed adherent to the mechanistic world-view, according to which the ultimate goal of knowledge of Nature was to demonstrate that all events in the material world could be traced back to movements of atoms governed by natural laws. Every natural process—that was the credo of the mechanistic maxim—rests ultimately upon the mechanics of atoms.

For Du Bois-Reymond, the rise of the natural sciences in the 19th century represented the epitome of cultural progress. This led him to formulate the provocative statement that "the real history of mankind is the history of the natural sciences" [2, p. 134]. It must therefore have appeared all the more contradictory when at the same time Du Bois-Reymond claimed, with almost missionary zeal, that certain world problems could never be solved by the natural sciences. Here, he was referring especially to humanistic issues. These, he maintained, could never be explained within the framework of a mechanistic view of Nature, because feelings, emotions and thoughts were fundamentally incapable of being naturalised and therefore could not be explained in terms of the mechanical laws of non-living matter.

By propagating this view, Du Bois-Reymond contradicted an idealised view of mechanistic Nature that went back to the mathematician Pierre Simon de Laplace. At the height of the mechanistic age, Laplace had conjured up the vision of a universal mind that, with the help of the mechanical laws and complete knowledge of the momentary state of the world, would be able to calculate all its future and past states. Nothing remained hidden from Laplace's "universal mind" in the transparent world of mechanisms. Even human thoughts, emotions, actions and suchlike were calculable in principle, as—according to the mechanistic world-view—all mental phenomena were merely particular expressions of material properties.

For Du Bois-Reymond this radical view of the mechanistic maxim was untenable. He was deeply convinced that mental phenomena were immaterial in nature, and for this reason were fundamentally inaccessible to any mechanistic analysis. The attainments of the human mind, he asserted, could in reality only reach a level that was a pale reflection of Laplace's Universal Mind. Notwithstanding, even this was subject to the same limitations as we are, so that the unsolvable riddles that tantalised human thinking would also be impenetrable for the Universal Mind.

In a famous speech, given to the Convocation of German Naturalists and Physicians, Du Bois-Reymond listed "seven world enigmas", which he considered to be unsolvable [1]:

1. The nature of force and matter,
2. The origin of movement,
3. The origin of life,
4. The apparently purposeful, planned and goal-oriented organisation of Nature,
5. The origin of simple sensory perception,
6. Rational thought and the origin of the associated language,
7. The question of free will.

Some of these issues Du Bois-Reymond regarded as "transcendent" and therefore unsolvable. Among these, in his view, was the question of the origin of movement. Other problems, such as the origin of life, he regarded as solvable, but only insofar as matter had already begun to adopt movement. However, Du Bois-Reymond saw the seven world enigmas as progressing upwards, each dependent upon its predecessors in the list; consequently, the sum of all these seems to constitute a coherent, fundamentally unsolvable complex of problems. In that sense, he ended his speech on the limitations of possible knowledge of Nature with the words "Ignoramus et ignorabimus" (we do not know, we shall not know).

With his "Ignorabimus" speech, Du Bois-Reymond set off a violent scientific controversy. It continued to be fought out, sometimes polemically, by the supporters and opponents of his theses. Du Bois-Reymond himself was completely aware that his "Ignorabimus" was ultimately "Pyrrhonism[1] in new clothing" and would inevitably evoke contradiction from the naturalists [1, p. 6]. In fact, Du Bois-Reymond did not need to wait long for this. Soon, his most powerful adversary emerged in the no less famous scientist Ernst Haeckel. The latter was professor of zoology in Jena and had already emerged as a vehement supporter and promulgator of the Darwinian theory of evolution. The central element in Darwin's thinking, according to which the evolution of life rested on the mechanism of natural selection, appeared to confirm to the fullest extent the materialistic world picture favoured by Haeckel.

On the basis of a materialistic world-view that was gaining increasing acceptance, Haeckel stood for a monistic doctrine of Nature. According to this, even intellectual phenomena are nothing more than material processes, unrestrictedly accessible to mechanistic explanations of the kind that Darwin had put forward. Haeckel took the view that the aprioristic forms of intuition, which according to Kant were prerequisites for the possibility of any cognition, could be interpreted and explained as a posteriori elements of phylogenesis. By so doing, Haeckel anticipated an idea that the ethologist Konrad Lorenz [11] took up in the mid-twentieth century and developed into the evolutionary theory of cognitive mechanisms in animals and humans.

Haeckel opposed vigorously the dualistic view of Mind and Matter. Consequently, he challenged the existence of unsolvable "world enigmas" of which

[1]Pyrrhonism, also termed scepticism, goes back to the ancient philosopher Pyrrho of Elis and refers to a philosophical movement that cast fundamental doubt upon the possibility of a true knowledge of reality.

Du Bois-Reymond had spoken. Except for the problem of free will, which he regarded as a dogma because it was (in his view) illusory and did not in fact exist, he saw the other world problems either as solved within the framework of the materialistic conception of Nature, or else as solvable in principle.

