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# LifeTime: A Unified Study of Life Preliminary Version

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# LifeTime:

## A unified study of life

***A preliminary version***

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***Historical antecedents***

In a complex and largely unpredictable world, completing the life cycle is the primordial function of all organisms. For the hominid ancestors of present-day humans, survival crucially depended on the combinatorial power of their enlarged brains. Conscious awareness of the ephemeral state we now call ‘life’ and the aboriginal recognition of the uncertainty and vulnerability of this condition seem closely connected; under strong selective pressure their evolution may have proceeded in parallel. Prehistoric cave paintings, so-called votive figurines, and other related archeological finds may be adduced as evidence for the antiquity of the conscious mental representation, i.e., of the *idea*, that some sort of contingent properties specifically determine and constrain the precarious living condition. Yet, as far as recorded speculations about this subject exist at all, the properties determining ‘life’ were never understood better than in some obscure, mythical terms.

The central subject of this study is the question: “What essentially differentiates living from non-living matter?” The phrasing of this question, as well as the suggested answers, have changed dramatically over the last few centuries. It follows that a study of this question should not ignore the historical horizon in which the idea of something called ‘life’ developed in the first place, inasmuch as the terms, the concepts, and their interconnections are unequivocally anchored in this historical past. In fact, the historical antecedents of the meanings of “commonsensical” concepts such as ‘time’, ‘order’, and ‘life’ are markedly biased. We make the obvious point that the present-day spectacular advances in the scientific knowledge of ‘life’, i.e., in the biological sciences, require a fresh review of the problem. But this endeavor will be inadequate and ineffectual if conducted independent of its historical background.

In the more restricted frame of Western civilization, the question “What is life?” has a long and variegated history, already appearing in the earliest *written* records.

Homer is generally deemed to stand at the origin of this tradition. In the Homeric poems, the difference between life and no-life is resolved by an entity called *psyche*. Its presence in a (human) being is required for life, as expressed in the belief that *psyche* abandons the body when the individual dies. Without however entirely disappearing, as *psyche* leads a shadowy existence in the nether world still keeping, in the main, the personality of the deceased. In many places in Homer, *psyche* and life can almost be considered synonyms[i]. Western civilization, to a large extent a tributary of this tradition, globally maintained the *psyche*-life connection, at least until the 17th century. The ‘modern’ approach to this subject represented a radical paradigm shift. It was now assumed that all matter, living as well as non-living, is essentially the same kind of matter, and that the explanation for this difference has to be located exclusively in the universal laws of physical nature. It did not prove easy to shake loose of the historical *psyche*-life encumbrance, and in fact this tradition partially survives unto our days in many different guises.

The emergence of the modern world-view is usually associated with the names of Descartes, Galileo, and Newton. The primary question Descartes asked was: “How do we know what the world is truly or objectively like, as opposed to how it appears to us?” He postulated that the unshakable foundation on which to base a ‘science’ capable of arriving at satisfactory answers was his indubitable conviction of himself being a thinking entity (*res cogitans*). As this basis proved much too narrow and largely insufficient, he was forced to introduce two additional postulates: (1) Humans alone possess a non-material, human-specific property of thought, and (2) all living things are material “automata”. By the first, an entirely subjective world-view was established, by the second, what animals and most of what humans do or are able to do can, in principle, be explained “mechanically”. These postulates led Descartes into further difficulties; trying to solve them required additional assumptions. Concordant with his system of ‘methodical doubt’, only extremely simple, distinct and clear ideas[ii] were to be admitted as foundations for the kind of special knowledge he called science[iii]. From what source can humans acquire these simple and evident statements? Such ideas are beyond human’s *reasoning* power, as they cannot be deduced from even simpler postulates[iv]. Consequently, he claimed, they can only come from God. In fact, he deduced the very existence of God from the presence in the human mind of such ideas (the so-called ‘ontological argument’ for God’s existence[v]). Further, he had to assume that God might be "subtle, but not mischievous", that is, God has not specifically decided to deceive Descartes (or Einstein). Finally, the non-deceitfulness of God guarantees the connection between Descartes' thoughts about the world and how the world really is, thereby settling his original quest. Descartes' reliance on simple initial propositions, and his trust in a God-guaranteed universal *order* or lawfulness in nature, became the basis of the mathematical way of understanding the world that has constituted the characteristic of modern science ever since his time[vi].

Galileo, a contemporary of Descartes, of course entirely subscribed to these postulates. He went a step further by experimentally (mathematically) testing the new paradigm. From the leaning tower of Pisa he dropped different bodies and, by proving – within the limits of his time – that they fell in similar manner, he showed that there are no different kinds ('substances') of matter as scholasticism had maintained, following Aristotle[vii]. Galileo's claim that there is only one kind of (atomistic) matter was deemed incompatible with the transubstantiation dogma[viii]. It has recently been suggested[ix] that this conflict, and not his defense of the Copernican system, may have been the primary cause of his condemnation in 1633. Newton, who was born the year Galileo died (1642), consolidated Galileo's ideas in the *Principia*. His first law can be stated as follows: "Every body perseveres in its state of rest, or uniform motion in a straight line, except in so far as it is compelled to change that state by forces impressed on it". In other words, all kinds of matter behave the same way; there is no 'substantial' difference between them. But there is more than that in the first law: Bodies, in rest or in uniform straight-line motion, do not exist! The first law is "only" a pure hypothesis that can never be proven, only *approximately* validated by experiment or observation. In sum, the 17th century marks the beginning of modern science, characterized by the demand of clear and distinct initial postulates and by the trust in the order and lawfulness of the world, together leading to a general reliance on universal mathematical laws[x]. Finally, it admitted a common material substrate for living and non-living entities, without resolving the question of their essential difference.

The question remained almost entirely clouded until the 19th century; remark how *recent* this epoch is in an evolutionary context of at least five million years since hominids diverged from other primates! Principally three observations caused problems. First, the preeminent position of humans, alone amongst all the creation provided with rational thought. An entirely material basis of the power of reasoning was considered inadmissible, further cementing the Cartesian split between mind and brain. Second, the amazing diversity of newly discovered fossils, presumably having lived and disappeared in the short time-span since Creation. Finally, it was accepted that in some cases life could appear ‘spontaneously’. All this changed radically when the great age of the planet became established, and when Darwin published in 1859 the *Origin of Species*. Now life – any kind of life – was considered a property of matter, of exactly the same and only matter present on Earth, subject to the same physical laws that regulate non-living things. Darwin’s evolutionary biology marks the end of the ontological preeminence of the human animal, as suggested by the gift of reason. Man, in continuity with the rest of the natural world, was now understood as the historical outcome of a mechanistic process, a non-purposive product of natural selection of randomly acquired traits that enhance fitness. Not less consequential, at least for this study, were the discoveries of Louis Pasteur. Around the same time Darwin published the *Origin of Species*, Pasteur conclusively showed that any microorganism is always derived from a pre-existing microbe, and that spontaneous generation does not occur. This established the remarkable fact that life always proceeds from pre-existing life, and that there is only one life-phenomenon and not a recurrent re-creation of living individuals. Yet, despite these groundbreaking discoveries, the question of what essentially differentiates living from non-living matter remained open.

Nor does 20th century evolutionary biology provide a straightforward answer on this for several reasons. First, the question “What is life?” has been overshadowed to some extent by the question of the ‘origin’ of life. It is now well established that life on this planet appeared around 3.5 billions years ago, and that all subsequent life forms descend from the same ‘primitive’ origin. The elucidation of this primordial event has sprouted into a research domain of its own. Second, the determination of the essential characteristics of life has become spread out over diverse separate branches of science. We mention physiology, biochemistry, molecular biology, embryology, and evolutionary biology, to name just a few. No generally accepted definition of life can be found in any of these disciplines, whereas there is a discernible tendency for each biological specialty to define life in its own terms. Moreover, each specialty is framed on a particular scale of analysis. As many orders of magnitude separate atoms, molecules, cells, individuals, and species, extreme care is required when extrapolating results valid on one scale to a different one. A case in point appeared recently: "We are now in a position [of ...] rephrasing the question What is life? in genomic terms: What is a minimal set of essential cellular genes?"[xi] This question led M. K. Cho *et al.* to state: "The attempt to model and create a minimal genome represents the culmination of a reductionist agenda about the meaning and the origin of life"[xii]. In other words, the reduction of the life phenomenon to one particular aspect, the sequence of nucleotides in the DNA molecule, is here put in correspondence with human ethical concerns which, of course, belong to an entirely different domain and scale of analysis[xiii]. Third, other fundamental branches of science, such as quantum mechanics, are rarely if ever considered pertinent (we show in Chapter 6 that this may be an unwarranted assumption). Fourth, the crucial historical aspect of the life-concept as indicated above, without which any discussion about 'life' might just as well be meaningless, is most of the times ignored. Finally, whatever turns out to be the answer, it will be framed in some language, and will clearly be following patterns long ago discerned and fixed by philosophers. Although 'philosophy' has nowadays an almost pejorative character, we feel that, unavoidably, the basic concepts and their connections, as established and clarified by centuries of philosophy, remain the sole basis of humans' educated speculations; biological science assuredly not being the exception.

The previous considerations have led us to re-examine the question "What differentiates life from non-life?" following a strategy that, in principle, has wide approval[xiv], but in practice is seldom observed. The overall method adopted in this study consists of looking at this problem from as many different perspectives, and in as much detail, as a short book allows. In each case, we tend to base our assertions exclusively on published observational and experimental data. Our working hypothesis is that 'life' cannot be understood from the isolated point of view of any particular research domain. Instead, it requires the coordinated confluence of at least the most outstanding pertinent disciplines. As evidently such a wide-ranging approach surpasses, not only the limits of our capabilities, but also the size of a reasonable text, it is clear that at most we will be able to hint at an answer and to point out the direction of future research. We now briefly explain the organization of this study.

### ***The concept 'life' as employed in this study***

For over three billion years an astonishing phenomenon has persisted on planet Earth: Life. It has become manifest in zillions of variegated ephemeral individual forms, almost all of which have by now disappeared. The two most conspicuous problems directly associated with life are: How did it arise, that is, how did it come to pass that abiotic matter became living matter, and which are the essential properties of living matter that unequivocally distinguish it from abiotic matter. In this study we eschew the first of these questions as any possible answer already implicitly assumes an unambiguous answer to the second question. How, when, and through what intermediate steps abiotic matter acquired the property of being alive, albeit a fascinating question in its own right, is a subject-matter we here settle by simply admitting two propositions. (1) Several sensible scenarios modeling this transition have appeared in the scientific literature, in conditions that can be reasonably assumed to have obtained early in the history of the planet. This allows us to conclude that a transition from abiotic matter to life according to well-established physical and chemical laws is at least plausible. (2) We admit that from this origin on, life has always remained as it is known in its present form, that is, in the more than three billion years of its history there has been only one kind of life. In other terms, we accept that life on this planet is but one phenomenon, and that in its long history life has never become interrupted nor re-started anew.

The concept to be scrutinized, ‘life’, refers here primarily to the uninterrupted planet-wide phenomenon that, according to the fossil record, has been present on Earth for over three billion years. To avoid confusion, when we refer to life in this special planet-wide aspect, we always write Life, with capital L[xv]. The present essay proposes a theoretical construct or model on hand of which Life might be (better) understood. For reasons to be given below, we call this model LifeTime. The proposed LifeTime model structurally incorporates the essential factors *distinguishing* the measurable changes occurring in living matter from those occurring in abiotic matter. Although constructed stepwise, by adding one component at a time, we consider the resulting model as a higher-dimensional whole, requiring the non-obvious mental effort to visualize the model in one fell swoop. Hence, re-thinking the life-phenomenon in the global sense here suggested is to replace the linear logical framework in which something locally defined as life is customarily understood by a complex multidimensional structural whole we call LifeTime. In chapters 2 through 8 the model is presented, whereas in Chapters 9 through 13 examples from well-studied organisms are adduced in its support.

### *Life and Time: the LifeTime unification*

Chapter 2 starts with the question: What is Life? showing why this question remains unresolved, the remarkable discoveries in all branches of the biological sciences notwithstanding. Interestingly, the global phenomenon Life, as manifest in individually living organisms, from a purely physical, i.e., from a thermodynamic point of view, remains just as controversial.  Thus, in Chapter 3 an excursus written by a specialist illuminates this problem. We then discuss the significant constraints imposed by the empirical fact that living matter is always in a state far from thermodynamic equilibrium.

The concept ‘time’ unavoidably enters the picture. Global, planet-wide Life is of course a *historical* fact, and as such inextricably time-like. Likewise, in its transient manifestation as diverse ephemeral organisms, Life can only be thought of as a physical process locally developing in time. The unstoppable asymmetric past-to-future time flux results in individual life as never being, but permanently becoming. Hence, time for a living organism never - so to speak - materializes: Whatever time-span an ephemeral living organism can envisage is always future time, the unknown period before its inevitable transformation back into abiotic matter. To signal that we do not understand time in the usual way, i.e., as what a clock dial shows, but as this finite, unknown, future “not-yet-dead”, we write Time, with a capital T, and argue that no understanding of Life separated from this Time is possible. This leads us to suggest the LifeTime unification, the validation of which is the main endeavor of this essay.

In Chapter 4 we treat the problem of time in more detail. This chapter epitomizes our method: the apparently so commonsensical concept ‘time’ is illuminated from several different perspectives. The accent here is placed on the past-to-future irreversibility of the so-called arrow of time. But no single approach provides a definite answer, only their ‘consilience’ may allow a better way to *think* about the question.

Thus, we believe the prevalent time concept to be directly biased by innate structures of the human brain, that is, that the commonsensical notion time is, in the main, a human artifact.

### *The unification of Life and Time*

Life and Time, as described, are of course entirely disparate concepts. To construct with them a structural whole may thus seem quite inadmissible. Still, there are illustrious precedents which, rather pretentiously, we may be allowed to invoke. To name only a few: Maxwell's unification of electricity and magnetism, Einstein's unification of space and time, Heidegger's unification of being and time. Fusing radically distinct concepts into an inseparable whole comes, however, at a price: difficult theories, the mastering of which requires years of hard apprenticeship, replace previous commonsensical intuitive models. Undaunted, we propose that the essential feature distinguishing living from abiotic matter may be suitably represented by a model that fuses into a structural whole Life and Time. However, this model requires further components as will be shown.

### *A limit: The common language*

At this point (Chapter 5) we interrupt our exposé by analyzing one of the major limiting factors of our study: our common language. Mankind's communicable languages all share a set of common features, many of them at least in part innate, which probably derive from the physiological constraint of mainly being restricted to convey information by modulating an air flow through the mouth. We believe it is especially important to remark in this context that a relatively complex form of a proto-language, at least substantially more complex than anything presently found beyond humans, must have appeared in hominids many hundred-thousands of years before present. In other words, insofar as these findings can be extrapolated to modern humans, if language is such an old adaptation in hominids, then probably its most primordial terms, life, time and order, directly relate to, and are crucially biased by, innate brain structures.

Precisely, the effort to escape the innate constraints manifest in our strictly linear communication system is what leads us to propose as model for Life a multi-dimensional whole, a model that pretends to transcend such a linear, one at a time, concatenation of ideas. The initially mentioned necessity of taking into account humans' pre-historical antecedents was meant in the following sense: Elucidation of the Life phenomenon is only possible in the light of the long evolutionary history of humans. We should never overlook the unavoidable bias fixed by natural selection eons ago, in completely different settings, in the brains of hominid hunter-gatherers.

### *The Algorithm*

Life and Time are only the first components of the model. A further element of the LifeTime structural whole is an information-theoretic component we call the Algorithm (Chapter 6). LifeTime-forms are 'individual' only in a coarse-grained sense, as no organism can be understood detached from its environment *lato sensu*. This includes the physical parameters outlining the particular environmental niche, the physiological parameters gauging the internal state of an organism, plus all the other life-forms sharing the niche with this organism, such as parasites, predators, symbionts, and conspecifics. Organisms decode the gigantic stream of information issuing from their environment by means of limited sense organs. Whichever forms they take, limited sense organs always are the stochastic result of an organism's evolutionary history. Due to the limits of these sense organs, environmental information is filtered, biased, and thereby drastically *simplified*. The complex manifold interrelationship of organisms and their environment (*lato sensu*) might be visualized by defining a parameter that measures the 'deficit' separating an individual from its theoretical optimal condition in that environment (see below). We here argue that organisms can always evaluate, by means of their limited sense organs, the deficit measure relevant in their particular environmental conditions[xvi].

In the LifeTime model, this sense-perceived deficit-information is considered to constitute the input to a LifeTime-Algorithm, the output of which is behavior leading the individual towards a reduction of the perceived deficit, that is, towards a state closer to its particular theoretical optimum. Hence, we argue that living organisms at all times process the environmental information as decoded (and simplified) by their sense organs according to this LifeTime-Algorithm. In other terms, we propose that ‘innate’ behavior of living matter is in the main the information-theoretic output of a deficit-reducing Algorithm. Of course, information processing is ubiquitous in nature and not restricted to living matter. The crucial difference lies in the presumption that living entities process impinging environmental information according to a LifeTime-Algorithm shifting the individual organism closer to its optimum condition. But what is this ‘optimum’? The optimum for a given organism in a particular environment is represented by those conditions that maximize its survival and reproductive success. Maximizing survival and reproductive success, of course, refers to leaving the greatest number of viable offspring (copies of its genes) in the next generation. We argue that organisms interpret the sense-perceived environmental information as providing them a measure gauging their particular distance from that optimum. This measure is the input to an Algorithm by which organisms strive to reduce that deficit. Endeavoring to reduce the deficit requires resources in addition to simply surviving. Resources are always scarce, or will soon become so, in every habitat. Inescapably, efforts tending to reduce the deficit are at conflict with similar efforts by all the other consumers of the same scarce resources. The conflict resulting from the scarcity of resources refers especially to conspecifics. The Algorithm, then, tends to enhance the conditions which maximize the chances of completing the life span of an organism so as to leave *more* viable offspring (copies of its genes) relative to other conspecifics sharing the environment. The function and output of the Algorithm is not always[xvii] that of unconditionally increasing the survival chances of an individual, but behaviors enhancing its *relative* reproductive success. We insist: It is not survival and reproductive success *per se* that characterizes *the result* of the LifeTime-Algorithm, but reproductive success *relative* to other conspecifics sharing the environment and competing for its scarce resources.

Unavoidably, the postulated Algorithm has apparent traces of teleology, as it seems to suggest that living organisms “know” their position relative to “the others” sharing the habitat and then “decide” to implement efficacious strategies in order to best outperform them all. Let us dispel this suspicion with an example. Newton’s gravitation is an algorithm evaluating the attractive force between massive bodies. Hence, stars and planets “feel” this attractive force acting along the line connecting their respective centers of mass. No foresight or superior wisdom on each occasion directs massive bodies to exclusively interact according to this particular kind of attraction, that is, to “measure” the distance separating them and then “remember” Newton’s formula instead of “choosing” to act in a different way. In our view, just as massive bodies react according to Newton's algorithm, so LifeTime-forms interact with their environment according to a particular Algorithm outputting a behavior tending towards the reduction of their particular deficits. Just as Newton's algorithm determines the interaction between massive bodies to conform out of an infinity of possibilities to its restrictive arrangement, so the Algorithm, out of the infinite available possibilities, consistently results in a narrow range of space-time paths for LifeTime-forms to follow.

But how and where is the Algorithm implemented? In human and non-human animals the Algorithm must be hardwired in neuronal structures, whereas in bacteria, protozoa, fungi, and plants, a direct molecular correlate can be shown to exist in some cases. In animals, where in a narrow sense the term 'behavior' is of course more apposite, neuronal structures in the brain react in particular ways to external (and internal) stimuli. By classifying stimuli (sense-perceived information) as either appetitive or aversive[xviii], the result of the Algorithmic information processing can be outlined by invoking a network of rewards and punishments. Reward is an operational term for describing the positive value an individual animal ascribes to an object, a behavioral act, or an internal physical state. The reward value associated with a particular stimulus is dependent on the internal state of the individual at the time it encounters the rewarding stimulus and is further dependent on its previous experience. The neuronal connection between reward and prediction based on previous experience of a stimulus has been documented in many conditioning experiments. With this terminology[18], the output of the Algorithm could be described as consisting of a system of rewards and punishments leading the individual towards a reduction of the perceived deficit. The LifeTime model predicts the Algorithm to be operative in *any* life form, at every level that 'life' can be encountered. Hence, the Algorithm must already be operative at the level of the single cell, but at this scale of description a different approach is required.

We present in Chapter 6 some suggestions proposing a quantum mechanical interpretation for the postulated Algorithmic information processing at the single-cell level. Information processing in the sense here employed is nothing but a computation: received information is processed, according to some fixed rule, whereby it is transformed into the output or emitted information. The Turing machine, an imaginary device hypothesized of being capable of performing any possible computation, epitomizes the current computational paradigm. It is based on a strictly linear approach, as a Turing machine computation proceeds one step at a time. In the last few years the idea of a quantum computer has gained ground; working models, albeit the simplest ones, have been presented. A quantum computation proceeds from input to output simultaneously evaluating all possible combinations, as reality, in quantum mechanics, is the simultaneous superposition of all its potentialities. The speed of arriving at an output via a quantum computation is thus immensely superior. As in the last resort a cell is nothing but the constant interaction of quantum elements such as atoms, a quantum approach may explain some of the most astonishing capabilities of living matter. For instance, proteins in the living cell fold into their native conformation in less than a second, thus finding the 'correct' result among the gigantic number of possibilities in such a short interval, whereas with a Turing machine approach this would take billions of years[xix]. As stated, LifeTime organisms are entirely based on atoms and molecules and consequently obey throughout the laws of quantum mechanics, counter-intuitive as they may seem. Also, the perception and filtering of environmental information is predominantly realized at the molecular level, basically by the proteins coded by the genome. For instance, the plethora of molecular receptors on the cell's membrane, upon contacting their ligands, start different information-transducing cascades that further interact in non-linear ways with other signaling pathways, determining the final 'behavior' of the cell. Hence, it may be stated that at the cellular level LifeTime-forms evolve as a quantum mechanical superposition of all possibilities. The summation of all its cells is the macroscopic individual. On the macroscopic level, a new phenomenon appears: the decoherence of the superposition of all the quantum states so that macroscopic observers always observe a unique result. We suggest in Chapter 6 that the postulated Algorithm is the overall quantum mechanical Life-specific rule biasing the outcome of this superposition so that, most of the time, an external (macroscopic) human observer discerns behaviors enhancing the relative reproductive success of individual organisms.

Admitting thus the presence of a ubiquitous Algorithmic information processing according to the LifeTime model, what behavior can be predicted based on this model? If the Algorithm permanently and constantly processes environmental information, as perceived by a given individual organism, with the sole view of reducing its particular deficit, the main result can be no other than permanent relentless *competition*. This arises from the fact that resources are always scarce and “the others” stand in the way of the attempted deficit-reduction[xx].

### *The brain*

In the historical-evolutionary approach we favor, any animal brain, human or non-human, is the result of a long non-purposive development only shaped by natural selection. For hominids, the stochastic occurrences molding their brains over evolutionary epochs may have taken place in circumstances completely different from those now facing modern humans. The question we here raise is: Is the split between brain and mind, historically associated with Descartes, a convenient ‘philosophical’ artifact that eventually will be removed by modern science, or does it represent part of the brain’s hardware, and thus must be reckoned with as a further[xxi] limiting constraint? In any case, modern neurobiology has not yet succeeded in completely exorcising the dualistic split between brain and mind. We briefly review in Chapter 7 the aspects of this ancient problem in the light of the LifeTime model. It turns out that recent research provides quite compelling evidence for the Algorithmic functioning of the brain, at the level of individual neurons. Thus, although the proposed model cannot explain away the notion of ‘mind’, it finds strong support in recent neurological studies of the ‘brain’.

This said, the relationship between our mental constructions and the external reality these constructions are assumed to mirror remains, in Einstein’s words, extra-logical. What does this mean? Humans interact with the external reality via their sense organs. We already mentioned that this is equivalent to a drastic simplification. Nevertheless, the question Descartes already posed was “What degree of confidence can we assign to the mapping from the world as it appears to us to the world as it is?” The world as it appears to us is the perceived phenomena (from the Greek *phainô*, to appear). Modern science is satisfied if a well constructed *model* allowing testable predictions has so far resisted all falsification efforts. Or resists such efforts better than a competing model, or if the chosen model is simpler and more concise than other competing models. This of course has led to an astonishingly successful accumulation of knowledge. But sense-perceived phenomena are always drastic simplifications, and the majority of scientific models only cover the most elemental situations (Chapters 2 and 3). Finally, whatever knowledge the scientific approach has provided, it remains a mental construct and thus we already are moving in a circle. In sum, to radically eliminate the mind and entirely reduce human mental activity to neuronal architecture or to neuronal chemistry remains an open research field.

***Trust-in-order***

The theoretical optimal condition and the associated deficit for a given individual can only be ascertained in an environment with properties that remain meaningful at least over its life span (Time). Widely fluctuating environments preclude the correct functioning of the Algorithm. This directly implies that the Algorithm is functional only under stable conditions. Stable here means: fluctuations not surpassing a given threshold. In other terms, implying the presence of *order* in the environment. Put differently, stability of an environment means, for an organism, that its limited sense organs are capable of continuously gauging its particular deficit from optimal conditions, as they apply in that habitat. This allows us to define *adaptation* in the LifeTime model: A particular organism can be said to be adapted to a specific environment if its particular Algorithm is functional in that environment. Thus, the sense-perceivable physical conditions of a given environment have led over evolutionary periods to a fine-tuning of the sense organs *and* the Algorithm of the organism, and this fine-tuning *is* adaptation. But always presupposing stable and permissive, i.e., ‘ordered’, environmental conditions[xxii].

Consequent with our adopted methodology, in Chapter 8 we study ‘order’ from different perspectives, taking care not to confuse this term with the probability of past experiences being bona fide predictors of the future. Order in the LifeTime scenario is the undefined result of the conjunction of several factors. It directly depends on the particular perceptive capabilities of the organism, on the scale at which the environmental quality is analyzed, on the drastic simplifications of the environmental information registered by means of limited sense organs, and on the fact that the organism has become adapted to that environment. Hence, environmental ‘order’ is a physical property the definition of which depends on the environment as much as it depends on the particular organism adapted to it. Consequently, we here replace the term order by *trust-in-order*, as what here really counts is not to clarify a certain hard-to-define concept of order, but to pinpoint a necessary information-theoretic component of the LifeTime model.

Successful survival and reproduction resulting from a functional Algorithm requires the prior simplification of the sense-perceived environment. Only then, when the environmental complexity has been filtered out, within a certain degree of approximation, in a given restricted range of conditions, within a limited context, and not beyond a characteristic period of time, can an environment be *assumed* to be predictable for a limited subset of individuals. This assumption, here called trust-in-order, corresponds to an information-theoretic fine-tuning of the Algorithm. It is equivalent to stating that an individual, Algorithmically processing information originating from an environment, is adapted to that environment. This fine-tuning of the Algorithm, dependent on the particular environment (*lato sensu*), has a direct correlate in the resulting behavior of an individual. The LifeTime model predicts that organisms, provided they have become adapted to a particular environment, behave *as if* they *trust* that the environmental order necessary to keep their Algorithm functional is guaranteed in (future) Time.

With the inclusion of the trust-in-order component the LifeTime model is complete. In the next chapters we test the model by examining for different species the validity of its predictions.

### *Sexual competition, the Algorithm, and the barn swallow*

The LifeTime model predicts for all life forms a permanent effort to reduce their perceived deficit. As this requires resources in addition to those needed just to survive, the Algorithm directly exacerbates competition among individuals sharing a particular habitat. In sexually reproducing organisms, choosy individuals (usually females) may compete intensely for access to individuals of the other sex deemed to have properties leading to enhanced reproductive success. In Chapter 9 we test predictions that arise from the LifeTime view by scrutinizing several aspects of the life of a small migratory bird, the barn swallow. Intense competition relates directly to the relative amounts of resources available for individuals differing in phenotype (appearance, behavior and physiology), but therefore also for the perceived deficit between optimal conditions for growth, survival and reproduction and those experienced. This deficit directly affects the general “well being” of individuals (the reward[18] system). Although restricting our example to just this animal, we imply that the behavioral pattern of this small bird can be considered to be a general case showing more similarities than differences with, for instance, humans.

The Algorithmic competition for reproductive success includes, in sexually reproducing organisms, the effort to choose the ‘best’ available mate. This form of competition should have given rise to the evolution of exaggerated ornaments or other desirable features, called secondary sexual traits, with which to preferentially attract mating partners - and thus eventually outperform less gifted competitors. Darwin alluded to the cost of secondary sexual characters in his writings, and numerous subsequent studies have demonstrated that males of a diverse array of species suffer such viability costs of their ornamentation or display. The presence of adornment results in increased risks of being eaten by predators and acquiring parasites and diseases. The sexually attractive trait in male barn swallows is the length of the outermost tail feathers. This is an attractive but costly trait. Males pay important survival costs for their ornamentation. These costs of ornamentation reduce the fitness of the individual, and therefore the average reproductive success of the barn swallow. Such ornamentation is, however, still selected by females because the costs of ornamentation are by far exceeded by the reproductive benefits acquired by the most well adorned males.

But preferences for males with particular phenotypes and the resulting mate acquisition are not necessarily the end of the game: sexual competition is also ubiquitous in other domains. Observations coupled with paternity studies have shown that covert sex and extra-marital liaisons are commonplace throughout the animal kingdom. The best way to understand such relationships is that mating systems such as monogamy put severe constraints on female mate choice. Given that there are few very attractive males available, only the first females to choose will have a chance to mate with the most preferred male in the population, while the last female to mate may have no choice at all. However, females are able to adjust their mate choice by copulating with such attractive males if constrained in their mate choice. Hence, female copulation with multiple males considerably increases the intensity of sexual selection through an increase in the variance in male reproductive success. As a final aspect of Algorithmic sex-dependent competition we briefly look at the phenomenon of infanticide. Summing up, the unceasing competition for reproductive success relative to all “the others”, fought out at every level, is consistent with the presence of the Algorithm.

### *Algorithm, environment and stress*

Biological systems such as swallows and humans are continually processing the information issuing from their environment, understood as the habitat, “the others”, and the internal state of the individual. Organisms modulate their behavior as a function of the order-structure assumed to obtain in their environment. This modulation was incorporated into the LifeTime model as trust-in-order, an information-theoretic term indicative of the degree of fine-tuning of the Algorithmic software, equivalent to the adaptation of the individual to its environment. The Algorithm and trust-in-order information processing leads to a disjunction[18] of perceived stimuli as being either aversive or appetitive. Individuals behave by avoiding the former or reinforcing the latter, thus fundamentally constraining their options. Importantly, aversive information is interpreted as an alarm signal, and these alarm signals automatically initiate defensive behavioral reactions. This *modus operandi* can be found from bacteria, to plants and animals. In humans, distressing alarm signals may not always be devalued or removed as, for instance, in some mental disorders. In normal conditions, alarm signals produce physiological effects that have evolved for prompt but limited reactions to danger. However, their continuous action is in most cases directly detrimental to the individual. In these circumstances, the individual may be unable to cope with the resulting *stress*[xxiii]. In Chapter 10, a specialist analyzes the intricate interrelationship between stress and health status and how it affects survival and reproductive success. The conclusions of this analysis lend support to the validity of the predictions implied by the LifeTime model.

### *Religious Belief*

In all known present and past human societies, at least in those that left decipherable testimonies of their cogitation, religious belief is indubitably attested. In Chapter 11 we suggest that religious belief may be a direct consequence of the trust-in-order feature of the LifeTime model and, thus, that religion most probably has a discernible biological root substantiating its ubiquity and perseverance. Moreover, we argue that religious belief may be an adaptation arising early in human evolution.

For a great number of animal species, humans included, individuals form a social organization. This organization is part of the environment and contributes to the determination of each individual's deficit. For humans, even in the earliest stages of their development, competing conspecifics constitute a relatively complex social organization. When language in its most aboriginal form appeared, it added a further degree of complexity to the environment. On the one hand, the environment for primitive humans is now enlarged by a shared mental world; on the other, language makes deceptive strategies only too easy.  Language is a means to convey signals. In the entire animal world, the weight of a conveyed complex signal is approximately proportional to the cost of producing it; this enormously simplifies the environment by facilitating the distinction between honest and deceitful signals (Chapter 9). However, the extremely low cost of linguistic utterances makes the distinction between honest and deceitful signals problematic. Language represents a crucial environmental change for humans, the adaptation to which requires ways of ensuring a correct gauging of the deficit in these altered conditions. Thus the deficit, and the ensuing Algorithmic competition, take completely novel forms that in turn have led to novel patterns of adaptation.

In the LifeTime model, adaptation filters out the complexity of the environment so as to attain the required fine-tuning of the trust-in-order component. As will be pointed out in Chapter 8, 'order' is a restrictive property only definable in drastically simplified circumstances. It follows that human adaptation to the novel complex (social) environment requires its perceptual simplification and a restoring of trust-in-order. Deficient adaptation to the novel situation may lead to stress and its obnoxious consequences, as described in Chapter 10. Here the adaptive perceptual simplification conflates with a clarification of the individual's status in the altered (social) situation and the establishment of novel means of information processing.  We argue that what in humans is called 'religious belief' is, at least in part, the adaptation to the challenges arising from a modified social structure resulting mainly from the acquisition of a complex language. This adaptation must be very ancient and deeply ingrained, explaining how for so many centuries humanity has struggled in vain to provide a rational underpinning for its various religious beliefs.

In the most important recorded ancient religions a supreme god becomes established only after a violent confrontation with the powers of chaos. Victorious, his primary function consists in guaranteeing the maintenance of order: the seasons, Nile floods or necessary rains, fertility in humans and useful animals, and last but not least the social order as represented by the king. Submission under the unquestioned authority of the king, in principle an aversive stimulus, is now re-cast as a primary virtue. Another fundamental role of the gods is assuring the validity of oaths, and the enforcement of the attached dire curses. Oaths were during millennia the only manner of (partially) checking deceptive maneuvers by conspecifics that, with language, had become only too easy. By keeping apart the trustworthy from the unreliable, the enforcement of oaths leads directly to a simplification of the environment. The gods thus fulfill several roles. They drastically simplify the environment, as now the forces of nature and the status of the individual are more easily categorized. They provide mechanisms to cope with a much wider range of environmental stressors, basically by favoring submission schemes in which a lower status can be reinterpreted as an appetitive stimulus. And by enforcing oaths the gods allow a disjunctive categorization of conspecifics as either honest or deceitful. Simplification of the environment is indispensable for the gauging of the particular deficit, and thus a prerequisite for Algorithmic functionality, while a fitness enhancing reinterpretation of external stimuli signals a fine-tuning of trust-in-order, i.e., adaptation. As a final point, we remark that several medical studies have shown a direct relationship between strong religious belief and health, thus showing a fitness advantage being associated with the acceptance of submission schemes.[xxiv]

We provide two examples substantiating our claims. First, in Chapter 11.1 a specialist provides an overview of Hesiod's *Theogony*, showing how the ancient Greek understood their gods as simplifying guarantors of environmental order. A similar conclusion is provided by the overview in Chapter 11.2 of ancient Mesopotamian religious beliefs. This, one of the oldest recorded testimonies of the role of the gods, again supports our model. We have chosen these ancient examples primarily because they reveal their biological roots in a less culturally clouded manner than, for instance, in present day religious manifestations. In sum, in the LifeTime scenario religious belief appears as a predictable phenotype in humans.

### *The placebo effect*

Placebo is a Latin term for the medicine-like control treatment containing a physiologically inactive substance that is used in tests of the efficiency of new types of medicine. The use of a placebo treatment and a real medical treatment in a double blind design is a standard means to allow distinction between true pharmacological and psychological effects. A comparison of the health status of volunteers receiving a placebo treatment and those receiving none at all often differ dramatically, with purely psychological effects causing an improvement in health status[xxv]. The literature on placebo effects is extensive although researchers only recently have started to gain a scientific interest in the placebo effect as such. Hence, placebo has changed status from a pure control treatment to a potential treatment of its own.

The human immune system is influenced by feedback between mental and health state. This pattern of connectivity may render interpretations of the possible causal relationships difficult, particularly in humans where experiments are often not possible. However, the feeling of well being either based on the state of self or that induced by an inactive substance, such as a placebo treatment, has been shown to directly affect the probability of recovery.

We mention in Chapter 10 the noxious consequences of unchecked stressful circumstances. Stress is not a state confined to modern city-dwelling humans. Although numerous definitions of stress exist, many biologists agree on defining stress as the physiological state that results from the incongruence between optimal and experienced living conditions for that particular individual, i.e., as a consequence of an intolerable deficit, as defined in this study. As conditions deteriorate, the costs of maintenance of normal physiological processes will increase, and a smaller proportion of available resources can be utilized for growth, survival and reproduction. Situations of sub-optimal environmental conditions are commonplace for all living organisms for part or all of their lives, and a number of different coping mechanisms have evolved that adjust the allocation of limiting resources to essential activities that ensure a high survival probability of the individual. Placebo effects may be one of those coping mechanisms.

As will be shown in Chapter 12, in the LifeTime scenario placebo effects fit in naturally. To function, i.e., to stay alive and compete for relative reproductive success, individuals assess the deficit representing the input to their Algorithm. The measure of deficit is the result of decoding the particular environment by means of limited sense organs, thereby drastically simplifying it. This simplification is essential to establish an order, so that past experiences can be considered by the (adapted) organism to remain meaningful in future situations. The term ‘environment’ in the LifeTime model also includes the internal state of the organism. But no individual ever attains the optimal condition, a situation that may be especially stressful in more complex social settings. Adaptation to stressful environments is equivalent to a simplifying reinterpretation of the environment, especially as referred to the most prominent stressors. Religious belief was already shown to be such a simplification. Placebo effects likewise result in a simplified *internal* environment. The result is a substantial reduction in complexity and the re-establishment of a dependable world, resulting in the reinterpretation of aversive stimuli as appetitive, thus directly leading to well feeling. Since well feeling undoubtedly has a physiological basis and is associated with a superior health status, placebo effects follow naturally.

### ***Self-deception***

The main difference between other life forms and humans lies in the fact that humans may become, at least in part, consciously aware of their deficit in a particular situation. A perceived discrepancy between actual state and the optimum that maximizes growth, survival and reproduction may cause stress-induced immuno-suppression[xxvi]. The larger the consciously perceived deficit, the more pernicious may be the stress induced by this situation. The LifeTime model predicts that a behavior masking the conscious awareness of this deficit will be selectively favored. This will be the case if (1) it relieves the otherwise severely fitness reducing stress, and (2) if it enhances social status in relation to “the others” by better deceiving them, thereby leading to individual gains in social and sexual competition. The first behavior is treated in Chapters 10, 11 and 12; the second, called self-deception, is analyzed in Chapter 13. Thus, self-deception refers exclusively to the sham deficit-reducing, stress-relieving mechanism operating in a particular individual in a social context.

Self-deception is the mechanism by which humans distort or mask information about their own true status to obtain an advantage in competition for limiting resources. This mechanism effectively enhances fitness of the self-deceiving individual. This fitness enhancement is directly correlated with the superior social position that an individual may achieve by masking his true status for others. What in the first place has led to the evolution of self-deception in humans is the ubiquity of deception commonly found in all biological systems[xxvii]. Self-deception mainly occurs in association with sexual and social competition, during which individuals exaggerate and perform other self-deceptive activities so as to enhance their fitness at the expense of others with less developed self-deceptive faculties. Self-deception is a natural extension of mind reading, or actually being mind read, since self-deception hides for self and thus also for others (but does so in an exaggerated way) the status and the qualities of self. Self-deception as we know it is an entirely human phenomenon, although there are no reasons to believe that similar phenomena may not also occur in other animals.

Self-deception comes in a frighteningly large number of disguises. This should be no surprise given that humans have been perfecting hidden belief systems for themselves and others for millennia, with only the most ingenious cases of self-deception not being countered. The most exaggerated animal and plant signals have evolved in social contexts of conflict such as that between potential mates, between parents and offspring, and between predators and prey. The great diversity of signals and the incredible intricacy of design of these signals bear direct testimony to the high level of conflict.