As a rhetorician, Haeckel was by no means second to the "orator of Berlin", as he decried his opponent. Haeckel, too, knew exactly how to popularise his world-view, and he used this as an opportunity to exacerbate the "Ignorabimus" controversy into a battle of cultures, between the monistic and dualistic world-views. Du Bois-Reymond, on his part, mocked the "prophet from Jena" and adhered tenaciously to his "Ignoramus et ignorabimus" slogan, which for him—together with his seven world enigmas—was an "unchangeable and inflexible verdict" [1, p. 51].

The "Ignorabimus" thesis made up the strongest countercurrent to the optimistic attitude to knowledge taken by the natural scientists of the 19th century, which is why it provoked such violent criticism from Haeckel. The modesty of "Ignorabimus", according to Haeckel, is a false modesty; in reality, he asserted, it is an expression of presumptuousness, as it claims to lay down limits to knowledge of the natural world that apply for all time, and to raise ignorance to the status of an absolute truth.

Yet, Haeckel proceeded to pour more oil onto the fire: "This seemingly humble but really audacious '*Ignorabimus*' is the '*Ignoratis*' of the infallible Vatican and the 'black international' which it leads; that mischievous host, against which the modern civilzed state has now at last begun in earnest the 'struggle for culture'. In this spiritual warfare, which now moves all thinking humanity, and which prepares the way for a future existence more worthy of man, spiritual freedom and truth, reason and culture, evolution and progress stand on the one side, marshalled under the bright banner of science; on the other side, marshalled under the black flag of hierarchy, stand spiritual servitude and falsehood, want of reason and barbarism, superstition and retrogression." [6, p. xxii f.]. Du Bois-Reymond, in turn, felt himself "denounced as belonging to a black band of robbers" by such utterances and saw in them the proof of "how close to one another despotism and extreme radicalism dwell" [3, p. 72].

The long-lasting effect of the "Ignorabimus" controversy in science is revealed clearly in a radio broadcast given in 1930 by the mathematician David Hilbert, who was one of the leading intellectual pioneers of his time. Hilbert ended his talk with the words: "We must not believe those who today, with philosophical bearing and in a tone of superiority, prophesy the downfall of culture and admire themselves as adherents of the Ignorabimus. For us there is no 'Ignorabimus', and neither, in my view, is there any room for it in natural science. In place of the folly of the 'Ignorabimus', our watchword is: We must know, we shall know." [8]. In the same spirit, Hilbert had challenged his colleagues at the beginning of the 20th century with a legendary list of fundamental mathematical problems, the solving of which he considered to be of highest priority.[2] Hoewever, very soon after Hilbert's

[2]At the International Congress of Mathematicians of 1900, held in Paris, Hilbert formulated with exemplary exactitude a list of fundamental problems that he claimed to be solved. In 1928 he extended this list.

broadcast, the logician Kurt Gödel proved that one of these problems, known as Hilbert’s 23rd problem, was principally unsolvable.

Today we are well aware that there indeed are unsolvable problems in science, or at least in mathematics. In retrospect, it seems like an irony of fate that Hilbert, of all people, set out a problem that was finally found to be unsolvable. Nevertheless, Hilbert’s maxim “We must know, we shall know” became the unchallenged *Leitmotiv* of modern science, which persistently ignores the “Ignorabimus” and resolutely endeavours to comprehend the incomprehensible, to calculate the incalculable and to measure the immeasurable. And, in the same spirit, the exact sciences are perpetually pushing at, with the aim of overcoming, the various boundaries of our knowledge of the world.

2.2 Crossing Boundaries in Science

All areas of human life are criss-crossed by boundaries. These clearly constitute—irrespective of any question of whether they are real or imaginary borders—a rich picture of reality. It is only on the basis of the manifold boundaries between natural and artificial, living and non-living, law-like and random, simple and complex, regular and unique, and many other pairs of opposites, that we encounter reality in differentiated forms. However, human thought has always felt the challenge to question these boundaries and, where possible, to cross them. This is true not least of the—presumably—most fundamental boundary, that of human self-awareness: the abyss between mind and matter, on which, in its time, the “Ignorabimus” controversy flared up.

At first glance, it would appear that the differentiated richness of reality must become lost in precisely the same measure as the acquisition of knowledge moves or abolishes borders. Yet the apparent loss is compensated for by the gain in unity of human knowledge. This is in turn a prerequisite for a coherent picture of reality, one that is free of internal contradictions.

The human drive towards discovery and thirst for knowledge are ultimately impelled, to a large extent, by perpetual reflection on the various boundaries that cross the material and non-material world. However, what kind of boundaries do we encounter in science? The first that springs to mind is a conceptional boundary in mathematics that was discovered by Gödel in the 1930s (see above). With the proof of his so-called “incompleteness theorem” Gödel had demonstrated the unsolvability of Hilbert’s 23rd problem, and had revealed the fundamental unrealisability of Hilbert’s idea that the path of mathematical proof could in principle be completely automated.

Indeed, Hilbert’s programme aimed at placing mathematics on a new foundation, and had for a very long time pursued the goal of constructing a completely formalised system in which all true theorems of mathematics could in principle be proven by applying a standardised procedure. When Gödel managed to prove with mathematical rigour that any such formal system is for fundamental reasons incomplete, he showed once for all that mathematical intuition and insight are fundamentally incapable of being replaced by formalised thought. In other words: an ultimate demonstration of the truth of any knowledge by an automatic proof is not possible, because truth encompasses more then mere provability. In this way, Gödel had uncovered a boundary in formal thought, one that constitutes a genuine and insurmountable barrier.