Chapter 13 mainly deals with self-deception in its own right, but self-deception also plays an important role in understanding the phenomena investigated in previous chapters. For example, self-deception makes individuals believe that things are better than they actually are. This relates directly to the effects of well being on immune function and health status (Chapter 10). Similarly, self-deception plays an equally crucial role in understanding placebo and self-healing (Chapter 12). Such effects can only arise in a context where self is unconscious about the actual mechanisms at work. The role of self-deception in religion is certainly no less than in any of the previously mentioned contexts (Chapter 11). Finally, the general perception by humans of their "true" status in their particular social context is masked by a smoke screen of self-deceptive phenomena that include hope, love, nationalism, racism and many others. These different phenomena obviously interact in a number of intricate, synergistic ways.

### ***Concluding remarks***

The LifeTime paradigm allows an elucidation of the life-phenomenon independent of anthropomorphic qualities such as purposefulness, foresight, or the 'wisdom of nature'. Also, debatable categories such as complexity, harmony, lawfulness, and others, can be avoided. To show this, we analyze the mechanisms of social and sexual competition as an evolutionary force in barn swallows and humans. The role of religion in human society and the mechanisms that have given rise to religious beliefs will be related to the LifeTime concept, and the beneficial effects of placebo and belief in maintaining health and hence providing an advantage in social competition will be discussed. Finally, the role of self-deception in human existence will be investigated. We consider that these examples lend support to our claims about the LifeTime concept, showing the ways in which it affects the evolution of mechanisms that relate directly to the irreversible arrow of time, the ubiquitous discrepancy between actual and optimal conditions for growth, survival and reproduction, and the resultant perpetual competition for scarce resources.

# *2. Life*

### *Focus*

This study proposes a conceptual model on hand of which the difference between living and abiotic matter can unambiguously be established. It will be guided as far as feasible only by explicitly stated, scientifically controlled observations. Individual constituent aspects will be incorporated stepwise into the model. They are considered to be the discernible components of a unified construction of a higher dimension. Hence, the end result should be thought of as a structured *whole*. The focus of the research is the astonishing occurrence, for billions of years, of the most diverse organisms in almost any location on this planet. Any reference to life in this global-historical sense is written Life, with capital L. The conceptual model to be constructed is called LifeTime. Considering LifeTime as an indissoluble whole while nevertheless discussing its discernible structural aspects is here presented as a possible rephrasing of the question: What essentially distinguishes living from abiotic matter?

At first sight this endeavor may appear entirely futile, for what can be more commonsensical and better understood than life? Don't we all know what life is, and don't we all just too well understand what its contrary, death, is? Agreed, perhaps we all know, or at least we all believe we know. Still, the customary comprehension of the concept life might be decisively influenced by biases originating from our evolutionary past, thus inextricably linking our conscious perception of life to the way our brains are hardwired. This would put 'life' in the same category as 'mind', 'time', 'order', and similar elusive concepts. A study of life will thus inescapably require an examination of the *biological roots* of the key categories biasing its comprehension.

A revision of this question has a partial analogue in mathematics. For twenty-five centuries mathematics was sanctioned as the ultimate paradigm of pure reason and posited as the quintessential method that all human effort aimed at the acquisition of "true" knowledge had to follow. Then, in 1931, Gödel changed all that by proving that mathematics was either inconsistent or incomplete and, in 1936, Turing proved that certain fundamental mathematical assertions, precisely those that might constitute the foundation on which this ideal, error-free reasoning method had to be based, were undecidable. This *Grundlagenkrisis* ended two-and-a-half millennia of human illusion by thrusting into a glaring light the limits of mathematical reasoning and, by implication, the limits of human pure reason as such[xxviii]. After these discoveries, it became necessary to replace the view of mathematics as an ideal philosophical construct by a conception resembling the one adopted by modern physics, in that the quest for a definite founding set of self-evident axioms and rules of inference was abandoned[xxix]. It is our conviction that the recent advances in all branches of biology require a similarly uncompromising critique of the life phenomenon. As a result, here we suggest replacing standard easy-to-grasp traditional speculations about life by the complex multidimensional model we call LifeTime.

### *Partial aspects of Life*

Several prominent features of biological systems are commonly taken as constituting their defining properties. In our view, none of these are sufficient for unequivocally differentiating living from abiotic matter. However, they must be considered as partial descriptions of Life as incorporated in the proposed LifeTime model.

Life from a *physical* perspective can be characterized as the transient stable state of a local, partially secluded system far from thermodynamic equilibrium, requiring a constant input of energy while increasing the entropy of its surroundings by dissipation a part of that energy as waste and heat. Such a system, dissipating energy while remaining in a state far from equilibrium, can only exist if sufficiently isolated from perturbing environmental fluctuations by an adequate barrier or “membrane”. Thus, life can physically be defined by the set of properties that allow individual membrane-bound entities to maintain a transient state far from equilibrium under perturbations arising from the environment. *Chemically*, biological systems are characterized by a myriad of enzyme-catalyzed reactions, which mostly take place in the condensed phase. These reactions proceed with remarkable efficiency and selectivity as rarely found in non-biological systems. The solvent directly surrounding the active site of vital chemical reactions in biological systems is quite often a highly organized protein with a three-dimensional structure directly influencing the chemical behavior at the center of reaction. This architecture is crucial, but also apparently quite universal: Life appears as the result of applying a common set of chemical assembly rules to the elementary atomic and molecular building blocks, consistently producing patterns such as spirals, helixes, pentagons and triangles. One might then consider the maintenance of such patterns and architecture a fundamental property of life, and life might be defined as the result of the counteracting *chemical* forces that tend to stabilize its structure, while keeping the entire system in a transient state far from thermodynamic equilibrium. From a *developmental* point of view, the manifold forms of life arise when genes are transcribed following complex patterns. "Single genes can be expressed in several distinct domains, each of which is precisely delineated in space, time, and by level. A complicated regulatory apparatus controls the development of the embryo. In the genome of an animal, regulatory regions called promoters typically span a few hundred to several thousand bases of DNA. [...] Scattered through these promoters can be dozens of regulatory elements that act as binding sites for distinct transcription factors"[xxx]. Again life appears as the result of an overall organization correctly guiding the development of chemically complex membrane-bound systems far from thermodynamic equilibrium. Life could thus be defined in terms of information contained in the DNA molecule allowing construction of the myriad of different forms in which life has appeared from a reduced set of chemical building blocks. However, the state far from thermodynamic equilibrium is only transient: According to the second law of thermodynamics the system unavoidably degrades, i.e., "dies". Life can only last billions of years if degraded systems are replaced in time by new entities. This of course is *reproduction*; we take up this subject below.

From an *evolutionary* perspective life is associated with variation, selection, inheritance and evolution by natural selection. Biological entities differ for environmental or genetic reasons, and they compete with other entities for scarce resources. Entities that are better able to exploit resources and win at competition with others grow, survive and reproduce at a higher rate. Any character that provides an individual entity with an advantage, and that has a genetic basis, can be transmitted to offspring and hence accumulate during subsequent generations due to differential reproductive success. Obviously, chance and entirely stochastic phenomena may affect the evolutionary trajectory by influencing survival of individuals, but also the range of entities on which selection acts. In such a view, life is the result of an historical process, starting from an a-biological setting leading to extant organisms. In other words, life appears as an accumulation of changes over geological time, each change just a chance event that as a consequence provided the concerned entity with a fitness advantage in a particular environmental situation. This does not preclude that many adaptations are lost over geological time, presumably when no longer of adaptive value under changing circumstances, or for entirely stochastic reasons.

Each of these features must be considered indispensable constituents of the component Life structurally incorporated in the LifeTime model, but none alone neither their sum is sufficient to unambiguously differentiate a biological system from abiotic matter. To achieve this end, an additional primordial property of the planetary phenomenon Life must be considered.

### ***The overlooked factor: Time***

Life is usually defined either from some or all of the above mentioned different properties. However, neither of these are in themselves the most primordial, the logically *first* in an Aristotelian sense On the other hand, *time* is in all of them an aspect that is simultaneously included and overlooked. Time is a primordial defining property of Life, as we will show.

First, life is physically a *temporarily* stable state far from thermodynamic equilibrium. Chemically, life proceeds in chemical reactions that necessarily develop *in time*. Likewise, from the developmental viewpoint, the progression from embryo to adult proceeds *in time*. Reproduction is similarly a process that progresses in an *irreversible future-oriented time direction*. It follows inescapably that the concept time is inextricably entangled with life. But which is logically first? Can these two concepts be considered separately? Here, we argue that these two should be *unified* so as to form a new concept: LifeTime.

### ***The LifeTime unification***

The physical sciences have witnessed the *unification* of several apparently disparate concepts. Initiating the series in the 17th century were Newton's laws of gravitation unifying radically different (for the people at the time) phenomena. The fall of heavy objects on Earth, the tides of the oceans, the revolution of the Moon around our planet, and the revolution of the Earth plus the Moon around the Sun, all became unified under one law. In the 19th century, Maxwell's unification of electricity and magnetism had an especially striking consequence. Light, which the God of Moses' book of Genesis created on the very first day, now had to be understood as just one particular manifestation of the unification of the two conceptually completely different phenomena electricity and magnetism. The most celebrated unification was that of the even more fundamentally differentiated concepts of space and time into the unique four-dimensional space-time of relativistic physics. In this scenario, time and space fuse into space-time in such a way that traditional time loses its meaning. Not only is strict time-simultaneity abolished, but the unambiguous division of the world into "events that have already occurred" and "events that have not yet occurred" is no longer objective and essential, but arbitrary and entirely dependent on the particular observer. Furthermore, if the relativistic requirement for the laws of physics being independent of the frame of reference chosen for their mathematical expression is taken seriously, then traditional time is abolished. Now *change* in its widest sense (the *kinêsis* of the Greek philosophers) is only an illusion resulting from our particular perceptual mode of living, similar to the illusion of movement resulting when playing a reel of film[xxxi]. The latest addition to the series is the grand unified theories (GUTs) of contemporary theoretical physics. According to these theories, the fundamental interactions among elementary particles, the electromagnetic force and the weak and the strong nuclear force[xxxii] are the outcome of spontaneous symmetry breaking processes of a basic super-symmetric state[xxxiii] of energy and matter only encountered in the universe "shortly" after the Big Bang. Unfortunately, all these unification projects come at a high price: Instead of providing easy-to-grasp, commonsensical interpretations of physical reality, intricate mathematical descriptions reserved for the specialist take their place. However, if these difficult theories are testable, and if they partly lead to a better understanding of the world, then the greater effort is deemed warranted and the additional complexities acceptable.

A similarly steep price is attached to the "unification" attempted by the philosopher Martin Heidegger in his book *Sein und Zeit* (1927). In this work, the classical metaphysical concept of *Sein* (being) is fused with a special aspect of *Zeit* (time), here the time-span an individual human has yet to live before his unavoidable death. According to Heidegger, humans do not ever really "live", but commence as soon as they are born the inevitable trajectory leading to their individual deaths. As soon as they are born humans start "dying". Hence, only future time is essential with the added complication that this future time-span is non-measurable under normal circumstances. For Heidegger, the time-oriented character of being constitutes its absolutely essential structural quality. However, it is also the *a priori* condition for what he calls the historicity of humans, their distinctive relationship to a past irreversibly gone, to an impossible to hold now, and to an undisclosed, but hopefully yet to come future time-span. This latter aspect of time is the only significant time for mortal humans. Thus, in Heidegger's unification, time emerges as the unknown individual "not-yet", the unknown time remaining before death, and it forms the basis for the death-(not-being)-orientation of his analysis. However, the price is high: Heidegger's book is particularly difficult to read in its original German, to say nothing of its translations.

Here we attempt a further unification. We propose to unify Life, taken as the planetary phenomenon and including all the separate features mentioned above, and Time, understood in this special Heideggerian sense. The elusiveness of this concept leads us to replace traditional time by this unknown, individual, future "not-yet-dead" time. We write this Time, with capital T. To elucidate the essential features differentiating living from abiotic matter, we construct a model in which Life (as outlined above) and Time (as here defined) constitute a structural, inextricably entangled whole. Of course, this unification also comes at a price: Short descriptions are replaced by such a disquisition as presented in this book. However, the model is certainly testable as will be shown with several examples. In summary, we propose a 'critique' of the basic assumptions (*Grundbegriffe*) underlying the distinctive, defining features of living matter.

***Life on this planet***

We start this exercise by discussing Life in relation to some admitted ‘facts’ that might appear completely obvious to a modern reader but, from the perspective of the human species, were admitted as such only very recently. Earth is part of the solar system. It is constantly immersed in a stream of electromagnetic energy released by the Sun, and re-radiates a degraded form of that energy as heat into the surrounding space. The part of this radiation reaching Earth drives life on its “surface” (several kilometers deep). Life and Time are inseparable; timeless creatures are merely possible in myths and non-rational settings (the “immortal gods” are intrinsically non-alive in the same sense we humans are temporarily *alive*).

So, what do we imply by stating that Life is time-like? Life has been present on Earth for over three billion years. Setting aside for the moment the time-like character of this historical consideration, over that long period Life has physically appeared in a plethora of *transient* forms. Observed from a space-time “distance”, Life thus appears as an uninterrupted kaleidoscopic scintillation powered by solar energy. Here the emphasis is on *transient*: In the history of Life the different Life forms appear and disappear in extremely short intervals. Extant Life forms thus constitute just a vanishing small showcase of what the Life-phenomenon has produced historically.

Life *is* whatever essentially distinguishes this spectacular phenomenon from its abiotic surroundings. Of course, solar energy is a *sine qua non* condition, but energy in itself may drive all kinds of phenomena. Likewise, the atomic and molecular building blocks of Life are necessary pre-conditions, but insufficient, given that we assume the entire abiotic universe being composed of nothing but the same elements. Equally unsatisfactory is a reduction of Life to the chemistry and physics governing the interactions of these atoms and molecules, as we further admit that there exists no “special” Life-chemistry or Life-physics. Neither are growth and duplication by fission, since these are feats that crystals, clouds, stars, and galaxies routinely accomplish without being alive. Even less convincing is complexity that equally applies to all kinds of physical reality, alive or not[xxxiv].

Reproduction and heredity are more difficult concepts. But, what is exactly transmitted and inherited? Life as such? If so, then reproduction and heredity do not define Life, at least not exhaustively, but only establish the permanence of a *unique* Life phenomenon throughout its planetary history, a point we admit *a priori* as an axiomatic fact. From a different perspective, one may speak of reproduction and heredity as the transmission of the information contained in a molecular structure (DNA, for instance). Does this information essentially determine Life? Probably not, as so far the known complete genomes of several organisms do nowhere present this condition.

Lastly, there is adaptation. This somewhat tautological notion: If it is alive, it has adapted, otherwise it would not be around (be alive), has a further drawback. What is adapted is living *individuals*, not Life as such. Adaptation is a historical concept. In the fossil record, we observe environmental variation and parallel variation in the characteristics of transient survivors: For instance, cold climate and a thick fur, or changes in the running ability of predators in relation to the running abilities of their prey. Being maladapted equals reduced fitness and ultimately extinction, but adaptation as such is not the primordial quality we are searching for. The fossil record shows that the immense majority of all organisms that ever appeared have by now gone extinct. As many now extinct species survived for millions of years, we must admit that they were, in the main, well adapted. Presently, only the vanishing small proportion of extant organisms remains. We interpret this fact as proving that adaptation of particular biological systems, far from determining the essential property of Life, is but one of its salient features. Obviously, these qualities are all necessary for correctly *describing* Life, but their summation is just as clearly insufficient for defining the essential properties distinguishing it from abiotic matter.

If the global Life-phenomenon is a notion so hard to discern, its contrary when applied to individuals seems to be crystal-clear. For instance, *we* all know exactly, without any doubt, what death is, or at least what it means for each of us individually; that is, we are clearly aware of the temporal limits of our individual existence. In fact, what humans and non-humans are most of the time and in most circumstances exclusively engaged in is plainly just staying alive, simply laboring to survive, i.e., to postpone death - for a while. When eating or procuring food, sleeping or resting, avoiding extreme heat or cold, escaping predators or other dangers, or fighting parasites, all that is alive is just striving to stay alive. Hence, we might say that Life is the sum of the strategies a physical entity implements to avoid death. Thus, physical entities phenomenologically employing such strategies *are* alive; otherwise, they are either abiotic or dead. These strategies are effective, albeit only temporarily: Everything that is alive will shortly[xxxv] die. So these individual strategies have to be further implemented if Life as a planetary phenomenon has persevered for billions of years. Life must be able to jump, so to speak, from one Life form to the next in due future time. This is obviously reproduction, but we will show that reproduction *per se* is not the primordial feature characterizing biological systems.

### *Life as a thermodynamic process*

Life appears and disappears in manifold transient material entities that from the standpoint of contemporary physics are defined as being in a state far from thermodynamic equilibrium. What does that mean? Classical thermodynamics deals with the study of phenomena in which energy is irreversibly degraded by producing work. It is based on two "laws": First, the energy of the universe is constant, and, second, the entropy of the universe never decreases. Furthermore, the local equilibrium hypothesis is admitted: Knowledge of the values of the parameters of the system at present is sufficient to specify unambiguously the complete behavior of the system. When studying a thermodynamic system *near* equilibrium, one must additionally presuppose that at least locally such a system depends on the same set of variables which govern its behavior in strict thermodynamic equilibrium: temperature, pressure, entropy, chemical potential. Further, it is assumed that all these parameters remain well defined in the near-equilibrium state. In other words, if the local equilibrium hypothesis holds, one is allowed to treat the system as split into a series of cells sufficiently large to allow them to be treated as macroscopic thermodynamic subsystems. However they must simultaneously be sufficiently small so that equilibrium is very close to being realized in each cell. Thus, under the local equilibrium hypothesis, one can claim that all variables remain significant and unambiguously defined, and in each cell these quantities remain uniform, that is, their change depends continuously on the space and time coordinates.

However, *far* from equilibrium, as is the case in living physical systems, a new set of variables, generically called dissipative fluxes, need to be considered: heat flux, diffusion flux, momentum flux. When these dissipative fluxes are introduced in the equations of near-equilibrium thermodynamics, one obtains “unphysical” results such as a negative entropy. Thus new approaches become necessary, introducing new variables such as generalized, non-equilibrium entropy.

Several physical processes, among which are life understood as a physical phenomenon, do not comply with the framework of classical equilibrium thermodynamics. The above mentioned introduction of new variables is designed to measure the entropy increase, not just globally between two equilibrium states of an isolated system, but to describe the entropy increase in any position in space and any instant in time of the system, for whatever its development. Under conditions far from equilibrium, the assumptions of the local equilibrium hypothesis do not hold anymore, and completely new approaches are required. As they are as yet in an only very preliminary stage, this means that a complete theoretical-physics understanding of the phenomenon Life is still lacking.

However, two very general results can confidently be established. Systems far from thermodynamic equilibrium are inherently unstable, because they tend towards equilibrium and an increase in entropy. In other words, living systems physically tend to degrade and eventually die. This would be the case if the thermodynamic system were placed in an unchanging environment such as the laboratory. However, the unceasingly fluctuating environment in which organisms are immersed is continuously perturbed. Thus, something very special from a purely physical standpoint must be happening if such an unstable state has persisted on this planet in a myriad of ephemeral forms for billions of years. No stable entity far from equilibrium is physically conceivable unless enclosed by some “membrane” providing the minimally sufficient degree of seclusion. Thus, the global phenomenon Life appeared from its very inception with two main characteristics. A secluding barrier making them distinct physical individuals encloses living entities. Furthermore, competition between entities must have arisen from the very beginning since physical systems far from thermodynamic equilibrium are dissipative systems requiring a constant energy input. As inescapably the energy source is a limiting factor, distinct membrane-bound physical entities permanently compete for scarce resources to temporarily maintain their physical state far from equilibrium.

***The pre-eminent behavior of all biological systems is ceaseless competition***

Individual Life-forms strive just to stay alive and briefly maintain their state far from thermodynamic equilibrium before thermodynamically decaying to a state near equilibrium, i.e., before their individual demise. Note the future-time component of this seemingly self-evident statement: To stay alive always means to stay alive in the next time-span, be it seconds, days or years. Every basic physiological function points to this primordial goal. In every case, what is done *now* is somehow related to what will happen to this individual *later*. "Every squirrel or bird who stores nuts for the winter is sacrificing immediate consumption in return for consumption at a later date; [e]very investment decision is a choice involving costs and benefits that accrue at different times"[xxxvi].

However, the behavior of living organisms is more than just attempting to survive and reproduce: Survival and reproduction *per se* are not the primordial features characterizing biological systems. The distinguishing feature is reproductive success *relative* to that of conspecifics. Thus, the term 'an individual's reproductive success', i.e., an individual's Darwinian fitness, is understood as signifying the share of its genes relative to "the others" in future generations. It is in this restrictive sense that competition appears as a distinguishing attribute of Life. The permanent competition for individual reproductive success relative to "the others" will be accounted for by what we call the 'Algorithm' and 'trust-in-order', described in detail in Chapters 6 and 8.

Thus, unceasing competition for *relative* reproductive success appears as a universal property of biological entities. We incorporate this essential feature into the LifeTime model as an information-theoretic Algorithm. Life as a physical process can be understood as an information processing system. All physical interactions in nature leading to change (*kinêsis*) are based on information being received, decoded, processed, and re-emitted. We postulate that living organisms decode and process the environmental information constantly impinging on their senses in a Life-specific way, resulting in incessant competition for relative reproductive success. However, note that this 'success' only materializes, if at all, in a different individual, in a future time that the individual usually will never encounter. This is the Time-component of the LifeTime model, describing the inherent future-orientation of Life.

Below, we investigate three particular aspects of this competition in some detail: (1) Reproduction, producing for a future-time a different living individual. (2) The cost of defenses against challenges that may never materialize. (3) Altruism which benefits other individuals. We briefly focus on these aspects, showing that in each case it is always the individual's self-centered exertions, permanently tending to increase its own relative reproductive success, that account for these behavioral patterns.

*Reproduction*

Competition for relative reproductive success is costly in terms of time, energy and survival. Why do individuals invest by far the largest part of their resources in the production of more viable offspring than "the others" instead of caring for their own survival? The simple answer is because they are alive. It follows that the LifeTime model must incorporate the structural component called the Algorithm, which is a general rule by which biological systems interpret and react to their environment[xxxvii] and its fluctuations so as to reproduce at a relative rate larger than that of their competitors. In other words, to understand Life we must construct the LifeTime model incorporating not only Time (in the sense of "not-yet-dead", Chapter 4), but additionally the Algorithm, as developed in Chapter 6.

Hence, reproduction per se does not define Life. The fundamental step of transmission of an individual's genes is the faithful replication of the information-carrying molecule, in most cases DNA. This assures conservation of genetically based adaptations to the next generation, and thus constitutes an essential link in evolution. DNA replication is performed in a regulated chemical and physical background, requiring energy input to proceed. Recently, such faithful DNA-replication has become a standard laboratory technique in the form of the Polymerase Chain Reaction (PCR). Given a minimal amount of DNA, plus the required chemical and physical background, the PCR reaction proceeds automatically to replicate a particular DNA molecule for as long and as many times as the necessary reactants and energy are supplied. In addition, a recent study[xxxviii] showed that it is possible in the laboratory to replicate and exponentially amplify DNA analogues, creating a self-sustaining chemical system capable of undergoing Darwinian evolution. These laboratory procedures show that DNA-replication can proceed in non-biological settings. In consequence, DNA replication and by extension reproduction is a necessary, but insufficient property defining Life. To define Life, we claim, a further ingredient is necessary: The Algorithm by which Life forms restlessly compete against each other in a Life-specific manner.

### *Defensive arrangements*

Live entities are far from thermodynamic equilibrium maintaining this state in a constantly fluctuating environment. This is physically unfeasible beyond an environmental fluctuation threshold: Either the environmental fluctuations have a narrow range, or the living systems are endowed with defensive arrangements adequate to allow survival under a range of conditions. All organisms that survived, albeit briefly, somehow coped with a range of challenges, and the range suitable for survival and reproduction is that which has shaped the adaptations of that organism in the evolutionary past.

This leads us to incorporate an additional aspect into the LifeTime structure called ‘trust-in-order’. ‘Order’ is an elusive concept recalcitrant to a clear-cut definition (Chapter 8). The trust-in-order structural component of the LifeTime model incorporates three different components. (1) The particular environment of an organism to which it has become adapted; (2) the sensory equipment by which it gauges its maintenance and survival; and (3) the particular form of the Algorithm by which the individual constantly tends to increase its relative reproductive success.

Minimal physical stability of an environment is necessary for past experiences to apply in present circumstances. This physical property of the environment is defined by ‘order’. Individuals extract information about the order of their environment, and they behave *as if* they firmly *trust* the future maintenance of this order.

### *Altruism and mutual help*

Social behavior appearing as 'altruism' has been described not only in humans but also in many other animals. This behavior appears not to favor *directly* an individual, and thus to contradict the rule of ceaseless competition implied by the Algorithm. Altruism was considered an unresolved evolutionary problem until recently. We will consider three categories of cooperation that resemble altruism. First, kin selection[xxxix] may result in the spread of genes for helping relatives since related individuals benefit indirectly through their relatives by any superficially altruistic act because these relatives partially carry the same genes. Second, reciprocity[xl] is based on the idea that it is favorable to help an individual that may provide help in return at a later stage. Provided a certain probability of future encounters, this strategy may spread in a population. Third, group selection postulates that an individual benefits by allotting part of its resources to its group[xli]. Given that group membership can be recognized, and costly behavior thus can be directed mainly at other group members, behavior favoring the group may spread. This category appears to be relatively unimportant because the importance of selection is reduced by an order of magnitude at each subsequent level of organization from selection at the level of the genome to individual selection and to group selection[xlii].

In sum, these altruistic strategies are nothing but manifestations of the richness of the Life phenomenon. In all cases, ceaseless competition in a particular environmental order (Chapter 8) results in specific forms of the Algorithm. This Algorithm (Chapter 6) is a general rule by which organisms process information constantly extracted from their environment, their own internal state, and their relation with their competitors.

## ***Concluding remarks***

The rest of this book presents the idea that a holistic structural concept called LifeTime, incorporating Life as the planetary phenomenon, Time as the future not-yet, and a special type of Algorithm evaluating the current condition of an individual, may constitute an elucidating manner to *think* about Life. Life is a global phenomenon manifest in ephemeral individual Life forms, the immense majority of which is by now extinct. Individual Life forms constantly engage in competition to optimize their individual survival and relative reproductive success. We start by admitting the historical fact of the Life phenomenon. Although we are inescapably trapped in the physical constraints of our brain, our language and our evolutionary heritage, we nevertheless try to think about the phenomenon Life at a level above most commonplace assertions, finding that thinking about Life may only be possible when focusing on a structural multi-dimensional whole.

Let us take the assertion “birds build nests before laying eggs” as an example. In common language, we are forced to ascribe to birds some foresight, or to locate this foresight in their genes which then are being thought of as pushing the birds into that activity while “selfishly” perpetuating themselves. It is clear that this viewpoint simply displaces the teleology to a higher level. Genes are molecules, and we can easily manipulate these molecules in the laboratory without them ever showing these surprising abilities. However, in the proposed LifeTime framework, we can at least partially overcome these annoying aspects by understanding nest-building birds as LifeTime-entities.

In the following part of the book we begin with a discussion of the thermodynamic aspects of Life (Chapter 3), and the intricate relation between this thermodynamic approach and the ‘arrow of time’ asymmetrically pointing from past to future. Then, in Chapter 4, we analyze Time in more detail. Since we believe time is essentially a human artifact, the next part (Chapter 5) focuses on our exclusively linear communication system, i.e., our language, and highlights the relation of Time to the structure of common language.

# *3.Thermodynamics, Time and Life*

### *Introduction*

Here, we explore how thermodynamics relates time and life. In the first section we recall the essential ideas of equilibrium thermodynamics. In the second, we present an introduction to non-equilibrium thermodynamics. The third section deals with the relation between thermodynamics and time: The arrow of time defined by the second law of thermodynamics; the role of time in the efficiency of actual processes; and the conflict between reversible microscopic laws and irreversible macroscopic phenomena. We consider in the fourth section two topics in connection with the compatibility of thermodynamics and life: Living systems as open systems and as non-equilibrium structured systems. Finally, we outline three connections between time and life: Entropy production as time-scale, time constraints on biological strategies, and scaling laws of life span.

### *Overview of thermodynamics: Equilibrium theory*

Thermodynamics is the part of physics that analyzes the restrictions on energy transformations establishing a deep and general correlation amongst the macroscopic properties of systems. Sadi Carnot first recognized thermodynamics as a science in an essay on the motive power of fire, published in 1824. He showed that for any heat engine working between two heat reservoirs, i.e., an engine that receives heat from a hot source, transforms part of it into work, and delivers the remaining heat to a cold sink, the efficiency is maximal when the engine works in a reversible way. This maximum value only depends on the temperatures of the reservoirs, but neither on the structural details of the engine nor on the materials used in it. Carnot's ideas remained unnoticed during almost twenty years, but were subsequently rediscovered and appreciated by Clapeyron and Thomson, and later Lord Kelvin, who used them to define an absolute temperature scale.

Carnot's work was based on the caloric theory, namely, on the interpretation of heat as a subtle, weightless substance, named ‘caloric’ after Lavoisier. This material interpretation of heat arrived at a crisis with the new ideas appearing during the 1830s and 1840s, due mainly to Mayer and the experiments made by Joule. It was finally realized that heat is not a substance but a form of energy. This led to the so-called first law of thermodynamics, which states that the change in the internal energy of any system is the sum of the work done on the system plus the heat supplied to the system. This law had interesting physical consequences, as it was pointing to a quantity that is conserved during the development of the universe. Therefore, during a short period of time, some scientists proposed to abandon the search for the atoms, which originally had been proposed as an element of permanence behind the transformations observed in nature since the conservation of energy had already shown such a deep permanence. This ‘energetist’ trend was during some time an obstacle for the development of ‘atomistic’ theories.

### *The second law*

**The first law, the conservation of energy, allows in principle many phenomena, which are never observed in practice. For instance, it indistinctly allows heat to flow either from cold to hot bodies or from hot to cold bodies, while in actual circumstances only the second flow is observed, while the first is never observed. To account for this difference, the irreversibility of the macroscopic world is elevated to the status of a physical principle in the second law of thermodynamics.**

The second law of thermodynamics, one of the most general laws of physics, may be formulated in several different, but equivalent ways:

1. “It is impossible to build a heat engine which works in a cyclic way and whose only net effect is to transfer heat from a colder source to a hotter source”. Note that this statement is not at conflict with the existence of refrigerators, which make heat flow from colder to hotter bodies at the expense of an external supply of work.

2. “It is impossible to build a heat engine which works in a cyclic way and whose only net effect is to transform completely heat into work”. A heat engine which would perform this operation would be called a *perpetuum mobile* of the second kind. This engine would not violate the energy conservation implied by the first law of thermodynamics, in contrast with the so-called *perpetuum mobile* of the first kind, which would be able to do work without any expenditure of energy.
3. The two previous verbal statements of certain physical impossibilities were reformulated and synthesized in more mathematical quantitative terms by Clausius in 1865. He introduced *entropy*, defined as the ratio of the heat reversibly exchanged between the system and a reservoir divided by the absolute temperature of the reservoir. In terms of entropy, the second law is stated as the impossibility of entropy decrease in any process in an isolated system; entropy in an isolated system can only increase. If a process implies no variation in entropy, it may be inverted, and is called reversible. In contrast, if the process implies an increase in entropy, the inverse process would imply a decrease of the entropy and, therefore, the second law does not allow it; thus, a process with an increase in entropy is irreversible and cannot be inverted.

If a system is not isolated but in thermal, material, or any other form of contact with the external world, one may consider the total world (system and environment) an isolated system and require that the total entropy of the world increases, rather than the entropy of the system itself. In these situations there is a compromise between energy minimization (usual in mechanics) and entropy maximization. We will come back to this important point in the next section. In its application to open systems, the second law allows, for instance, to determine the conditions of chemical equilibrium.

Entropy has been interpreted in several different ways. The three best known and influential ways have been: The quality of the energy (understanding ‘quality’ as the ability of being transformed into work), the microscopic disorder of the particles constituting the system, and the loss of information of the macroscopic description with respect to the microscopic description. We consider some of these interpretations below.

***Microscopic versus macroscopic descriptions***

Entropy was originally defined as a macroscopic quantity. In 1872 Boltzmann related it to the microscopic disorder of particles constituting the system. For instance, a gas state in which all molecules are located in a small region of the available volume is more "ordered" (and thus, according to this view, less probable) than another state of the same gas with the particles distributed over all the available volume. Maxwell emphasized, through the appealing image of his well-known "demon"[xliii], the essentially statistical character of the second law. Indeed, the first attempts by Boltzmann to derive the macroscopic irreversible behavior from the reversible microscopic behavior of the particles immediately faced several paradoxes; for instance those proposed by Zermelo and by Loschmidt, outlining the difficulty of deducing from first principles these different behaviors. In fact, the irreversibility arises from the statistical character of the entropy rather than from the mechanical character of the motion of the particles.

Whereas the microscopic laws of classical mechanics are reversible, the macroscopic world shows irreversible situations. Since the macroscopic world is constituted of microscopic particles whose motion follows reversible laws, there is clearly an inconsistency between the macroscopic and the microscopic physical descriptions of reality. This inconsistency has received much attention in the scientific literature. According to the classical point of view, the reversible mechanical behavior is considered the most fundamental one, and thus the irreversible macroscopic behavior is considered to be only an illusion due to our inability to follow the trajectory of each of the gigantic number of particles constituting the macroscopic system.

In recent times systems with many degrees of freedom have been found to exhibit irreversible behavior in practice, but also some deterministic systems of only a few degrees of freedom like those showing deterministic chaos. In such systems, the behavior of the system is extremely sensitive (exponentially sensitive) to the initial conditions. Therefore, slight variation in initial conditions has as a consequence that the actual position of the system after a short time may be very different from the position predicted by solving the equations of motion. Hence, reversing the motion at some time would lead the system not back to the actual initial position, but to a very different position; it follows, in practice, that this motion is not reversible. Therefore, although the equations of motion of a system may be reversible in principle, the slightest uncertainty in the initial conditions implies a practical irreversibility.

***Non-equilibrium thermodynamics***

The classical theory of thermodynamics relies on equilibrium states. The entropy is defined only for such states. As recalled, a process from a constrained equilibrium state $A$ to a less constrained equilibrium state $B$ is only possible in an isolated system, if the entropy of the final equilibrium state $B$ is higher than in the initial equilibrium state $A$. However, equilibrium thermodynamics does not describe the actual process that leads the system from $A$ to $B$. For instance, it does not provide any information about how long it will take for the system to go from $A$ to $B$.

Non-equilibrium thermodynamics describes the laws governing temporal development of the systems during the actual processes, and describes the systems in non-equilibrium steady states. Both problems imply basic challenges. The most important ones are how to describe non-equilibrium states, how to define entropy for such states, and how to formulate the second law in such a way that it is valid for any process. None of these problems has been answered in total generality, and this may be impossible. Nevertheless, from a practical point of view, the theory based on the local equilibrium assumption was shown to be very satisfactory in a wide range of situations.

***Near-equilibrium regime***

**The essential idea of local-equilibrium thermodynamics is that, in spite of the system as a whole not being in equilibrium (meaning that there is heterogeneity in temperature, pressure, concentration and other variables in the system), the system may still be subdivided into smaller subsystems (which are however sufficiently large to contain many microscopic particles). This subdivision is assumed to be possible in such a way that, locally, each of these smaller subsystems is in internal equilibrium. Therefore, to each of these subsystems is assigned the entropy, which would correspond to a thermodynamic system at the corresponding values of temperature, pressure and concentrations. The**

**total entropy of the non-equilibrium system is thus the sum of the entropy of the local small subsystems. Note that this hypothesis implicitly admits that the variables used in the description of the non-equilibrium state are the classical variables of equilibrium thermodynamics, plus the local velocity of the system, expressed at every point of the system.**

The second law is stated as the positive character of the local entropy production. Indeed, the entropy at any small subsystem may change either by an exchange of entropy with the nearby subsystems or by a local increase as a consequence of irreversible processes taking place (viscous effects, for instance). Whereas the exchange of entropy may be either positive or negative, entropy production should always be positive. This statement places restrictions on the coefficients appearing in the classical transport laws. In other words, it implies the positive character of thermal conductivity, diffusivity and viscosity. Furthermore, in the linear domain it provides a systematization of transport laws which implies relations (Onsager reciprocity relations) between different transport coefficients related to cross-effects (for instance, relating a heat flux with a gradient of chemical potential and a matter flux with a temperature gradient).

### *Far from equilibrium*

One may interpret the concept of “far from thermodynamic equilibrium” in two different ways: far from global equilibrium, and far from local equilibrium. From the first point of view, a system is said to be far from thermodynamic equilibrium when it is submitted to nonlinear transport laws (this means that the flux is no longer proportional to the thermodynamic force which is causing it to flow), and when such a force (for instance, the temperature gradient or the affinity of a chemical reaction) is sufficiently high so as to make the regular steady state unstable. In such a situation, the system may reach a different steady state where it acquires spatial structure or temporal rhythm. The classical example is the so-called Bénard problem: A horizontal layer of viscous fluid is heated from below; when the temperature gradient is low, the liquid states remain at rest. However, when the temperature gradient exceeds a critical value, the fluid starts an organized motion in the form of horizontal rolls which turn in such a way that the hot, less dense liquid flows upwards and the cooler, more dense liquid sinks to the bottom again. This structure persists as long as the heat supplied to the system per unit time is sufficiently high. When the heat supply becomes too low, the structure disappears. This kind of structure has been named ‘dissipative structure’ by Prigogine, in order to emphasize its fundamental difference from equilibrium structures, for instance crystals, which may remain for a long time in the same state, of course only in so far as they are isolated or at a steady temperature.

A more drastic separation of equilibrium may be found when the fluxes are very high or when the processes are too fast in comparison with their internal characteristic times (for instance, the average time between successive collisions of its particles). In this case, it is no longer possible to assume that the system is locally at equilibrium, and it is not known in general how to define the non-equilibrium entropy. Some particular but rather interesting situations have been analyzed in the context of so-called ‘extended irreversible thermodynamics’, where the local entropy is assumed to depend on the fluxes. This generalized entropy allows one to deal with transport equations with ‘memory’ and with non-local effects in such a way that these equations are compatible with a definite character of the production of the extended entropy, whereas they violate the positive character of the local-equilibrium entropy. This shows that the formulation of the second law in non-equilibrium situations still remains a challenge and open to discussion. Indeed, one cannot impose the usual requirement of monotonously increasing entropy in non-equilibrium situations, and so one must try to define more general entropy. But even in this relatively simple situation, although this kind of analysis is helpful for clarifying the limits of validity of the local-equilibrium theory, it is still found that the physical meaning and the measurement of such a fundamental quantity as temperature remains problematic.