At the centre of Hilbert's formalistic programme there already lay, in essence, the notion of an idealised computer, a so-called "Turing machine" – even though this idea only took on form some decades later, when it was set out and developed into a fully-fledged theory by the mathematician Alan Turing.

In the theory of Turing machines, the problem investigated by Gödel is presented as a "decision problem". The quintessence of this problem is the conclusion that in any formal system, however extensively and carefully it may have been constructed, there are certain statements that are indeterminate and which cause the Turing machine to become entangled in an endless loop of calculation. The existence of indeterminate statements is in turn an expression of the fundamental incompleteness of such systems. Moreover, subsequent research has shown that—from a mathematical point of view—the non-existence of hidden algorithms cannot be proved. As we will see in Chap. 3, this finding also casts a revealing light on a long und vain debate on the particular nature of living matter.

However, not only in mathematics but also in the empirical sciences one encounters objective boundaries that have important consequences for our scientific understanding of the world. Let us take a look at physics. In physics, too, there are many kinds of boundary. At first sight, these seem superficially to be boundaries set for all natural events, for example by the magnitudes of the fundamental physical constants. The speed of light, setting an upper limit for the speed of anything else, is one of these—as is the absolute zero, or lower limit, of temperature. Another example is the impossibility of constructing a "perpetual motion machine", capable of doing work indefinitely without an energy source: here again we encounter a physical limit.

More difficult to understand are the strange boundaries revealed to us in the microphysical world. There are two main reasons for this: the limitation of the descriptive capacity of human language, and the obscure rôle played by chance in quantum physics.

Let us first examine the linguistic barrier. The concepts dealt with in our language are, in the nature of things, best adapted to describing the "mesocosmic" world of our experience, that is, the world of objects (not too large and not too small) that we can perceive with our sensory organs. In the description of the microcosm, in which the laws of quantum physics apply, the concepts dealt with by our everyday language soon encounter their limits. Here, phenomena can only be described adequately in the language of mathematics. Thus, this limit is actually not a genuine physical boundary, but just an apparent one—one, however, that shows us clearly that human language is only able to depict physical reality to a limited extent.

Alongside the linguistic barrier, another limit confronts us: In the world of elementary physical processes chance plays a central part. This restricts severely the calculability of microphysical events. For example, the point in time when a radioactive atom decays obviously depends entirely upon chance. For this reason the laws of radioactive decay are of a purely statistical nature.

Much thought has been given to the question of whether the world of quantum physics may perhaps, after all, be subject to as yet unknown laws or hidden parameters that determine these elementary processes. This ultimately reduces to the question of whether chance in quantum physics is merely a symptom of our lack of detailed knowledge, or whether it really determines the course of events in an objective sense. At present everything seems to point to the objective nature of the limitations that are placed upon deterministic explanation in quantum physics. A strong indication in favour of this conclusion is a theorem of John Stuart Bell. This theorem, which is supported by experimental evidence, excludes the possibility of “local” theories of hidden parameters. Thus, by all appearances, the possibility that chance makes an essential contribution to quantum phenomena can no longer be ruled out.

The influence of chance naturally places a limit upon the calculability of physical processes. Conversely, though, limited calculability need not necessarily mean that the phenomena under discussion are dominated by chance. On the contrary: unpredictability can even be a direct consequence of deterministic laws. In physics, systems with this property are termed “chaotic” and the phenomenon itself as “deterministic chaos”.

The idea that systems may be totally subject to deterministic laws and at the same time behave as though they were governed by pure chance seems to be self-contradictory at first glance. However, this peculiar phenomenon can be made comprehensible by a closer look at the nature of causal determination.

First of all, we need to distinguish between the “causal principle” and a “causal law”. The causal principle simply states that nothing takes place without a cause; thus, every event has its own cause. A causal law, on the other hand, is a statement of how cause and effect are linked to one another. This link can be “linear”, so that similar causes always have similar effects. However, it can also be “non-linear”, so that similar causes can have completely different effects (this issue is discussed in detail in Sect. 8.2).

In the linear case, the system’s dynamics can be calculated over a long period, because small indeterminacies in the initial conditions—that is, in the causes—do not change significantly the development of the system. In the non-linear case, on the other hand, even small fluctuations in the starting conditions can have tremendous consequences for the further development of the system because these disturbances, in the course of time, reinforce each other and lead to an avalanche of change. To predict the dynamics of such systems over the long term, the starting conditions must be known with arbitrarily high accuracy. As such accuracy fundamentally cannot be attained, the calculability of systems of this kind lies within very narrow limits.

It is therefore a consequence of the non-linear coupling of causes and effects in chaotic systems that leads to the extreme sensitivity over against small changes in their starting conditions and that makes the dynamics of these systems in practice unpredictable.