## *Thermodynamics and time*

**Here we deal with aspects of the relation between thermodynamics and time: The arrow of time defined by the second law of thermodynamics, the role of time in the efficiency of actual processes, and the**

**compatibility or the conflict between reversible microscopic laws and irreversible macroscopic phenomena**.

***The arrow of time***

*The monotonous irreversible* increase *of entropy in* isolated *systems defines an arrow of time. A sign may be understood as an arrow of time if it allows one to decide in which direction a film representing a physical phenomenon should be shown so the film reproduces the actual phenomenon rather than its temporal reverse. Reversible mechanical processes do not provide an arrow of time. For instance, in a film that shows the apparent trajectory of a planet over the sky we would not be sure whether the film shows the observed actual behavior of the planet or rather its reverse. On the contrary, in a film showing how an object falls to the ground and breaks into pieces, we would know that it represents the actual phenomenon. This would be in contrast with what would happen if the film were projected in the opposite direction, namely, showing the spontaneous assembly of the dispersed pieces to form the object and then the reconstructed object making spontaneously a vertical jump upwards.*

Thermodynamic irreversibility is the arrow of time par excellence. We could admit as representing reality a process in which heat flows spontaneously from a hot body to a cold one, but not the reverse. If we were shown the entropy corresponding to each state, we would know that the film must be passed in the direction of increasing entropy, and not in the opposite direction. However, there are other known physical arrows of time. One is the characteristic cosmological length scale: Since the universe is expanding, a higher length scale (and a lower temperature of the universe) would indicate a later time than a shorter length-scale (or a higher temperature). Another arrow of time is related to electromagnetism: It is easier that a point antenna emits spherical waves than it receives spherical waves isotropically from everywhere. Finally, although microscopic laws are reversible, there is a rather exceptional microscopic arrow of time, related to the decay of kaon particles. These break the parity and conjugation (CP) symmetry, in such a way that, according to the famous theorem requiring the inviolability of the CPT-symmetry, it must break the time-reversal symmetry and thereby distinguish forward from retrograde time-flow (see Chapter 4).

***Degradation of energy: A conflict between power and efficiency***

Irreversibility implies a decrease of the efficiency of heat engines. Since irreversibility is related to an increase of entropy, it follows that the increase of entropy implies a degradation of energy, in the sense that an increase of entropy makes it more difficult to obtain useful work. Indeed, in thermodynamics energy is not equivalent to the capacity of doing work. For instance, if one has two thermal reservoirs, the fundamental condition of converting part of the thermal energy of the reservoirs into useful work is that the temperature of the reservoirs must be different. If both have the same temperature, the Kelvin-Planck statement of the second law implies that it is impossible to extract thermal energy from them and convert it into useful work[xliv]. The meaning of 'saving energy' does not refer to the first law, according to which energy is conserved, but to the second law, which implies a degradation of the quality of the energy.

However, in thermodynamics the reversibility of a process implies that it should be infinitely slow and, therefore, the power of the reversible Carnot machine is zero. In practice this situation cannot be used, as one always requires having the work done in some finite time. The constraints of a finite duration of the cycles have stimulated the so-called finite-time thermodynamics. The constraints of time lead to a compromise between efficiency and power. Maximum efficiency implies zero power. An increase in power implies a decrease of efficiency. Power as a function of the frequency of the cycle of the engine increases from zero (for zero frequency) to a maximum and afterwards it decreases for increasing frequency, until it again reaches a value of zero. The availability of resources or time strongly influences the optimal value of the frequency of the engine. If resources are abundant and/or cheap, high power is more desirable than high efficiency, from the economic point of view; in contrast, if resources are scarce and/or expensive, high efficiency is very valuable. If one only has a short time to do some work, high power is desirable, rather than high efficiency. However, the preferences depend on the criteria used. From an economical point of view, maximum power corresponds to maximum profit per unit time (if resources are abundant and cheap). However, from an ecological point of view, it would be desirable to have less power and more efficiency, in order to minimize the depletion of resources and the production of waste.

### *Thermodynamics and life*

We have already stated that from a microscopic point of view, entropy is related to molecular disorder. For instance, it is assumed that an intact macroscopic object is more ordered than if broken into many pieces. Thus, the fact that entropy increases in isolated systems means that disorder increases. In biology, instead, order and structure increase, either in the individual, during embryogenesis, and at the level of populations and species, by evolution. Previously, there seemed to be a conflict between physics and biology. Boltzmann and Darwin were, apparently, the representatives of two opposite tendencies.

### *Open systems*

However, living beings neither are isolated systems nor are they in equilibrium. Since they are open, non-isolated and dissipative, they can increase external entropy while simultaneously reducing their local entropy. For instance, they employ as nutrient macro-molecules, which they metabolize by breaking them down into several smaller molecules, some of which are incorporated into the individual whereas others are expelled to the external world. Since there are more possibilities of disorder with several smaller molecules than with a single macromolecule composed of the ensemble of the smaller molecules, this metabolic process is a way to increase the entropy. Thus, open systems may locally increase in order at the cost of increasing the disorder of the external world.

Another example is provided by planet Earth, which receives energy in the form of radiation from the Sun, and after absorbing it (and reflecting a small part), it re-emits it again to the external world. Since the Sun's surface temperature is $6000^0$ K and the Earth's temperature is $300^0$ K, and since on average the photons emitted by the Sun are 20 times more energetic than those re-emitted by the Earth (this value corresponds to the ratio of the temperature of the Sun to that of the Earth, 6000/300, as the average energy of emitted photons is proportional to the absolute temperature of the emitting body), it follows that in a steady-state situation the Earth emits 20 photons for each photon that it received from the Sun. Thus, the same amount of energy received is re-emitted in a much more disordered form (since it is distributed over many more photons). This increases the entropy of the external space and so the entropy of the Earth may be reduced at the expense of this increase.

### ***Far-from-equilibrium systems***

Thus, the decrease of entropy in living beings does not contradict the second law. However, this does not help very much in understanding how order and structure appear in living beings. It is essential to remember that biological systems are not in equilibrium. Consider, for instance, the simplest situation, comparing the $Na^+$ and $K^+$ concentration inside and outside the cell. Inside, the cell is at a lower potential than outside (typically, some 70 mV); $Na^+$ is more abundant outside than inside, whereas $K^+$ is more abundant inside than outside. It follows that $Na^+$ has a tendency to enter and $K^+$ a tendency to leave, and in fact they are continuously flowing. These flows are compensated, to maintain the rest state, by active flows impelled by molecular pumps located in the plasma membrane of virtually all animal cells, which obtain their energy from the hydrolysis of ATP molecules. Thus, there is an essential difference between equilibrium and non-equilibrium steady states, in spite of the fact that none of them exhibits temporal changes in their parameters. The non-equilibrium steady state is usually heterogeneous in contrast to the equilibrium steady state and, more importantly, the non-equilibrium steady state must be sustained by energy expenditure.

Far from thermodynamic equilibrium the systems may acquire new structures or temporal rhythms. In 1952, Turing was the first to point out that the combination of autocatalytic reactions and diffusion may lead to morphogenesis. Indeed, diffusion tends to eliminate heterogeneity in concentration. On the other hand, autocatalytic reactions tend to enhance heterogeneity, because a substance is produced with a higher rate in the regions where its concentration is higher. If the system is sufficiently near equilibrium, diffusion predominates and the system tends to homogeneous states. If, in contrast, the system is sufficiently far from thermodynamic equilibrium, the reaction predominates and the system may become spontaneously heterogeneous by amplification of minute perturbations.

In the 1960's, Prigogine and collaborators studied the auto-organization of simple systems far from thermodynamic equilibrium, where microscopic fluctuations are amplified and become macroscopic structures. The Bénard-Marangoni convection of viscous fluids, mentioned above, or the Belousov-Zhabotinsky oscillating chemical reactions are the experimental landmarks in this field. The analysis of spatial and temporal auto-organization of simple systems (also called synergetics) was one of the central topics of research in the 1970's that marked an interesting interdisciplinary confluence of physics, chemistry, biology, mathematics, and even economy and sociology.

The double requirement of being an open system and far from equilibrium can be achieved only if the system is constrained by boundaries able to regulate the influx and outflow of matter. Probably, the presence of a primitive "membrane" was a necessary condition for the appearance of life from abiotic settings. Indeed, the essential role played by membranes in the existence of cells is well known. Furthermore, the environment may be submitted to intense fluctuations in temperature, concentration of chemical substances, pressure or energy of the external medium. Under all these circumstances the living system must maintain its internal stable state. Thus it is not sufficient that the boundaries of a living entity maintain the internal non-equilibrium situation at the expense of an energy-consuming active transport (for instance, the $Na^+$-$K^+$ pump), but they must also play an active role in making the external fluctuations compatible with the internal stability.

## Time and life

**Let us finally examine the relations between life and time. The two main ideas are the irreversibility of time and the fact that biological time is finite. The arrow of time set by thermodynamics indicates irreversibility, a basic characteristic of time in living beings. Thermodynamics does not**

**imply by itself an end of time, but implies an end of processes in isolated systems: "Thermal death", which arrives when the entropy of the system reaches its maximum value and no more processes are allowed in the system.**

The finite life span of biological individuals has implications for their survival strategies, which are restricted not only by the requirement of maximizing efficiency but furthermore by the need to adjust their activities to a finite availability of time. On the other hand, the requirement to remain during their transitory life-span in a state far enough from equilibrium in order to keep the necessary degree of auto-organization imposes conditions on the minimum amounts of matter and energy that must be supplied to the individual per unit time. Here we will examine these ideas in more detail.

### *Entropy production and the flow of time*

The irreversible flow of time is indicated in thermodynamics by an increase in entropy. From the point of view of the thermodynamic arrow of time, it would be impossible to order different states with the same value of entropy, but one could order states according to increasing values of entropy. Thus, from the thermodynamic perspective, it could be said that time does not flow unless there is an entropy increase. Consequently, it has been proposed that entropy production per unit time would be a measure of the irreversible flow of time. In fact, a reversible system would not show an actual progress of time. For instance, a purely periodic non-dissipative motion would repeat itself indefinitely. It could be questioned whether the perpetual repetition of the same state (system arrest), or of the same family of states (periodic motion), really represents a flow of time or a form of eternity (in fact, in mechanical clocks regulated by periodic motions, the actual flow of time is found rather in the irreversible world outside the clock than in the clock itself). The more irreversible a process, the higher is the entropy increase per unit time and the faster is the flow of time. Thus, two systems showing the same entropy increase would have suffered the same irreversibility, but the system with less production of entropy per unit time would have taken much more time to reach the same entropy increase.

The connection between entropy and information may be of some help in elucidating this aspect of the flow of time. In our life, we have the impression that time does not always flow with the same speed. In some periods, many relevant events happen in a short interval, and we have the impression that time is flowing very fast. In other periods, life is monotonous and repetitive, and we loose the impression of the progress of time. If entropy were related to the information necessary to describe what happened in a period, a high information rate (high entropy production) would indeed correspond to a fast flow of time.

Prigogine has shown, under rather restrictive conditions (linearity of constitutive equations), that a system submitted to fixed boundary conditions reaches minimal entropy production at the steady state (when the boundary conditions do not depend on time). If the boundary conditions allow an equilibrium state (for instance, if temperature is uniform over the boundary), the steady state is itself an equilibrium state with vanishing entropy production. But if, for instance, the temperature of opposite walls is different, the steady state will be a non-equilibrium state characterized by a non-vanishing heat flux. Although the constitutive relations of many biological processes are nonlinear, entropy production is often rather high in the first stages of life, but decreases and tends to a minimum when the colony or its individuals get older, as if time dilated in approaching the end of time.

### ***Time constraints on biological strategies***

In living systems, time is an important factor to take into account in the analysis and the understanding of biochemical and biophysical processes underlying biological entities. The scarcity of time implies that individuals are not maximizing efficiency, but power. Indeed, survival and reproduction require on many occasions a high expense of energy in a very short time. The criteria of equilibrium thermodynamics (with their infinitely slow processes) are very far from the actual biological situations. In contrast, if the individual is seen as a slave of its selfish genes, as being only a part in a chain of transmission, this interest in maximizing power rather than efficiency indicates that the individual is also selfish with respect to future generations. This can be seen from its waste of resources in a short-time perspective rather than considering a long-time perspective.

One example of the importance of the temporal factor is protein folding. From a thermodynamic point of view, it seems clear that the protein tends to the structure with minimum free energy. However, since the number of structures to be explored by the macromolecule is very high, and since many of these structures correspond to local, but not global minima of free energy, the process should take a long time. In fact, a naive analysis indicates that the folding time should be of the order of the age of the universe. Thus, even when the thermodynamic criteria are clear, the dynamic aspects of a process far from equilibrium such as protein folding in living cells are beyond the limits of classical thermodynamics, which only compares equilibrium states.

Another aspect of time constraints is to be found in the rhythm of biological processes. Many biological processes exhibit periodic or quasi-periodic rhythms, whose period is due to the internal processes in the living being. In some pathological conditions, these processes may become chaotic. For instance, the quasi-periodic motion of the healthy heart may become chaotic in fibrillation. Recently, increasing attention has been paid to dynamic anomalies of physiological processes. Other processes, on the contrary, are chaotic even in the healthy individual. This irregular behavior may have useful, practical advantages in exploring many possibilities that would not be explored by a periodic or quasi-periodic process. This is of interest, for instance, in the brain and the immune system, which indeed show some degree of deterministic chaos, according to the mathematical analyses of the time series associated with their activity.

### ***Scaling laws of life-span***

In the previous paragraphs we mentioned how the finite amount of time available to biological systems influences biological strategies. It is also of interest to consider which factors could determine the total available duration of a living being. A factor influencing time-span of individuals is the length scale. Vertebrate hearts, for instance, beat faster in small animals (mice) than in big animals (elephants). This is because heart beat frequency is proportional to the amount of blood that must be supplied to the body per unit time, and inversely proportional to the volume of blood that is set in motion at every beat of the heart. Since the volume of the heart increases faster than the requirements of the metabolic rate, the heart beat frequency decreases with increasing mass of the living being. The fact that most big animals have longer life spans than smaller ones is perhaps related to this scaling law. Indeed, it has been argued that if the number of contractions of the heart measures the duration of life, this duration is approximately constant in small and big animals. Thus, since in small animals the frequency is higher, time would flow faster and life span would be shorter. This idea, although purely speculative, has some similarity with what we have mentioned earlier about entropy production and the flow of time: The heart beat frequency would play a role analogous to that of entropy production.

The situation is opposite in stars: Bigger stars have a shorter duration than smaller ones. Indeed, although the former has more material to be burnt, the rate at which this is burnt is higher than in smaller stars. The reason is that the higher gravitational forces require a higher value of internal pressure and temperature, and this requires a faster consumption of matter in order to compensate for the higher power emitted by the star. This power is very sensitive to temperature (proportional to the fourth power of absolute temperature) and size (the area is proportional to the square of the radius).

### *Concluding remark*

From a thermodynamic perspective, biological systems are non-equilibrium, auto-organized, transient systems. Stars are also structured systems far from equilibrium having a limited life span. But an important difference between them and living beings is that the latter entirely depend on the external world as they need a continuous supply of nutrients, in contrast to stars, where all the “nutrient” is given from the start. The crucial dependence on the environment, which always is fluctuating, results in the self-organized character of biological systems being much more ‘complicated’ and more demanding than that of ‘simple’ dissipative structures such as stars[xlv].

# 4. Time

### *What is time?*

In the preceding chapters we raised the problem of the difficulty associated with an unambiguous delimitation of the essential features differentiating living from abiotic matter. From a historical perspective, this is a recent problem as the defining property contrasting living with non-living matter has traditionally been obscured by having recourse to *angh, psychê, anima, ruah,* and similar transcendent entities, whose presence or absence, at least in humans, signaled the difference between life and death. Time, on the other hand, has since Antiquity been recognized as posing an unsolved problem[xlvi]. It appears as founding principle in many ancient cosmogonies, often opposed to Chaos, and became very early a frequent subject of philosophical speculation. In this chapter we present a number of different approaches to the question of what is time, all showing that the question remains in fact unanswered and problematical, suggesting that the time-concept is in the main a human mental artifact. This said, we somewhat restrain the scope of the term time, in the previously mentioned "not-yet-dead" sense, in order to incorporate it in the proposed LifeTime model. When employed in this restricted sense, we write Time, with capital T.

### *Subjective time*

The subjective temporal experience, being more than any other aspect of human existence all pervasive and immediate, is in all probability inextricably connected with the very functions of the mind. The idea of time seems to be an unavoidable constituent of every manner of human knowledge, experience and mode of expression: It consistently appears as a fundamental feature of the way in which the universe can be understood. For humans, life, death and time fuse into a structural whole that, although hard to define and difficult to apprehend, repeatedly appears in symbolical form in every great religion. These considerations inescapably suggest that the subjective temporal experience is mainly a human mental artifact, not necessarily possessing a direct correlate in nature but in the absence of which no understanding of nature is intuitively possible.

The subjective temporal experience of humans, perceived as an apparently explicit separation of individual occurrences into ‘before’ and ‘after’, is an undeniable fact of human consciousness. Moreover, this separation process is realized on a unique *linear* before-and-after sequence: the one-dimensional time-axis. At a very early developmental stage, humans establish a primary correlation of assumed objective events and their position on the subjective time-axis: ‘External’ events are approximately one-to-one associated with ‘internal’ time experiences. Presumably, the human temporal experience of the linear, unstoppable, asymmetric past-to-future “flow” of time is an innate feature, on which mankind’s power of foresight is based, the capacity to plan ahead, to envisage and devise protective measures against as yet never experienced challenges[xlvii].

If it is *a priori* admitted that the idea of time in humans is partly the conscious manifestation of an innate, neuronal structure, then the following questions arise. How can one scientifically assert that the human subjective feeling of continuous becoming is unequivocally correlated with the continuous becoming presumed to obtain in the physical world? Is the unit of time as put forward by the watchmaker, the philosopher, the scientist, the psychologist, or the theologian in each case the same object? How can human descriptions of objects as being spread out in space, and events being described as successively enduring for shorter or longer periods of time, be unambiguously associated with the dynamic picture of modern science? Can a common denominator be found for the subjective feeling of duration, the apparent future-oriented “purpose” in living organisms, and the useful time of the physicist? In sum, in what manner are the concepts of life and time interrelated?

Time can be viewed from so many different perspectives that a preliminary clarification is unavoidable if a scientific approach to Life (or LifeTime) is to be attempted. Such an effort of clarification will emphatically not answer the question ‘What is time?’ but should reduce it to the essential ingredients. To make the subject tractable we only analyze a reduced set of pertinent aspects.

### *Psychological time and measured time*

The human capability to read time on clock dials is acquired by children around the age of 8 years. For smaller children, the relationship between time, speed, and duration is still in flux. In particular, the idea of speed, and the much more complex idea of the *constant* velocity underlying the functioning of mechanical clocks, requires a more advanced degree of maturation. Initially, children develop a simple notion of the succession of events, i.e., time-independent ordinal ideas of rank and order of events, but are still lacking any notion of duration, i.e. the interval between any two events. On the other hand, the notion of velocity develops as a consequence of the interplay of a series of physiological factors related to the particular organization of the human retina, giving rise to visual pursuit eye movements, retinal persistence, and retinal processing of moving stimuli[xlviii]. The resulting subjective evaluation of physical duration seems to indicate that physical time appears as a relation between a spatial distance traveled and the speed of this traveling. This physiological relationship between time and velocity lies at the heart of the circular definition of time in terms of speed, as the concept of speed remains undefined lacking the notion of time. By the same token, in the absence of physical events, such as in waiting, subjective time seems much longer than under more eventful situations, pointing to the intimate subjective connection between time and velocity - here, the speed at which salient (as opposed to uninteresting) events succeed each other. The idea of time thus appears as the result of a progressive elaboration as the child develops into an adult. The initial step consists of an elementary ordering of independent events, establishing with the aid of memory the before and after classification of the events under consideration. The second mental operation must be the classification of duration: Events not only take place in a certain order, but definite intervals separate them, and these intervals are of *unequal* “length”. The idea of a measurement of time can only occur as a final development, when an association between the before/after ordering and the differential classification of unequal duration becomes established. At this point, the logically more complex notion of a constant velocity as underlies, for instance, the apparently constant speed of the Sun and the fixed stars, or of the hourglass or the water-clock, can take form. The final step, as described for instance in Plato’s *Timaeus*, the association of time with the natural numbers and thus with a mathematically defined constant speed[xlix], became generally established in the minds of humans only after millions of years of evolution.

## *Time in Biology*

We here present three different perspectives in which ‘time’ is studied by biologists. They show the intricate connection of time and living systems but, this must be stressed, the concept as such is assumed without further analysis as a clear and unproblematic precondition.