Yet the example of deterministic chaos already shows us that our insights into the limits of predictability can themselves be a source of further knowledge. Thus, the physics of chaotic systems has led not only to a deeper understanding of causality and physical order, but also to new insights into the nature of unique processes, such as are characteristic, for example, of historical events (Chap. 8). In this way, the incomputable ultimately appears computable after all.

Deep insights into the structures of the world also arise from the investigation of "floating" boundaries. Such borders are only ostensible, because in their case no exact demarcation, such as might arise from the ontological character of the objects of reality, can be drawn. As an example, let us take an object which we regard as living. Normally, we have no difficulty in recognising a living being as such, because we learned as children to tell the difference between living and non-living entities. Even if small children might sometimes make a mistake when confronted with a cleverly made toy, which looks exactly like an animal, it nonetheless seems as though the ability to distinguish "living" from "non-living" is part of the basic equipment of our cognitive apparatus, and thus is one of the fundamental forms of our implicit knowledge.

The situation, however, is quite different when we come to consider the conceptual delimitation of living beings. This is seen especially clearly in the exact sciences. Any attempt to set up a scientific theory of the origin of life must obviously be able to explain how living matter emerged from non-living matter. This in turn implies a smooth transition between the non-living and the living. Only on this assumption is it possible to sketch out a coherent physico-chemical theory that includes all steps of material self-organisation, from a simple molecule to a living cell. If, however, the transition from non-living to living matter is continuous (or quasi-continuous), then a complete answer to the question "What is life?"—including all necessary *and* sufficient criteria—is impossible, for logical reasons. This in turn means that any scientific theory purporting to offer a complete explanation of the origin of life must inevitably rest upon an incomplete concept of what life is. In this case a certain element of arbitrariness is present concerning the degree of complexity above which a material system is to be regarded as living. For that reason, one can engage in lively discussions about whether viruses are alive or not (see Sect. 3.1).

In the social and political debate about the use of modern biological and medical technologies, the problem of definition is reflected with especial clarity in the problem of defining at which stage of development one should regard a fertilised ovum as a living organism and thus define the beginning of human life. From this enduring debate, however, we cannot draw the conclusion that all attempts to decide this debate by appeal to scientific insights are necessarily doomed to failure, because science is obviously not in a position to state unambiguously the difference between living and non-living matter. Rather, the exact sciences always have the task of abstracting from complex reality. In the present case, the task is to draw a "scientifically" meaningful demarcation line between living and non-living matter, even if in reality no such strict demarcation exists.

Such demarcation lines in science usually emerge from the context of the scientific question being asked or studied. In the case at issue, the specific questions being addressed result in certain properties of "living" matter being emphasised and others being excluded from consideration; only in this way does the scientific concept of "life" constitute an object of research.

In physics, for example, the transition from "non-living" to "living" may be primarily regarded in connection with the origin of certain ordered states of matter, those that are self-preserving. An understanding of this properly requires appeal to thermodynamic principles. Therefore, the physical definition of a living system will involve not only the property of self-preservation, but also (especially) the turnover of free energy. The latter is gained by the decomposition of energy-rich into energy-deficient material, that is, by the process we call metabolism. This process is indispensable, because the living system can only sustain its complex, material order if it receives a perpetual supply of free energy. Only in this way can the continuous production of entropy in the system be compensated for and thereby the "entropic death" of thermodynamic equilibrium be avoided.

In molecular biology, however, other properties of living matter come to the fore. One of these is the fact that all basic processes of life are driven by information. A working definition that takes account of this aspect must therefore give a central place to the concept of genetic information. We could continue to extend the list of different viewpoints from which living matter can be considered, but we would never arrive at a complete definition that could provide us with a logically clear concept for distinguishing it from non-lining matter. All of the characteristic properties that we have mentioned—metabolism, self-reproduction, information and the like—can be found, in some form or other, also in systems that we would clearly denote as non-living.

Now, one might argue that the difficulty in finding a comprehensive concept of what is actually the living is the result of wrong thinking. Perhaps we have been setting out from a false premise by assuming that the transition from the non-living to the living is a smooth one. This immediately prompts an alternative consideration. Maybe the transition is actually a discontinuous one. In that case, it should certainly be possible to draw a sharp borderline between living and non-living matter, and that should make it possible to state necessary *and* sufficient criteria for defining life. However, this would come at an unacceptably high cost. For, a complete definition would have to contain at least one criterion that expresses the ontological difference between living and non-living matter. According to our point of departure, this could only be a *specific* characteristic of life, so that a complete definition of life would always contain a tautological element. Comparable considerations apply to the relationship between mind and matter. Here too, a sharp demarcation cannot be made, because (as we may reasonably assume) the mental properties of matter have developed continuously from its material properties in the course of the evolution of life.

The question “What is life?” finally leads to a unique, and even paradoxical, situation: If we assume that living and non-living matter are in their essence different, then the concept of life can no longer be defined in a logically flawless manner, and the origin of life becomes inexplicable in physical terms. If, on the contrary, we assume that there is no sharp border between living and non-living matter, then a complete physico-chemical explanation is in principle possible—but only at the cost of a reduced concept of life.