### The circadian clock

Biologists have studied ‘time’ in all kind of organisms, and not only in humans, albeit without arriving at a definition of time that does not presuppose this concept in the first place; but that, as we maintain, seems unavoidable. They discovered that all organisms have activity patterns that are firmly regulated by internal clocks. The French astronomer Jean Jacques D’Ortous De Mairan, who left his heliotrope plants in the dark, first described this phenomenon of an internal clock affecting the behavior of an individual in 1729. Surprisingly, he discovered that they continued to open and close their leaves on a regular schedule in the dark just as if sunlight had been present. This simple experiment demonstrated that the plant was not simply responding to the presence of the sun, but was regulated by some sort of internal clock. Thus the biological clock had been discovered. Since then numerous experiments in all kinds of organisms including humans have shown similar diurnal patterns of activity. These circadian rhythms regulate the timing of different kinds of activities from awakening to start and cessation of activity and diurnal patterns of various physiological processes. The rhythms are called circadian because they are approximately of 24 hours duration, with the timing being reset by external cues such as the presence of daylight (so-called *Zeitgebers*)[l]. Many humans are familiar with the internal clock when suffering from jet lag. The displacement across several time zones gives rise to awakening and drowsiness at awkward times of the day because a local *Zeitgeber* such as the sun has not reset the internal clock. This adjustment will take some days, until the clock again is adjusted to local conditions.

The internal clock is conserved across organisms. Experiments with cells from the retinas of the eyes of animals like lampreys, frogs and reptiles to hamsters have shown that these contain clock cells, and the diurnal rhythms of these cells are remarkably similar[li]. Thus, the mechanisms of time keeping have remained virtually unchanged among species that were separated into different lineages more than 450 million years ago. This conservative system suggests that timing of events is essential for living organisms. Any individual that forages or seeks mates at the “wrong” time of the day would have been at a disadvantage because little food or few potential mates would have been encountered. The exact mechanism that accounts of time appears to be a biochemical clock, a special protein produced by ‘clock’ genes[lii]. The amount of proteins accumulates during the active part of the day until they reach a threshold when they switch off the clock genes to end the active cycle, after which the process continues anew until the clock genes are switched on again. The clock genes appear to be located in many different parts of the body of different organisms. Scientists working on *Drosophila* fruit flies managed to insert genes from fireflies into the genome of fruit flies, thereby creating a mutant fly that glowed every time its clock genes were switched on. Surprisingly, clocks were present all over different parts of the body of the fruit flies, making them virtual clock shops. Humans are no different! Until recently, it was believed that humans only used information coming in through their eyes to set their internal clocks. However, observations had indicated that even blindfolded humans could react to external light stimuli suggesting that there were extra-ocular sites sensitive to light. If such sites could be found, this might have applied consequences such as resetting the clock for people suffering from sleep disorders or from jet lag. Astonishingly, the scientists found that they were able to turn the internal clock by up to several hours by shining a bright light on the back of the knees for a relatively short time period[liii]! Whether the clock was moved forward or backward depended on whether the light was applied before or after the switching on of the internal clock during night.

Long-lived organisms also have annual rhythms, so-called circannual patterns of activity that last approximately one year. This annual clock is reset by external

*Zeitgebers* to make it precisely one year in duration. Again, experiments keeping animals under constant environmental conditions have shown that they maintain their annual cycles. For example, migratory birds kept under constant conditions for years continue to become active for migration at fixed times of the year during fall and spring, coinciding with their natural times of migration from and to their breeding grounds[liv]. Similarly, the annual increase and decrease in the size of their reproductive organs are equally well timed, as is the annual start and end of molt[9]. Humans have equally fixed annual rhythms as demonstrated by long-term experiments under constant conditions. The biological significance of such long-term clocks is equally obvious to that of the diurnal clock. Any migratory bird that started to migrate too late would run a greater risk of dying than an individual that started “on time”. Similarly, any individual that started to reproduce before food became available for the offspring would have few surviving descendants, as would an individual that started to reproduce after the annual peak in food abundance. Hence, organisms generally have fixed times of reproduction. This also applies to humans who used to have a peak of births during the start of the growing season[lv]. Even in the tropics, where the annual changes in light conditions are minute, there is evidence of clear annual peaks of reproduction, again coinciding with the main growing season[lvi]. Studies of birds have shown that even slight changes in the duration of the day of just a few minutes are sufficient to trigger the annual clock to turn on or off[lvii].

## The life-cycle clock

Most organisms start as juveniles, may become sexually mature, and eventually age and subsequently die. It seems as if animals have internal clocks that tell them when to turn their activities on and off and at which rate this should be done. Several studies have shown that animals during the final stages of their life just before dying invest all their effort into reproduction, just as if they “knew” that this is the last reproductive event[lviii]. Perhaps it is the condition or the deterioration of condition of the individual that provides the cue to “this being the end”. The presence of life cycles may suggest that organisms even have clock-like mechanisms affecting the timing of different activities during their lifetime. All these different processes such as start of puberty, start of reproduction and timing of death typically take place at specific stages of the life cycle.

The timing of such events has been molded by natural selection. Any individual that started to reproduce very early would experience severe costs of reproduction and hence leave fewer descendants during its lifetime than an individual that started to reproduce at the species-specific “normal” time. In experiments with small birds, the number of offspring in a single year was manipulated by experimentally adding or removing two nestlings from a brood. Parent birds that had worked very hard, because they suddenly had two more offspring to care for, aged at a faster rate than control birds that reared the number of offspring, which they had planned, and therefore left fewer offspring during their lifetime[lix]. In other words, it does not pay in terms of number of successful descendants to produce “too many” offspring early during life because such parents eventually are penalized and produce fewer descendants during their lifetime than the average individual in the population.

## Discounting the future

Humans live in the present, at this very moment, and although we may have some foresight and hence may “plan” the future, such planning often seems to be of relatively modest scope. Humans generally prefer to enjoy benefits now rather than waiting to have these served at a later time in an unknown future. Such *discounting of the future* is what we pay in terms of interest rates to banks in order to enjoy living in an expensive house or have other benefits now. Perhaps surprisingly, such discounting is not restricted to humans, or even humans living in industrialized societies. Anthropologists and other social scientists have for a long time suggested that indigenous peoples had evolved mechanisms so as not to over-exploit the natural resources on which they subsist. This myth of “the noble savage” has so much become an indisputable truth that many indigenous peoples have been allowed to exploit resources in national parks because it was believed that they would only take what they needed. Recent studies of optimal foraging in several indigenous cultures have shown that this is far from being the case[lx]. Indigenous humans exploit the natural resources at a higher rate than they “need”, they harvest the crops or the animals that are most easy to harvest, but not those that allow better productivity or long-term sustainability of the resources. Hence, indigenous people are not so different from modern humans, or from animals for that matter, when it comes to exploitation of resources and conservation for the future. This is what we should expect because of discounting of the future: Our current needs are more essential to us now than the needs of somebody else, and particularly of somebody else in a distant future. This willingness to enjoy current benefits at a cost has recently been investigated by evolutionary psychologists in some interesting thought experiments[lxi]. Subjects were asked to choose between two alternative career options in which they could either live in a town with a relatively modest salary, but a clean environment, or in another town with a considerably higher salary, but with a polluted environment. Many subjects preferred the high salary alternative even though this was achieved at the cost of a poor environment that would remain degraded for the future. Most surprising was a very clear gender difference in the preferences. Men preferred the high salary option to a much higher degree than women did. This difference makes sense when viewed from a sexual selection perspective since men compete for limiting resources that allow them an advantage in terms of reproductive success, because women prefer such men with resources that will allow them to successfully raise their offspring.

Discounting of the future is not restricted to humans. Biologists have been studying similar phenomena in animals by allowing individuals to either chose current or future benefits that differ in their costs[lxii]. Such experiments are made by using trained individuals that will have to press a bar or a button a certain number of times to obtain a reward. Hence, in the discounting experiments animals such as pigeons, starlings, rats or monkeys will have to work a different amount to obtain current or future benefits. The species involved in these experiments are very different in terms of ecology and evolutionary history. Pigeons are socially and sexually monogamous birds with a high degree of sexual equality in their reproductive roles. Starlings are socially and sexually polygynous with males investing considerably in attraction of females. Rats are polygynous mammals with a high degree of sperm competition and no paternal care, and the same applies to rhesus monkeys. Surprisingly, all these different species including humans discount the future by preferring current to future benefits. The preference for current benefits can be described by the curve that relates how many benefits are discounted in relation to when such rewards are provided. The discounting functions are very similar in shape in these very different animals. Thus, we prefer current to future benefits to a similar degree and in a similar fashion independent of whether we are pigeons, rats, monkeys or humans. The common basis for this discounting phenomenon seems to be the ticking internal clocks in all organisms. Independent of whom you are, there is a time for doing different things, and such activities will be made with little or no regard to the needs of others. Individuals will discount the future by exploiting current resources selfishly in competition with others, because any individual that has done so in the past will have left a disproportionately large number of descendants.

Summing up, “To every thing there is a season, and a time to every purpose under the heaven”[lxiii].

### ***Time and the experience of music***

Information about the external and internal environment reaches regions of the nervous system of animals coded in different ways. Nervous systems can decode and assess information contained in a particular linear sequence of stimuli. For instance, vocalizations and other auditory and visual signals in vertebrates and invertebrates, chemical signals in vertebrates and invertebrates, electric signals in fish, and distinct dance sequences in bees[lxiv]. Humans with their enlarged brains and highly developed language can decode a much wider set of information-containing sequences: This is clear in spoken and written language and, in a very suggestive way, in music.

The human ear is superior to the eye in making fine temporal discriminations; not surprising considering how the ear perceived sounds strung out linearly in time, whereas visual cues are spread out in two- or three-dimensional space. Hence, the human brain discovers features that are clearly different from the visual-mechanical model of physical reality in the linear temporal structure of a melody. In musical rhythm, time becomes a privately experienced order of occurrences: Each note, each “event”, is significant only in as much as it occupies a determined place in the temporal sequence. Moreover, a violation of this *order structure* is perceived as a dissonance, as interrupting or destroying the “feeling well” emotion associated with harmony, replacing it by the “disagreeable feeling” of disharmony or simply of “noise”.

The example of musical experience again shows that the phenomenon time cannot be analyzed as a distinct, separate entity, since it has to be taken as a given feature of our relation with the environment; inescapably so, we claim, because time is an essential component of the structural whole LifeTime. Moreover, this short commentary on the human musical experience sheds light on two additional aspects of the LifeTime phenomenon. There is a close association between musical experience and an inherent order structure. Experiences conforming to this expected order are deemed pleasant, while experiences deviating from this order are experienced as painful and distressing.

### *The binary elementary event: The here-and-now*

***Die Welt ist alles, was der Fall ist,* the world is the summation of all the events: This is the opening assertion of Wittgenstein's *Tractatus.* What is an event? It is something that happens here, now, something that might or might not happen. Something is the case (from Latin, *cado*, to fall; *der Fall*), like when a fair coin falls showing either heads or tail, when the observer, i.e., myself, here, where I am located, register the outcome of the fall of the coin. Register at the point in time that for me is "now". This elementary binary "event", irreducible to anything simpler, is taken as the primordial event of the physical world, and the summation of these primordial events then constitutes the universe. Note further that nothing at all "decides" whether an event does or does not happen. This is the essential stochastic character of Wittgenstein's world. But that is not only the case in Wittgenstein's philosophy, for this is also so in contemporary physics, for instance, in Big Bang-type cosmologies based on Einstein's theory of relativity.**

However, I register a particular event, since I am the only one that physically occupies the particular here and now where and when the happening of the event is observed. Can I ever communicate to somebody else this experience, in a meaningful way? The answer that is hard to believe is negative: No, I cannot, *unless* a number of very strong assumptions are admitted *a priori*. Let us just mention one simple problem.

To communicate my experience, I must communicate to my interlocutor that I observed the event in question happening at a certain "time". This "time" both of us read off similar "Seiko" timepieces, and we assume they are identical. But how do we synchronize our Seiko watches? This seems easy enough: I send him a message: "My Seiko now reads 12 o'clock", and upon receiving this message, he immediately[lxv] sends back: "My Seiko now reads 12:10". If I receive his message at 12:20, can I deduce that our Seiko watches are synchronized? Not unless I assume *a priori* that we are separated by an isotropic medium, so that my message to him always takes the same time (10 minutes) covering the distance separating us, as his message to me. Can I ever prove or test the assumption of the isotropy of the medium? No, this is impossible, since in order to test this assumption the synchronization of our Seiko watches must first be established! Obviously, and fortunately, this becomes a problem only for interlocutors whose separation is measured in light-years. Where does all this lead? According to Wittgenstein, no meaningful discourse about the world is possible; there is nothing left but silence. And this, we believe, may be the case, unless, of course, the necessary and sufficient assumptions are previously agreed upon and admitted as useful, heuristic axioms. In this study, the inextricable entanglement of Life and Time is presented as such a fundamental assumption.

### *The asymmetric "arrow of time"*[lxvi]

As an every-day experience, humans are certain that our free will, in whatever extent this freedom is admitted, can only address future events, but never modify past occurrences. It thus seems that the subjective asymmetric time experience is necessarily awakened when humans are faced with a potential freedom of choice. Here the subjective arrow of time pointing invariably from past to future appears inextricably associated with the basic causal structure of the *if-then* type that underlies the experience of free will decisions.

The apparent time-asymmetry may further be ascribed to certain limitations inherent in the human condition. Given some physical system in a particular initial situation plus the well-established laws of classical physics, it is then unambiguously feasible to predict with a certain probability the state of the system at a future time.

Although only probabilistic in nature, this prediction is straightforward in that the human experimenter can in many cases freely choose the initial situation. The reverse is, however, not at all the case. Starting from the same initial situation, to retrodict a previous state of the system will most often be impossible. The reason is that the causal chains leading from the past to the present situation can originate from a gigantic number of different past states, this number growing exponentially with the length of these causal chains. The stipulation of the initial limit values of some classical physics problem is, on the one hand, the necessary condition for predicting its future dynamic course; on the other, it represents a formidable bias in that only one particular setup among an infinity is “freely” chosen by the experimenter. This *ab initio* determines an arrow of time: Given a present cause, its probable future effect can sometimes be evaluated; given a present effect, however, its past cause may in most cases be impossible to retrodict.

Why is the theoretically exact prediction of classical physical science in practice “only” probabilistic? Because the macroscopic description used results from averaging over the near infinity of microstates; that is, to arrive at tractable solutions, it is imperative to neglect an enormous amount of collateral information. In contrast, retrodiction does not freely neglect information: This information is here simply unavailable, even in principle. In this manner of describing the physical world the arrow of time arises as a consequence of the asymmetry of the pertinent information available to the experimenter.

It is also possible to look at the asymmetry of time from a historical point of view. History is based on what may well be the essential character of reality: the uniqueness of facts. And facts are logically superior, or at least more authoritatively incontrovertible than speculative thought. The question then arises: In what manner should the historical facts be concatenated? Is there an obligate ordering procedure also founded exclusively on facts? The usual answer is that historical concatenation of facts should be accomplished following a logical order. But “logic is not time-reversal invariant”![lxvii] Hence, the time asymmetry becomes *ab initio* incorporated in our view of history as a logical sequence in time of unique facts. As we show below, the origin of this asymmetric ordering of historical facts may be based on one unique, indisputable, irreversible, asymmetric future event: my (and your) own personal future demise.

In the current scientific literature, one can find other "explanations" for the asymmetry of the arrow of time. Some were pointed out in the preceding chapter. The expansion of the universe, starting at the Big Bang, is another suggestion. Aside from the inescapable tautology, we are not especially attracted by this approach in view of the substantial number of additional and mostly unverifiable assumptions of this particular cosmological model. The increasing "complexity" of life forms, starting from certain "simple" abiotic building blocks and culminating in *Homo sapiens* is a further example. This approach hinges on a clear-cut definition of the term complexity as applied to organisms, but the definition of complexity in this context remains controversial at best.

***Time irreversibility in quantum mechanics***

A cornerstone of current quantum mechanics is the CPT symmetry postulate. The <u>C</u> in CPT stands for the charge conjugation symmetry, meaning that the physics predicting the behavior of a set of particles will predict the same behavior for the corresponding set of antiparticles. In the <u>P</u>arity operation a system (e.g. a particle) is reflected through the origin of the coordinate system (as in a mirror). Again the <u>P</u> symmetry implies that the physics of the system are unchanged by this operation. Finally, the <u>T</u> symmetry connects a process with that obtained by running it backwards in time, i.e., by reversing the arrow of time. Symmetry under time reversal implies that if any system can evolve from a given initial state to some final state, then it is possible to start from that final state and return to the same initial state by reversing the directions of all the components of the system. The combined CPT symmetry is obtained by operating these three symmetries simultaneously. Modern quantum mechanics assume that this combined symmetry holds *exactly* in nature. This assumption has been experimentally verified to an impressive number of decimal places.

The CPT postulate implies that for perfect time reversibility, i.e., for T symmetry, the combined CP symmetries must identically hold. But it was found in 1964 that in certain cases the combined CP symmetries do not hold. Experiments have shown that the neutral particles called kaons occasionally decay in a way that clearly violates the CP symmetry. Since it is assumed that the CPT postulate is inviolable, it follows that for these interactions a precise time asymmetry must exactly cancel out the observed CP asymmetry so as to restore the sacrosanct CPT symmetry. In other words, this means that nature must incorporate, at least at that level, the arrow of time.

In 1998, experiments by the CPLEAR collaboration at CERN in Switzerland and the KTeV collaboration at Fermilab in the U.S. observed for these interactions a time asymmetry at about the level required to compensate for the CP violation and thus restore the overall CPT symmetry. In other words, the neutral kaon's decay looks different in a past to future time direction from a future to past direction, and this difference precisely cancels out the observed CP asymmetry[lxviii].

Why this is so no one at present knows, although it could lead to speculations that this asymmetry in nature underlies the subjective time asymmetry as experienced by self-conscious humans.

### ***Time as the future "not-yet"***

In the course of human evolution, what we now call 'time' became a *conscious* experience presumably leading to optimizing strategies in competition for scarce resources[lxix]. At some point, self-conscious human beings, becoming aware of their impending personal death, consciously realized their temporality. It seems quite plausible that at this stage, and not before, humans discovered something that they subsumed under an aboriginal concept "time". Or, more exactly, *future* time, a time-span yet to live, unknown but in essence the only significant time-span (for ephemeral living things). Here we argue that the "discovery" of our personal mortality is what "individualizes" us human beings. Humans are as entirely immersed in the environment and as closely connected with "the others" as are most organisms. However, death is the experience impossible to delegate[lxx]. This "discovery" of the *future* "not-yet" is inseparable from the idea of individual freedom of decision, inasmuch as such decisions are entirely and exclusively future-oriented. Such freedom, whether existing or not is here beside the point, is in turn the pre-requisite for the acquisition of modern ideas of justice, retribution, punishment, and so forth. In sum, they are the basis of most normative interactions in human groups, ultimately leading to civilization.

We are proposing a conceptual model holistically incorporating Life, in the restricted sense of the observed planet-wide historical phenomenon, and time with a view to determine the essential difference between abiotic and living physical matter. Now we are in the position to more precisely characterize the restricted sense of the notion of “time” that we incorporate into the model, and which we write Time. It is specifically this altogether human “not-yet-dead”, the unknown “future-before-reverting-to-abiotic-matter” sense of the concept. As shown in this chapter, time is a multifaceted idea, the different aspects of which are not necessarily complementary; neither is the possibility of contradictions between these distinct aspects excluded. What time *is* remains an open question. What Time, the concept incorporated in the LifeTime model, represents has at least been constrained by our definition.

### ***Time in history: The Hebrew-Christian interpretation***

A brief reflection on the innovation of that concept as it appeared in the Hebrew Bible and was later adopted by Christianity and Islam is appropriate to further highlight the mental artifactual character of the notion of time. Ancient Near East religions predating the Hebrew Bible by millennia may reflect the human innate time-concept, in that in these myths time systematically is conceived as circular[lxxi]: The main constituent of the divine order is the everlasting repetition of the same, a time-concept manifest in the ubiquitous fertility rituals. In fact, what the divinity guarantees, and that is what essentially divinities are mythical inventions for, is the assurance of the repetition of the imperative life-death-life recurrence. This may be the daily rhythm of the Sun, the yearly rhythm of the seasons, the Nile floods, the rains in arid Mesopotamia, the succession of generations in animals and humans, or the sprouting (resurrection) of the grain sown (buried in the ground, i.e., dead) the previous season. The entire cosmos is an ever itself-repeating whole in which everyone and everything occupies its pre-assigned place unless the gods are displeased and decide otherwise. On some occasions the displeasure or the fury of the gods can be avoided or placated by following the ritual in a pre-ordained manner with sacrifices, exorcisms, and other means. In this ever-repeating time-structure, the whole creation fits, and no surprises are in store. Note that this archaic idea of time seems to be rather close to our LifeTime concept: The entire universe circles continually according to the divine order and individual Life-forms briefly appear as ephemeral manifestations of this eternally recurring script. In other words, this archaic time concept seems to be much closer to the biological roots of the concept than the much later Hebrew innovation.