The unavoidable incompleteness of the physical concept of life is sometimes presented as a weakness of physicalism. However, this ignores the fact that the exact sciences always operate by using abstractions, simplifications and idealisations. “Point masses”, “frictionless movement”, “elastic collision”, “isolated system” and “reversible process” are typical examples of the numerous idealisations that we encounter in physics. The physical concept of life is no exception.

2.3 The Whole and Its Parts

To emphasize it once more: Abstraction, simplification and idealisation constitute the methodological foundations of the exact sciences. They determine the fundamental nature of scientific knowledge. For precisely that reason, the exact sciences cannot embrace the richness of the reality of our life, in all its breadth and depth.

In the public perception of science, this has always been a source of criticism, as it is often believed that even the methodological requirements of the exact sciences restrict fundamentally the knowledge that they convey, or cast doubt upon it. However, this is a grave misunderstanding: the methodological restrictions of science do not place any limits on its discoveries as such, but rather, at worst, on the scope of its discoveries.

The exact sciences, the tool of which is the analytical dissection of a scientific problem, are only able to explain narrow aspects of the phenomena that are under investigation. Accordingly, our scientific understanding of the world consists of a mosaic of innumerable components of knowledge, of which each component can be critically assessed and, if necessary, replaced by a new one.

The general procedure followed by the exact sciences is to explain the whole on the basis of the combined effect of its parts. In public debate this is often branded as the “mechanistic” world-view of the exact sciences and, it is claimed, as totally inadequate to explain the complex reality of our life or, especially, the idiosyncrasies of living Nature. Instead, critics of the exact sciences repeatedly demand a “holistic” understanding of reality. This criticism is irritating insofar as it not only paints a completely wrong picture of the sciences, but also instrumentalises this picture to feed a socio-political programme that is inimical to both science and technology. It usually culminates in the accusation that the scientific method, above all in the natural sciences, leads to a wrong understanding of reality and thus promotes ruthless exploitation of Nature by modern technologies. Some social philosophers do not even hesitate to dub science and technology as an “ideology”, the intention of which is entirely to obtain dominance over mankind and Nature (see [5]).

Mistrust of the exact sciences lies deep. For many people, progress in science and technology is regarded as in reality retrogressive and as leading to a cold and unfeeling society, one that threatens mankind and Nature alike. Needless, to say, the depressing prospects that these critics of science and technology project onto the screen cause fear, which in turn engenders a yearning to return to an unspoiled state of Nature. It is claimed that only an organic understanding of Nature, one that embraces the whole, can match up to the problems caused by the scientific and technological handling of Nature and the permanent, growing ecological problems. Little wonder, therefore, that many people are trying to replace the spectre of a reality regulated by mechanical laws alone with an old-fashioned and romantic vision of Nature.

The accusations directed against the exact sciences are always the same. First, it is claimed that the “reductionistic” programme—directed as it is by dissection, simplification, abstraction and idealisation—cannot but lose the “whole” perspective. Secondly, it is claimed that the causal-analytical method which endeavours to explain “the whole” by appeal to the combined behaviour of its parts is in itself completely unable to conceive of the fundamental nature of life, simply because any living system is an irreducible whole, a self-contained circuit of causes and effects.

The consequent demand for a holistic access to reality has in the meantime become a mantra of the “alternative” science scene. What we are supposed to understand by this, however, remains a closed book. It is perfectly correct to characterise the essence of an organic whole as a cyclically linked system of causes and effects. However, a real understanding of the whole—insofar as “understanding” is to be taken as implying a causal explanation—requires the analytical dissection of the whole. Otherwise the understanding of the whole is merely surrogated by a superficial overview of the whole.

The arguments adduced to cast doubt upon the reductionistic method are extremely vague. By appeal to the autonomy of wholes, it is demanded (usually in highly rhetorical terms) that analytical thought which is associated with mechanistic models of the reality should be augmented with “holistic” or “connected” thinking. Admittedly, one wonders which science is being criticised here. Modern science has long outgrown its infant belief in a simple mechanistic world. In fact, if we wish to attribute any real meaning to the holistic (but trivial) thesis according to which “the whole is more than the sum of its parts”, then there is no better place to look than modern physics. Quantum physics has even developed a proper terminology in order to take account of the holistic phenomenon of “entanglement” of quantum objects. Likewise, the holistic thesis of macrodetermination, according to which the whole determines the behaviour of the parts, is by no means foreign to the exact sciences. To see this, one does not need to look further than the “law of mass-action” in chemistry. When a chemical system is in a state of equilibrium, the individual molecules in the system are unaware of this. However, the system as a whole determines, by a mechanism of negative feedback of fluctuations, the behaviour of its molecules: the greater the (random) deviation from the equilibrium state, the stronger is the tendency of the system to move back toward this state. It is precisely this that is expressed by the term “mass action” (see Sect. 7.2).

As already pointed out by the biologist Peter B. Medawar, in reality the “reductive analytical-summative mechanist” does not exist. Rather, “he is a sort of lay devil invented by the feebler nature-philosophers to give themselves an opportunity to enjoy the rites of exorcism” [12, p. 144]. The criticism of the analytical sciences is in fact a relic of the romantic epoch. Then as now, the emphatic rejection of the mechanistic worldview was ultimately directed against the forward march of technical mastery over Nature. And, at the same time, loud demands were made that the “blind” and “unimaginative”, mechanistic approach to research should be confronted by a holistic, i.e., organismic understanding of Nature (see Sect. 1.4).