The Hebrew Bible introduces a thoroughly original modification: Time now becomes strictly linear. From creation[lxxii], starting on the first day, to God's rest on the seventh day, followed by a linear genealogy leading all the way to the present, nothing is anymore repeated. On the contrary, a history develops[lxxiii], from the paradise, to the deluge, to Egypt, the exodus and to the Promised Land. Christians add the unique historically clearly dated events of Jesus' incarnation, death, and resurrection, that will eventually be time-linearly followed by the only as yet undecided date of doomsday; Muslims additionally introduce the historical figure of the Prophet. In this modified perspective, every event is unique, and every individual is directly responsible for his singular existence lasting uniquely from birth to death. And the order of the universe is to be found, either nowhere (or, equivalently, in the inscrutable mind of God) or, at best, in the mathematical laws that partially seem to obtain in his creation.

Interestingly, death was the final irrevocable destiny of humans in ancient Near Eastern religious systems, as for instance revealed in Mesopotamian clay tablets dating from the third millennium BC. The after-life was a dire affair in an obscure nether world, and no hope for anything better existed. The same stark destiny awaited humans in the Hebrew Bible[lxxiv] or in Homer's *Iliad*. In Greece, around the 5th and 4th century BC, the conception of time began to evolve into the present-day strictly linear framework, again proving the mental-artifactual character of this idea. This can be seen in Plato's suggestion of a better destiny after death, at least for philosophers[lxxv].

### *A possible physiological correlate of the notion of asymmetric time in the human brain*

It should be clear by now that we favor the idea that the concept time may already be incorporated into the hardware of the human brain. This neuronal hardware allows humans to refer to specific external circumstances (actually: internal representations of external events) differentiating between ‘after’ and ‘before’. It follows that the world-order represented by the past-to-future causality structure and its embedding into the time-concept ought to be physiologically discernible in human brains, as a recent study suggests[lxxvi].

T. F. Münster and collaborators presented to subjects two types of sentences that differed only by in the initial word, being either ‘After’ or ‘Before’, and the sentences then being of the form *‘After X, Y’*, or *‘Before X, Y’*. *X* and *Y* were so chosen as to be in syntactic structure and lexical content identical. For instance the couple: “Before the psychologist submitted the article, the journal changed policy” and “After the psychologist submitted the article, the journal changed policy”. Thus, the event in each clause after the first word can be easily understood without reference to the other. Furthermore, each event includes no indication whatsoever of preceding or following the other; there is thus no time-component inserted in them.

The researchers measured and contrasted the event-related brain potentials of several subjects reading these two types of sentences. They found a prolonged (300 ms) event-related brain potential difference on sites on the left frontal scalp, and this difference correlated with the need for additional working memory engagement in sentences beginning with ‘Before’. As the only difference is the first word, this difference can only be accounted for if “the first word leads the reader to expect some non-arbitrary relationship between the two events”. That is, a sentence beginning with ‘After’ points to a probably innately prejudged causal order structure, whereas a sentence beginning with ‘Before’ reverses this order and its comprehension thus requires a longer computation. In other terms, assuming that a causal past-to-future structure is to some extent what a human innately expects to observe in “the world”, then a different structure should demand an additional computational effort. Consequently, at least in this type of task, humans show an innate effect differentiating between ‘before’ and ‘after’. In the next section we go one step further: A recent study shows how this seemingly ‘human’ behavioral trait is also found in animals.

### ***Episodic memory in birds***

Episodic memory in humans refers to the kind of binary memory of events that do or do not occur, situated in some precise space-time location. Episodic memory then registers that, at a distinct space location, and at a distinct time instant, a distinct event did or did not occur (*...was der Fall ist*, see above). For an individual to register in episodic memory the occurrence of an event assumes that the individual can temporally locate a sequence of events in relation to itself; it thus seems to presuppose at least a kind of self-consciousness. Moreover, in humans, this time-wise ordering of events in episodic memory is associated with a causal structure, leading to a particular before and after ordering of the event-sequence. A remarkable experiment[lxxvii] suggests that birds also possess this kind of memory[lxxviii].

It has been known for some time that food-storing animals, such as the scrub jay used in the experiment, remember the spatial location and the contents of their caches, sometimes hiding and later remembering the separate locations of as much as thousand caches. In the experiment, the researchers disconnected all external signals of the caches by removing all olfactory and visual cues that might have guided the animal, only the finding of these caches exclusively using their memory being tested. However, the birds consistently found the caches, relying on their memory. More surprisingly, after the birds learned that some caches containing perishable food such as worms that were unpalatable if recovered a specific time delay after hoarding, they would consistently avoid these caches. These birds distinctly preferred fresh worms to other food (for instance peanuts). However, it was observed that, although they preferentially searched for worms they had recently stored, they avoided worms they had stored after a time delay in which, as they had learned, worms decompose and become unpalatable (at that point they consistently preferred peanuts). Finally, the authors tested if birds also remembered the learned experience that other animals may pilfer food hoards, and that the probability of pilferage increases with elapsed time after caching. Again the results were positive, leading the authors to conclude: "[these results] can only be explained [if the birds] recall three types of information: (i) 'what' items (peanuts and worms) were cached; (ii) 'where' each type of item was stored; and (iii) 'when' [...] the worms were cached. [...] In terms of purely behavioral criteria [...] the cache recovery pattern of scrub jays fulfill the three 'what', 'where' and 'when' criteria for episodic recall and thus provide [...] conclusive behavioral evidence of episodic-like memory in animals other than humans".

### *Concluding remark*

We conclude: ‘time’, in general, refers to a large extent to a fitness enhancing innate trait shared by all animals and plants studied so far. Similarly imprinted in human brains, it escapes an unambiguous non-circular definition. ‘Time’, as defined and included in the LifeTime model, is a somewhat more restricted notion, particularly associated with human’s conscious awareness of their transience. It appears closely entangled with the Life idea, as individual life is always ephemeral.

# 5. The Language Problem

> Language always precedes its user and always imposes on his usage rules, conventions, opacities for which he is not responsible and over which his control is minimal[lxxix].

## *Human language*

Human language is the most sophisticated way of information production and transmission that has evolved by means of natural selection. Production, transmission and processing of information is, however, found at every level in all living organisms; at the molecular level, at intra- and inter-cellular levels, and at higher levels for inter-individual communication. Plants communicate with other organisms to enhance their pollination success and seed dispersal, send and receive messages from their parasites, decode information from their surroundings, and emit chemical signals staking out a territory. In non-human animals, communication systems appear to demonstrate features of adaptation. The vocal repertoire may include calls used for warning, alarm, contact, and mate attraction and territory defense. The intensity of a signal can provide information about the state of the signaler like hunger, rage, submission, and imminent aggression, and thus provide reliable information about the phenotypic quality of an individual. Examples are auditory signals of primates, birds, frogs and toads and many insects, visual signals such as extravagant feathers in birds, but also bright colors and specific patterns of coloration, olfactory signals in many invertebrates and mammals, and electric signals in certain fish.

Compared to this non-human information-processing manner, human language is strikingly different insofar as its possibility of variously combining phonetic discrete units into signifying utterances. By means of its grammar, it allows for a literally infinite number of distinct meaningful messages to be emitted and transmitted over the same channel[lxxx]. In fact, as S. Pinker points out, "[a] grammar is an example of a 'discrete combinatorial system'. A finite number of discrete elements (words) are sampled, combined, and permutated to create larger structures (sentences) with properties that are quite distinct from those of their elements. For example, the meaning of ‘man bites dog’ is different from the meaning of any of the three words, and different from the meaning of the same words combined in reverse order”[lxxxi]. The distinguishing aspect of human language therefore lies in the syntactic serial ordering of its discrete symbols. Millions of years of human evolution have produced a particular information-emitting system that functions by modulating the frequency and the amplitude of an oscillating air current blown out by the lungs. Humans employ for this purpose trachea, larynx, mouth, nose, teeth, lips, and tongue, and an equally complex receiving system in the inner ear. Decoding, i.e., the extraction of meaning from the message, takes place in specialized higher brain structures in the cortex that are connected to the auditory receptors for direct speech decoding, as well as to visual receptors in order to decode the variegated gestures accompanying human speech. Meaning is encoded onto the outgoing airflow in distinct areas of the brain that activate the numerous muscles required for this complex task.

This surprising capacity for encoding almost infinitely different meanings using a limited set of symbols and a grammar, that is, a relatively simple rule prescribing the structural organization of those symbols, appears in the form of ‘language’ in all human societies. This poses a series of problems directly related to our subject. We must first determine whether thinking about a problem - for instance the elucidation of the LifeTime model - is in some way fundamentally different from speaking or writing about that problem. In other terms, we must first settle if everything that is thinkable is also expressible in a communicable language without intolerable information loss. Then we must consider if the medium (*pace* McLuhan) of the written language can bias the available thought options. Since writing appeared so late in human evolution, this point will be deferred to the end of this section. For the moment we restrict our analysis to spoken language. In relation to this subject matter, scientists have been busy for a long time trying to settle the following problems: Does thought directly map onto language? Or is there an unavoidable and crucial loss of information associated with this mapping? Is thought necessarily modified when communicated by means of a mouth that can only utter a single word at a time? In other terms, is the unavoidable linearity of our spoken language somehow causally linked to the difficulties found when, for instance, searching for an elucidation of the LifeTime model? We try to understand LifeTime as a structural whole; still, can this structural whole consistently be mapped onto a linear symbol-sequence? Languages are different, not only in the sounds they associate with the same objects, but more fundamentally in that their grammars are different. Could it be possible that an elucidation of the LifeTime model is more straightforward in a language grammatically and syntactically different from the English grammar here employed? Is the possession of a complex language innate in humans? Is there a "Universal Grammar" common to all (known) languages? Is learning a language, as so easily performed by human children, and so difficult if not impossible for chimps, exclusively an innate human trait?

Before proceeding we establish a number of fundamental facts in the sense that we here admit them without further questioning. (1) We admit that human languages all share a basic theme, or basic design features. We highlight that all languages are constituted by linear strings of independent words, i.e., specific speech sounds. Words, i.e., speech sounds, are treated discontinuously; words have stable meaning. Languages can convey abstract meanings, or refer to events widely separated in space and time. Linguistic forms created by the grammatically 'discreet combinatorial system' are in principle infinite in number. All languages show a duality of patterning in which one rule system is used to order phonemes within morphemes independent of meaning, and another is used to order morphemes within words and phrases, specifying their meaning. (2) Human language is thought mapped onto a linear sequence according to a rule, usually called a grammar, and only in this guise presumed to allow rational communication. Reasoning, however, is a mental activity that is understood to be meaningful only in certain contexts; basically, when constrained by the Aristotelian logic. Admitting this point immediately leads to the question: If so, then what represent illogical utterances? Just bursts of verbal air, *flatus vocis*? And who decides? (3) Thought (reasoning) and language (thought communication) correspond to different mental activities. They are generated in different brain structures, and are functionally distinct. (4) Humans are capable of sudden hunches, creative leaps of the mind that "see" in a flash how to solve a tough problem in a simple way. Or of an artistic prowess such as Mozart's claim of being capable to mentally compress into one time-instant the complete symphony he just finished composing. Further, revolutionary ideas may suddenly occur to scientists that change the entire outlook of their research field. All these capabilities represent aspects of thinking (sometimes called "intuition") that owe very little to linear grammar, logic or reason, explaining why it is sometimes so difficult to communicate these insights to others. (5) A particular human language does not rigidly determine what people can think, nor does it cause fundamental differences in thoughts produced in similar circumstances and about similar subjects. Thus, the presumably same thoughts, insofar as they are at all linguistically expressible, can be dependably rendered in any one of the known human languages, i.e., the translation from one language to any other language is assumed to be feasible without intolerable distortions of the intended meaning[lxxxii]. (6) The capability (*Anlage*) to learn a language, as always found in children, is innate.

These numerous ‘facts’ admitted we still face a different set of problems. The human brain is the result of an evolutionary history that gave rise to the capability to learn and master complex language forms. This is partly anchored in innate brain structures that might constrain the type of language that can be learned and thus also the range of grammars. This latter point is further strengthened by the apparent occurrence in all languages of an underlying common design with their nouns and verbs, phrase structures, cases and auxiliaries. In sum, human languages seem to conform to a universal model and languages fundamentally departing from this model may be ruled out by the brain structures evolved in humans.

Thus, to what extent are languages restricted by the innate neuronal architecture of the human brain? Is the set of possible human thought-structures also biased by the brain and if so, to what extent? In other terms, can every thought always be unambiguously expressed in a language appertaining to the subset of possible human languages? Are there unsurpassable limits that restrict the expression in a possible language of a particular subset of thoughts? Is the linearity of language[lxxxiii] and the rational expression of thought the causative agent of these limits? Has the invention of writing, especially alphabetic writing, modified the limits of language? Up to what point do innate language structures mold concepts such as Life and Time? Are these innate constraints sufficiently strong to consistently prevent a clear understanding of the essential quality of the phenomenon LifeTime?

***The limits of language***

*"The limits of my language signify the limits of my world"*[lxxxiv] is a widely quoted statement to which we now direct our attention. We analyze the extent of an unavoidable distorting bias in our thinking patterns imposed by the innate part of languages. This presumed language bias has been repeatedly investigated from different viewpoints and disciplines. Making use of a rather unconventional approach, we determine the existence, the extent, and the importance of an innate bias for certain forms of rational discourse like when referring to contentious words such as Life and Time.

Aristotle in *Metaphysics Γ* 1006 b-6/12 writes: "If it be said that [one particular word, in this case, a name of a thing] has an infinite number of meanings (*sêmainein*), obviously there can be no discourse; for not to have one meaning is to have no meaning, and if words have no meaning there is an end of discourse (*logos*) with others, and even strictly speaking, with oneself; because it is impossible to think anything if we do not think of *one* thing; and even if this were possible, one name might be assigned to that which we think"[lxxxv]. In the *Tractatus*, Wittgenstein writes in the introduction: "This book wishes to trace the limits of [the possibility of] thought, or, more precisely, of the [linguistic] expression of such thought". In 3.02 he states: "What can be thought of is also possible", but in 3.031: "Of an un-logic world we could not *say* what this world looks like". Again, in 3.261: "Names *cannot* be decomposed [separated into elements] by means of definitions", because, 3.3: "Names have a meaning only in their [structural] relation within a [logical] sentence"[lxxxvi].

The preceding quotes reflect an implicit assumption already semantically contained in the Greek term *logos*, simultaneously pointing towards speech, thought and Aristotelian logic. It was thus assumed that the grammatically correct speech-act and the logical thought-act somehow overlap. In fact, the uninterrupted line of thinkers from Aristotle and Greek philosophy to the *Principia Mathematica* of Russell and Whitehead and to Wittgenstein, posits the existence of a unique rational method for the understanding of the world by means of expressing the concerned thoughts in a given *logical* language. This has been profoundly marked by a set of strongly held convictions. We emphasize those we believe to be the most relevant for the point under discussion: (1) Thinking about the world is only rationally meaningful when such thinking is framed in the mold of a formal axiomatic system, the paragon of which is the mathematical method. Formal axiomatic systems are constructed in accordance with the presumed universally valid postulates of Aristotelian logic including among others the principle of identity and the principle of contradiction, plus the restricted set of assumptions subtending the natural numbers. Formal axiomatic systems allow developing demonstrations unerringly leading from a limited set of assumed "true" axioms to certain theorems. (2) The mapping from the external world (as referred to a self-conscious human) onto the theoretical description of this world by means of formal axiomatic systems is assumed to be possible without an intolerable loss of information about the external world. Descriptions by means of formal systems can be encoded in terms of a logical symbolic language: We can thus speak about the world in a logical language, provided that we speak logically. The presumed definitely settled language in which to speak and reason logically was proposed by B. Russell and A. N. Whitehead in their *Principia Mathematica* (1925). (3) Thinking beyond a logically structured language such as the language constructed in Russell and Whitehead's *Principia* cannot be expressed in a communicable, universally understandable language; it necessarily can only lead to a private, sectarian result. This is the usual, but quite unfounded criticism leveled at philosophers such as Wittgenstein and Heidegger. Having mental experiences beyond such a formal framework is evidently possible and may furthermore be interesting as in a mystic or art-inspired experience, but is not supposed to lead to any "true" knowledge about the external world. If it does lead to a true interpretation of the external world, then this insight is by definition not communicable in the native language. This last point flies in the face of the *aha! Insight* -type[lxxxvii] of experiences widely recorded by scientists, artists, and philosophers. Aristotle wrote in *Posterior Analytics* II, 100b 5-18: "Now of the intellectual faculties that we use in the pursuit of truth some are always true, whereas others admit falsity; and no other kind of knowledge except intuition (*nous*) is more accurate than scientific knowledge (*epistêmê*). Also first principles are more knowable than demonstrations, and all scientific knowledge involves reason (*logos*). It follows that there can be no scientific knowledge of the first principles; and since nothing can be more infallible than scientific knowledge except intuition, it must be intuition that apprehends the first principles. This is evident not only from the foregoing considerations but also because the starting-point of a demonstration is not itself a demonstration, and so the starting-point of scientific knowledge is not itself scientific knowledge. Therefore, since we possess no other infallible faculty besides scientific knowledge, the source from which such knowledge starts must be intuition"[lxxxviii]. In other words, *aha!-Insight*-type of knowledge acquisition is admitted, but since it seemingly, at least initially, escapes logical reasoning, an *ad hoc* source called 'intuition' must be posited.

After 24 centuries, the Aristotelian *nous* is still a widely quoted entity "explaining" sudden hunches, creative leaps of the mind, and other related insight-phenomena, that is, any "true" or "factual"[lxxxix] approach to the objective "real" world achieved outside the rigid framework of logical reasoning. This representation of human rationality is entirely based on the possibility of logical demonstrations by means of formal axiomatic systems starting from self-evident, true, but *ultra*-scientific (according to Aristotle) first principles. It collapsed early in the 20th century when it was shown that there exist well-posed statements that are logically true for no logical reason. This paradigm shift was initially formulated in mathematics, when Gödel in 1931, Turing in 1936, and later others proved not only the existence of unsurpassable limits of the mathematical method, but further proved that the method as such was entirely inappropriate when addressing so-called philosophical problems[xc]. Wittgenstein in the *Tractatus*, with his notorious "Of that of what one cannot [logically] speak, one must [necessarily[xci]] remain in silence" also reached this conclusion. This famous *Grundlagenkrisis* has also influenced research of the innate human cognitive limits.

We rephrase our questions: Are the limits inherent in human language really that impregnable, or does there exist ways and means to – so to speak - tunnel through? Do there exist ways to reach an appropriate knowledge of the world, outside the established, logical language communicable to other rational beings[xcii]? We answer by posing another, quite different question: Could it be that these presumed innate hurdles, limiting our communication possibilities, are aggravated by the invention of the alphabetic writing system? Do we know examples of intents of understanding the world expressed in a language untainted by alphabetic writing? The answer is affirmative, up to a point. The example we have in mind are the Sumerians, inventors of writing around 3,400 BC, who not only left an impressive quantity of material but influenced all Near Eastern civilizations and through this avenue our Western world-view.

First, we show that a complex communication system may have been used by hominids well over a million years ago. This means that when the Sumerians invented writing, humans and their hominid ancestors must have been communicating with a relatively complex proto-language already for hundreds of millennia. We then look succinctly at Sumerian writing. Finally, we focus on that unique Greek breakthrough, the invention of a simple alphabet, now allowing a much easier expression of thought in writing. We conclude: (1) names and linguistic schemata referring to features crucial for survival and reproduction may have become fixed in human brains eons ago, and (2) the invention of the Greek alphabet probably further cemented an innate bias strongly favoring strict linear 'logic' thought-structures.