Since those days, the spectre of mechanicism has again and again been evoked, a purported ideology in science and technology, which—in the thrall of a mechanistic myth of progress—are set to destroy the natural basis of human life, without taking any account of the holistic character of the animate world. Yet experience has shown that in actual fact it is not analytical, but rather holistic, thinking that brings danger. If the whole determines the behaviour of its parts, or—as claimed by the representatives of the so-called philosophical holism—if “the higher entity is always the prime mover of the lower” [13, p. 356], then the temptation is very close at hand, especially in totalitarian political systems, to apply this thought in legitimising authoritarian structures of power in the society. Anne Harrington, who has made a profound study of the history of holistic thinking in the first half of the 20th century, has shown that holistic ideas have indeed made a substantial contribution to political indoctrination and to the propagation of totalitarian ideas [7].

2.4 Concerning Hypothetical Truth

There are also boundaries that are imposed upon science by society. These boundaries add up to a complex mesh of prohibitions and regulations that lay down norms for the process of research. These normative boundaries serve the purpose of controlling the gain of scientific knowledge and of steering technological progress in a “forward-looking” direction. But where should science and technology go? On what can the norms that we impose upon science possibly be based? Should we refer to norms that are based upon metaphysical grounds of being and lay claim to absolute truth, or should we only refer to such norms as can be derived from scientifically based knowledge itself that has basically an empirical, and therefore always a preliminary, character?

These and similar questions come to play a decisive role in situations where appeal is made to the “responsibility” of science. The exercise of responsibility by restricting the gain of scientific knowledge does not only mean that we have identified the problems that are posed by scientific and technological progress; it further implies that the alleged problems are in fact “genuine” problems. For this reason we cannot separate the concept of norm from that of truth. However, as the history of philosophical thinking shows, the concept of truth is many-layered. It includes absolute, empirical, hypothetical, contingent, historical, logical, mathematical, objective, ontological, subjective, practical, theoretical and utilitarian truths, and many more besides. Furthermore, all conceptions of truth demand, in some form or other, a theory of truth. The most prominent of those theories are the correspondence theory, the consensus theory, the discourse theory and the coherence theory.

More important, though, is the fact that the problem of fluid boundaries, discussed above, arises also with regard to the question of “truth”. In this case the problem is expressed in the phenomenon of unsharp truth-values. This phenomenon, which was already known to the ancient Greeks, has been passed down to us in the well-known trick question of Eubulides: How many grains of sand make up a pile? One grain of sand is certainly not a pile. Neither are two. Obviously, increasing the number of sand grains by one does not bring about the critical difference between a pile and a non-pile. Nevertheless, a sufficient number of grains of sand quite definitely constitutes a pile.

There are numerous examples in which the boundaries between “true” and “false” are floating ones, so that the truth content of statements may decrease on a slippery slope of diminution or vice versa. In basic research a special logic for this has even been designed, the so-called “fuzzy logic”, which takes account of the existence of floating truth-values. In quantum physics, too, there have been attempts to encounter epistemological difficulties arising there by creating a special logic in which, for example, probabilities are assigned to the truth-value of statements. To avoid disruption of the logical foundations of our thought, repeated efforts have been made to justify the unity of logic and to trace all logical forms back to the binary logic with which we are familiar and in which only true and false statements are recognised.

In view of the inflationary numbers of concepts of truth one may be excused a certain helpless perplexity, asking, along with Friedrich Nietzsche, what human truth ultimately is. Is it, as Nietzsche mocked, nothing other than the “irrefutable errors” of mankind [15, p. 265]? When dealing with purported truth, are we in reality dealing merely with truths devoid of truth content? Is truth ultimately only the difference between errors?

Even if, with these questions, we are up against the limits of human thought—we still cannot relinquish the concept of truth, as any thought or action that abandons in advance all claims to truth naturally loses touch with reality. In fact, any attempt to pursue the idea of truth *ad absurdum* can only be taken seriously if it at least claims to be true in itself—and in so doing tacitly admits the existence of what it opposes, namely, the idea of truth. This self-referentiality of truth cannot be disrupted by any critical theory of truth. Conversely, no theory of truth can ever prove the existence of absolute truths. Such efforts have no hope of success, if only because there is no Archimedean point outside of truth that would allow us an absolutely trustworthy perspective view of the truth issue. This is the actual essence of the aporia that is hidden in the concept of truth.

In consequence of this, the debate on the question of truth has never ceased to run in circles, although it admittedly has revealed, in the course of its long history, numerous truths about truth itself. All attempts to unify the concepts of truth or to deduce one such concept from another are inevitably condemned to failure, because it is precisely the multiplicity of concepts of truth that reveals a sophisticated and differentiated understanding of reality. On the other hand, an essential property of truth is that it cannot be forced into line. What remains is the idea of truth as a "regulative" idea, one that appears indispensable, because without the idea of truth the human endeavour to acquire reliable knowledge of the world would at once lose both its goal and its content.

In keeping with this, scientific knowledge of the world can also never claim more than hypothetical truth. This insight was stated clearly by the philosopher of science Karl Raimund Popper, who made it the basis of his treatise "Logik der Forschung", which appeared in 1934. Today it is generally accepted that the empirical sciences can never provide absolute certainty about the validity of any discovery. Rather, all scientific knowledge is merely of a provisional and hypothetical nature. Yet there remains, for the empirical sciences, the instrument of observation and experimental test, by which a claim to truth can at any time be critically examined and, perhaps, be refuted. It is in this that a scientific understanding of reality shows its strength over against any dogmatic world view that purports to possess absolute truth.

This automatically answers the initial question of which norms we should refer to in our dealings with science and technology. These can only be norms that in turn rest upon well-founded scientific knowledge. For only on the basis of scientific knowledge can a critical and forward-looking consciousness develop, one that is capable of taking issue in a rational manner with scientific and technological progress. This in turn presupposes the unrestricted freedom of gaining scientific knowledge.

2.5 We Must Search, We Will Search

The exact sciences can only live up to their own criteria of critical and enlightenment-directed thinking by drawing a sharp line between themselves and all kinds of pseudoscience. According to Popper, this demarcation is made possible by the criterion of "falsification": a hypothesis or a theory can only claim scientific validity when it leads to experimentally testable predictions and thus, in principle, is falsifiable (refutable).

Indeed, most theories in physics meet the demarcation criterion demanded by Popper. But what about the scientific theories that purport to describe the history of Nature? Historical processes, however, appear to be unpredictable in principle. A favourite example of this is Darwin's theory of evolution; this theory admittedly allows causal explanations, but makes practically no predictions. The most important reason for this is that the paths of evolution depend to a high degree upon chance. The issue is exacerbated by the enormous material complexity of living beings, even at the lowest stages of development, so that there is only very limited room for precise calculation. For this reason Darwinian theory, compared with physical theories, has only very limited predictive power. It has even been asserted that the Darwinian principle of "survival of the fittest" is a mere tautology, because the central concept of fitness is determined solely by the fact of having survived. In view of this, Popper went as far as to dismiss evolution theory as a "metaphysical" research programme, one which does not measure up to the status of a scientific theory—a viewpoint that he admittedly later revised [16].

Beside the general question regarding the scientific status of Darwin's theory there are other problems that challenge the idea of Darwinian evolution. One is known as the statistical problem of the origin of life. This encapsulates the fact that the spontaneous formation of a living being by the random association of its material building-blocks is vanishingly small (see Sect. 3.2). Further, the statistical analysis has shown that not even a simple biomolecule, carrying some biological function, could originate by pure chance during the past lifetime of our universe.

The statistical problem seems to indicate that the existence of life must be regarded as an enigma of Nature. Under these circumstances it is all the more astounding that one of the leading molecular biologists of the 20th century, Jacques Monod [14], invoked precisely the statistical objection in order to found his "chance hypothesis" of the origin of life. How is this to be understood? Here one has to remember that probabilities say nothing about the actual occurrence of a single event, but only about its relative frequency. For this reason it is perfectly possible to attribute the existence of life on Earth to a singular chance event, even though the probability of this happening is practically zero. The low probability only indicates that this event is not *reproducible* within the limits of the universe. In this sense Monod believed that he could interpret the origin of life as having been a once-off event in the entire cosmos, one that with a probability bordering upon certainty would never be repeated.

Even if we cannot exclude the possibility that life originated as a singular, chance event, a hypothesis of this kind is completely unsatisfactory for the scientist. It can hardly be the goal of scientific research to attribute the phenomena demanding explanation to the effect of singular chance. It is rather the task of science to understand the phenomena in terms of the law-like behaviour of Nature. Scientists remain equally unconvinced by arguments from the extreme opposite camp which assume hidden laws of life, or a cosmic or a divine plan that guide the processes of Nature. Such hypotheses are by their very nature non-falsifiable, because the non-existence of inscrutable plans, final causes, life forces and the like can never be proved [9]. Conversely, no-one has yet succeeded in adducing the most rudimentary evidence for the presence of life-specific principles in Nature.

As was expected, the open questions regarding the origin of life have become a playing-field for all conceivable kinds of pseudoscientific theory, of which the most influential today, camouflaged as a religious movement, styles itself "intelligent design". However, we cannot conclude from the present gaps of scientific explanation that there is basically no solution within the framework of science. In fact, the history of science shows that science has steadily closed gaps in explanation that first seemed to have no solution.

The same applies to the statistical problem of the origin of life. In place of the wrongly set-up decision "chance" *or* "necessity", modern biology has long offered a satisfactory reply to this question, one that joins up chance *and* necessity in the Darwinian sense (Chap. 3). The solution of the statistical problem has become possible through the discovery that natural selection is a universal principle of Nature—one which under the right physical conditions also operates in the realm of molecules, where these conditions can steer the selection of those molecular structures that are able to organize themselves into a precursor of the living cell [4]. On the one hand, this process is subjected to chance, while on the other the results of chance are "evaluated" by the law-like action of natural selection, so that the overall process of the origin of life, as denied by Monod's hypothesis, can *in principle* be a repeatable process. Moreover, at the molecular level of evolution precise predictions have become possible, which can even be tested experimentally.

With these achievements, the accusation of tautology is refuted, as is the assertion that evolution theory is merely a metaphysical research programme. In the face of the massive challenges that time and again have been raised against Darwinian evolution theory, we are obliged to acknowledge the triumph of Darwin's idea by the development of the molecular theory of the origin of life. Within the framework of this theory the evolution of biological macromolecules cannot only be justified theoretically; it can also be simulated in the test-tube.

The experimental technique for the study of the self-organization and evolution of biological macromolecules has now been developed to the extent that the experiments can even be performed by automata (Sect. 3.4). Moreover, such "evolution machines" are able to start a process of evolutionary optimization from any area of information space and thus liberate natural evolution from the constraints of its pursued routes. Already today, we can anticipate the time when we will be able to investigate the inexhaustible potential of life in all directions and bring it, supported by new techniques, to its full development. This marks the beginning of the dissolution of yet another fundamental boundary of our understanding of reality—the boundary between "natural" and "artificial" evolution.

Admittedly, this fascinating technical possibility opens up another range of novel questions; the most obvious one is that of the content of the genetic information that will be generated by artificial evolution. This in turn requires an approach to the semantics of information within the framework of the exact sciences (see Chap. 5). In this respect, promising first steps have recently been taken, ones that also throw a new light on the nucleation of semantic information in prebiotic matter [10].

Looking back on the scientific developments of the last hundred years we can conclude that not much is left of the seven "world enigmas" that Du Bois-Reymond regarded as fundamentally unsolvable. (1) The nature of force and matter has been made comprehensible by twentieth-century physics, in a depth that is without compare in our understanding of the world. (2) The question of the origin of movement, which seems to be a metaphysical relic of the Aristotelian doctrine of movement, has today found a scientific answer in the physics of self-organisation. (3) The problem of the origin of life has also become accessible to science, and its main outline is already well enough understood for it to be declassified as a world enigma. (4) The apparently purposeful, planned, goal-oriented organisation of Nature has found an explanatory basis in the modern theory of biological evolution. (5) Simple sensory perception, in modern brain research, has today come a long way, especially for the processes involved in visual perception. The seven world enigmas have thus shrunk to two: rational thought and the origin of language, and free will. Here we have without doubt arrived at a frontier of present-day research. However, nothing contradicts the expectation that these problems, too, will one day lose the aura of mystery that today continues to surround them.

References

1. Du Bois-Reymond, E.: Über die Grenzen des Naturerkennens. Veit & Co., Leipzig (1872)
2. Du Bois-Reymond, E.: Culturgeschichte und Naturwissenschaft. In: Vorträge über Philosophie und Gesellschaft. Veit & Co., Leipzig (1874)
3. Du Bois-Reymond, E.: Die sieben Welträthsel. Veit & Co., Leipzig (1880)
4. Eigen, M.: Self-oganization of matter and the evolution of biological macromolecules. The Science of Nature (Naturwissenschaften) **58**, 465–523 (1971)
5. Habermas, J.: Technology and science as an ideology. In: Toward a Rational Society. Student Protest, Science, and Politics. Beacon Press, Massachusetts (1971). [Original: Technik und Wissenschaft als ‚Ideologie', 1969]
6. Haeckel, E.: The Evolution of Man, vol. 1. The Werner Company, Akron ^{3}(1900). [Original: Anthropogenie oder Entwicklungsgeschichte des Menschen, 1874]
7. Harrington, A.: Reenchanted Science. Princeton University Press, Princeton (1999)
8. Hilbert, D.: Naturerkennen und Logik. The Science of Nature (Naturwissenschaften) **18**, 959–963 (1930)
9. Küppers, B.-O.: Information and the Origin of Life. MIT Press, Cambridge/Mass. (1990). [Original: Der Ursprung biologischer Information, 1986]
10. Küppers, B.-O.: The nucleation of semantic information in prebiotic matter. In: Domingo, E., Schuster, P. (eds.): Quasispecies: From Theory to Experimental Systems, pp. 23–42. Springer International Publishing, Switzerland (2016)
11. Lorenz, K.: Kants Lehre vom Apriorischen im Lichte gegenwärtiger Biologie. Blätter für Deutsche Philosophie **15**, 94–125 (1941)
12. Medawar, P.B., Medawar, J.S.: Aristotle to Zoos. Harvard University Press, Cambridge/Mass (1983)
13. Meyer-Abich, A.: Naturphilosophie auf neuen Wegen. Hippokrates, Stuttgart (1948)
14. Monod, J.: Chance and Necessity. Vintage, New York (1971). [Original: Le Hasard et la Nécessité, 1970]
15. Nietzsche, F.: The Gay Science. Cambridge University Press, Cambridge (2001). [Original: Die fröhliche Wissenschaft, 1882]
16. Popper, K.R.: Unended Quest. Routledge, London (1992)

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