In sum, we cannot overlook the long evolutionary history shaping our brain if the elucidation of the phenomenon Life is our goal. The reason is that to achieve this goal we inevitably must use our current language to communicate our results, nor can we avoid a linear formal approach in the presentation of our model. Furthermore the term (here: LifeTime) we wish to define refers to the primordial existential property of each of us. In addition, we cannot disregard the problematic correlation between our mental images, the names we assign to them, the language structures in which we frame them, the assumed reality into which they are embedded and to which they are connected by a presumed information-preserving mapping.

### *How old is hominid language?*

Presumably no one will ever be able to conclusively answer this question[xciii]. Recent publications suggest that hominids acquired a communication system of a complexity far beyond what is presently known from the rest of the animal kingdom very early in their history, maybe as early as one million years ago. Fossil remains recently uncovered provide compelling evidence for a very early appearance of a complex communication system. Should this be the case, then it is difficult to avoid the inference that a set of ancestral communication structures might be irreversibly imprinted in the human brain.

The onset of elaborate stone tool manufacture by hominids has been reliably dated to have occurred as early as 2.6-2.5 million years before present based on the recovery of hundreds of genuine and remarkably sophisticated artifacts from East Africa (Awash valley, Ethiopia)[xciv]. The possibility of these artifacts having originated by random impacts is convincingly excluded, fundamentally because of the uniform flaking patterns and the sophisticated control of stone fracture mechanics observed[xcv].

The manufacture of such stone-tools already requires an advanced degree of manual dexterity, hand-eye coordination and, finally, conceptual developments absent from the animal kingdom including the great apes. Although no hominid remains directly associated with these artifacts have as yet been uncovered, the inescapable conclusion is that already at this early date a hominid group had reached this noticeable level of mental progress.

The island of Flores in Indonesia lies beyond a deep strait that separates most Asian and Australian faunas. To reach Flores from the nearest place it is necessary first to go from Bali to Sumbawa, crossing 25 km of treacherous waters, and then again cross a 19 km wide channel. Recently[xcvi], at Mata Menge in Flores, 14 stone artifacts have been uncovered that confirm the presence of tool manufacturing *Homo erectus* as early as 800,000 years ago. This finding implies that at this early date Far Eastern hominids had developed the capability to build and use the appropriate watercrafts, robust enough for the difficult voyage needed to reach Flores. Inescapably it follows that these hominids commanded communication skills and possessed a social organization at least sufficient to cooperatively build and man these floating devices, skills that far outpace anything encountered in the rest of the animal kingdom. Whether these hominids, or those mentioned above from East Africa and China, can be considered directly preceding modern *Homo sapiens* is beside the point. We are here only interested in suggesting that a given form of communication system, substantially more sophisticated than anything presently found in the animal kingdom, must already have been at the command of hominids at least 800,000 years ago.

Even more surprising is the uncovering in Schöningen, Germany, of a remarkable collection of wooden tools and hunting spears dating to 400,000 years before present[xcvii]. In one level of the excavation, together with numerous flint artifacts, three worked branches of common silver fir, length 170-320 mm, width 46-42 mm, show diagonal groove cuts in one end. These are assumed to have been placed there in order to hold flint tools or axes; these may thus be the oldest composite tools yet discovered. At a different excavation level, three wooden spears were found, length 2.25-1.82 m, maximum diameter 29-47 mm, made from individual spruce trees, all manufactured to the same accurate pattern. Although of different lengths, the maximum thickness and weight of these carefully tapered spears is at the front, i.e., the part of the spear made from the base of the tree where the wood is hardest. These spears closely resemble modern sport javelins and were most certainly also designed for throwing means. Other shorter spears were also found. The northern location of these remarkable artifacts and their age place them at a time when the climate in northern Europe was colder then at present and where winter survival must have been particularly demanding. Again the conclusion is inescapable: to learn the trade, to transmit the technology, and to collectively use these weapons in hunting requires a degree of social and communication sophistication unknown today anywhere except in modern humans. Whether these hominids are directly related to *Homo sapiens* is a moot question. What for us appears as crystal-clear is that quite elaborate communication systems must have been at the command of different hominid groups, in widely separated locations on the planet, hundreds of thousands of years before our age!

We conclude from these discoveries that human communication systems, including present-day language learning and mastering capabilities, necessarily must incorporate certain innate structures accumulated during thousands of years. It seems therefore probable that such terms as “life”, “time”, and “order” are partly biased by our common language, which may partially explain some of the difficulties we are encountering.

### *Writing in Ancient Mesopotamia*[xcviii] *and elsewhere*

Approximately in the fifth millennium BC, at the end of the last glacial period, Mesopotamia took its present form. In the south, the Sumerians became established. Remarkably, their language is entirely different from all known ancient Near East languages. To the north the Akkadians settled simultaneously. Archaic Akkadian is related to archaic Egyptian and the most archaic languages from Ethiopia. Mesopotamian civilization is the result of the encounter, in the fourth millennium BC, of the Semitic Akkadians and the Sumerians. In the third millennium other Semitic nomadic tribes invaded and settled in Mesopotamia, and the Sumerians proved incapable of resisting their onslaught. However, their language remained in use until the Christian era, first as the general official language and later as the language in which the entire Mesopotamian culture, religion and literature was expressed[xcix]. The influence of the Sumerian civilization stretched from the Indus valley to the diverse peoples inhabiting what is now Syria and Turkey; from there it extended to the Mediterranean basin and decisively influenced the Greek.

In the original form of Sumerian pictorial writing, each character directly represented the reality whose silhouette it reproduced. Later the pictorial representation of the symbol was not only correlated with the respective reality it was supposed to represent, but might also be correlated with the sound of the word used to describe this reality. That is, the transition from a pictographic to a phonetic form of writing was hereby discovered. Originally, writing was probably exclusively an *aide mémoire* for a commercial transaction or debt that specified objects and their number thus already requiring nomination and numeration in symbolic from. To this was necessarily added the name of the writer, a requirement for which the sometimes wonderfully carved cylindrical seals were invented. The writing material used was mostly a sun-dried clay tablet. When different city-states succumbed to an invader, they were usually reduced to ashes by the victor, with the results that complete libraries and archives of clay tablets, now properly heated, survived to our day. For instance the burnt down palace libraries of Uruk, Ebla, Mari, and Niniveh each yielded thousands of such tablets. Not surprisingly, coercive oaths and curses frequently accompany these early written testimonies of commercial transactions[c].

The crucial advance to phonetic writing only reached its full amplitude with the Mesopotamian discovery of a syllabic representation of the phonetic sounds. Now the written symbols represent a consonant-vowel or a consonant-vowel-consonant combination. This invention had revolutionary consequences. The world-view of ancient, as well as modern, humans is profoundly shaped by the set of myths[ci] to which a community prevalently adheres. In archaic societies these common myths were transmitted orally, and anthropological studies reveal that the adherence to them is based on the direct identification of the spoken word and the thing itself to which the word referred, or an identification of the name of a god, and the god itself[cii]. But when words and names became chopped up into syllables, when a syllabic writing was identically useful to name a Sumerian god or an Akkadian god, the direct link between man and gods was broken, and a mediation had to be established. In a certain way, the different forms of commonly acceptable mediations between gods and humans, between the “external” world and what we can learn about it (between the *Ding an sich* and our representation of it, in short, how humans can connect their personal internal mental images with whatever “external reality” they are prepared to admit) became, after the invention of the syllabic writing, a crucial unresolved problem. Answers to this problem were searched in religion, superstition, philosophy and science.

This cuneiform syllabic writing system was constituted by about a thousand different symbols not all used in the same way. Each symbol simultaneously allowed an ideographic and a phonetic interpretation. Thus one particular ideogram could be directly read as what it represents, for instance a mouth, *ka* in Sumerian, or only the phonetic value, here the syllable /ka/, could be used in a context totally different from the pictorial representation, i.e., from a mouth. By adopting this writing system, people speaking a Semitic language, such as the inhabitants of Akkad, Ebla, or Babylon, were now able to write phonetically instead of ideographically the words and the grammatical forms of their language and to translate the Sumerian cosmogony, astrology, and other poems. Interestingly, many clay-tablets presenting Akkadian-Sumerian dictionaries have been unearthed. However, each graphic symbol of the cuneiform system possesses several ideographic or phonetic referents. Some symbols are read differently when they mean something different, a property called polyphony. Or different graphic symbols may all share the same phonetic interpretation, a property called homophony. Consequently, reading and interpreting a Sumerian cuneiform text is a task for the specialist that presupposes arduous learning and training. As a result, very early the public scribe appears as a personage of highest esteem in the Ancient Mesopotamian hierarchy. More important is, however, that this writing system remained the privilege of an educated minority, resulting in the establishment of monopolies of interpreters of the “sacred texts”, and of performers of magic rituals, exorcism and, in particular, of divination, astrology, horoscopes, and so forth. In other words, this form of writing system must be understood as an essential component of a particular hierarchical social structure, and it is instrumental in determining the place of the king, the priestly caste, and other social categories. If this interpretation is correct, then by the same token one must admit a fundamental role of the adopted writing system in shaping the “collective archetype” of a human group[ciii].

All this changes with the next break-through: The invention, at an unknown date, of the consonant alphabets; the oldest consonant texts found so far are dated between 1,800 and 1,500 BC. The primordial rule now is that one symbol equals one sound. By noting only the consonant sounds, these alphabets represent an incredible simplification: The Phoenician and the Aramean alphabets have only about 30 symbols, the same as the Ugaritic consonant alphabet. Observe however that these alphabets do not have symbols corresponding to the vowels, which again introduces a degree of arbitrariness in the text and requires trained specialists to establish the “correct” interpretation, with all the consequences and disputes generated by this situation attached[civ].

The final development is the invention of the Greek alphabet. It seems that the Greek lost the use of writing after the Mycenaean period. But sometime around the eighth century BC the Greeks directly adapted to their language the Phoenician[cv] alphabet, keeping the Semitic names of the letters: *aleph* became *alpha*, *bayt* became *bêta*, *dalet* became *delta*, etc., and also the order of the letters: *aleph-bayt-gimel* was kept as *alpha-bêta-gamma*. As certain Phoenician symbols did not correspond to any Greek sound, the Greek used these symbols to represent the vowels. Thus for the first time in history a simple writing system appeared that could be read by anyone without too much previous training, making the highly placed public scribe, but also the monopolizing priest and other dignitaries in principle superfluous. In its final form, this writing system became the vehicle par excellence for the second enduring legacy of the Greek: philosophy. Was it a chance event that philosophy and logic came into being precisely when this easy alphabet was established? More importantly: Did this linear writing system, onto which the complex ideas of the philosophers now had to be mapped, have a causative influence on the development of a philosophic and later a scientific language? Did the fact that writing now became so easy (children could now master it!) make the linear way of expressing one’s speculations almost obligatory, and in this way exert a decisive influence in shaping and biasing the creations of philosophers?

The linearity associated with the way in which writing is performed since the Greek, and the now universal use of that medium to communicate ideas, necessarily biases not only the particular expression of ideas, but most probably as well the whole structure of thoughts that lie at their origin. In other words, there seems to be a biologically common root behind these apparently unrelated phenomena: (1) Learning to speak a language; (2) logically thinking in a language; and (3) writing down these thoughts in that language. A biological root manifest as a limiting bias, as a strait-jacket that stymies and obstructs the possibility of a clear understanding of the kind of phenomena this study tries to clarify: Life and Time. Moreover, we interpret Heidegger's *Sein und Zeit* or James Joyce's *Ulysses* as strenuous efforts to try to loosen this straitjacket. Joyce, for instance, resorts to a writing system reminiscent of archaic Sumerian. A word in *Ulysses* is frequently ambiguous in many senses. You may read it as if it was written in a non-English language (sometimes it is actually a foreign word) and then, by the sound of an English pronunciation of that foreign word, get the intended English sense. Or an English word, slightly distorted, may again sound as some phonetically similar non-English word, this last one then providing the intended sense. And so in *Ulysses*, Joyce, employing seventeen different languages (forty in *Finnegans Wake*!) endeavors to expand the traditional constraining frame of our communication system. Of course, Joyce's *Finnegans Wake*, his undisputed masterwork, is even more difficult to follow. Interestingly, time in *Finnegans Wake* is circular, and the book's end exactly fits its beginning so that, in principle, the reader might perpetually persevere in this hard exercise. From a different perspective, Heidegger, who deliberately rejects the classical logic, takes the reader in his essay *Was heisst Denken?* (What is meant by *to think*?) on a tour leading nowhere, pretending that just the fact that the student (the essay is an university course taught in 1951-1952) follows him *is* thinking. He calls these thought-acts 'roads leading nowhere' (*Holzwege*), roads cut out in the forest, sometimes there is a clearing where an understanding seems to be forthcoming, but mostly one is utterly lost. That is, no question is ever answered, all that can be achieved is a potentially better rephrasing of the original question. However, the choice of the question that is worth questioning (*frag-würdig*) is essential.

Without ever dreaming of reaching the extraordinary level of a Joyce or a Heidegger, we endeavor *mutatis mutandis* by suggesting the structural whole LifeTime as a solution to lead the reader to a 'clearing in the forest'. There, for a brief moment, a less obstructed view of the phenomenon Life might be achieved.

### *Concluding remarks*

To present language as a problem for the expression of complex ideas was the purpose of this chapter, and to argue that the origin of the associated difficulties stems to a great extent from its inseparable linearity that is further strengthened by the alphabetic writing system now in common use.

In this essay, we substantiate the claim that the unification of the concepts Life and Time into an indissoluble structural whole called LifeTime leads partly to a clarification of the planetary phenomenon Life. As a structural whole, the LifeTime model is a many-dimensional contraption. Yet we have no other means than using a common language to present our ideas. That is, we cannot avoid casting this multi-dimensional concept in a strictly linear mold that most probably is strongly biased by eons of evolutionary history. This remark should not be taken as an excuse, but only as an acknowledgment that the reading of this text may not always be easy and straightforward. In sum, the difference between abiotic and living matter is not a simple one, and its expression in a linear language framework even less so.

# 6. The Algorithm

### *The physical nature of information*[cvi]

To differentiate between biological and non-biological physical systems we propose a conceptual model termed LifeTime, structurally unifying Life, the historically attested planet-wide phenomenon, and Time, in the 'not-yet-dead' sense of individual transient Life forms. In this chapter we incorporate a further indispensable component into this LifeTime structural whole. This component is based on the way we humans understand nature. Traditionally, the most accurate understanding of nature has been provided by the physical sciences. It has been based on mathematics, which in turn is based on two fundamental assumptions. The first relates to the existence of the real number system[cvii]. By the second it is assumed that there exists a succession of unambiguously executable operations leading from the question to the answer. The universal Turing machine epitomizes this approach: a finite sequence of bits, each either 0 or 1, is processed by the machine according to a rule, an *algorithm*, leading to a result. But a definite result is obtainable only for a reduced subset of cases, as by a famous theorem[cviii] one cannot predict if, given an arbitrary program, a universal Turing machine will halt or run on forever without ever outputting a result. Thus, on these foundations is built our understanding of nature: "the laws of nature are algorithms for handling information, and must be executable in the real physical universe"[cix].

Living matter is physical matter subject to the same laws of nature, and thus also understandable, if at all, in terms of information handling algorithms. But whereas in general the problems that physics can solve are drastically simplified excerpts from nature, biology has not that luxury at its disposal, and must instead try to understand systems of staggering complexity. Consequently, studying biology from a mathematical perspective has been so far restricted to a reduced subset of selected problems. Here, we argue that this may be due in part by relying entirely on a Turing machine approach, and we suggest that a quantum computation paradigm is what might be required to connect the physics of living and non-living matter. Although entirely speculative, we however provide a number of insights tending to underpin this rather untraditional opinion.

***Information processing in biological systems***

Living organisms are continually and continuously receiving and processing information from their environment. This constant information processing cannot be completely arbitrary. On the contrary, there ought to be a distinct information-theoretic pattern uniquely characterizing biological information exchange, that is, uniquely differentiating living from non-living information exchange. Here, we argue that information filtering, decoding, and processing in all Life-forms is under the control of a Life-specific Algorithm, hereafter written with capital A. This Algorithm is proposed to operate in all Life-forms, under all circumstances. If so, it constitutes a defining element differentiating living from non-living matter, and therefore a fundamental component of the LifeTime model.

By definition, individuals attaining their specific optimal condition will on average leave disproportionately more offspring than other less favored individuals, i.e., will maximize performance in terms of Darwinian fitness. This is however a precarious advantage as the optimum will change when the environment changes. In any case, the optimum is only a hypothetical condition, as it is practically never attained. Most if not all individuals are living under sub-optimal conditions. Hence, there is always a *deficit* between the hypothetical optimum and the present conditions of an individual. This deficit is the outcome of a historical process: The present performance of an individual is the result of accumulated past stochastic and selective modifications integrated into its genome by natural selection and other processes and the factors causing this individual to live in a particular site. The genome is a memory register of past information processing results and the effects of stochastic events, recording the organism's interactions during past selective circumstances, which may or may not obtain in the present situation.

Darwinian evolution by means of natural selection acts on populations by permanently shifting genotypes in the direction of the hypothetical local optimum, resulting in additions or deletions in the genomic information register. Assuming stable environmental situations, individuals with genotypes farther from the optimum will be underrepresented in the next generation whereas individuals closer to the optimum benefit in terms of number of offspring. Still, to maintain a condition closer to optimum is only achieved at the cost of intense competition from other individuals.

### ***Competition***

Ubiquitous competition is an empirical fact in biology. This competition is fought out at every possible level where a deficit is experienced. The individual closer to the optimum is constantly subject to challenges. For that reason, optimization of survival and reproduction, even in the state closest to the optimum, always necessarily implies competition.

This unceasing competition is fought out at different levels. Organisms are the sum of their component parts. For genes, organelles, cells, and organs, a hypothetical optimal condition can also be envisaged. As an individual is basically the result of the sum of its component parts, and insofar as these component parts also possess the capability to play a role in this competition, the idea of competition must similarly be extended to each level. Thus, an individual's genes, cells and organs may all influence relative success in competition. In accordance with a currently widely held paradigm, the primordial level at which this unceasing competition is fought out is the level of the genome. In particular, competition may arise between paternally or maternally imprinted genes as a general struggle among alleles to be better represented in the next generation. At the level of individuals competition occurs for scarce resources such as food, a site for reproduction or a mate. Finally, group selection arising from competition between populations appears to occur, albeit relatively infrequently, as for instance between groups of social organisms[cx].

Importantly, the deficit mentioned above must be understood in terms not only of the particular physical environment and the place that an individual occupies in that environment, but as reflecting the relative position of an individual in comparison with conspecifics. Therefore, the tendency to reduce the deficit includes the constant effort and competition to survive and reproduce *better* than "the others" do. Not survival and reproduction *per se* but the unceasing effort to outperform all "the others" is what counts.

What drives this competition? Why in the first place are Life forms engaged in this permanent competition to survive and reproduce *better* than others? Remark that survival and reproduction always are accomplished in a future-Time. This has led us to propose the LifeTime unification. Now, based on the continuous competition, we add another component to the model.

### *The Algorithm*

We incorporate into the LifeTime model a special form of information processing. The ‘raw’ information processed by Life-forms is practically everywhere, in every aspect of the environment, in the electromagnetic radiation arriving from the Sun, in chemical and thermal gradients encountered in aquatic media, in the local hypothetical optimal conditions and the deficit from it experienced by a particular individual. In sum, we understand the LifeTime phenomenon as a specific form of physical information processing. As the environmental information impinging on any individual is gigantic, a preliminary filter first *simplifies* this information stream, thereby enhancing the signal-to-noise ratio. We call this effect trust-in-order and treat it in Chapter 8. Filtered environmental information is processed and evaluated by each individual. This information processing necessarily requires the capability for *temporarily* storing and registering partial results, a capability that appears in living organisms as memory, and which is directly associated with the Time concept.

We are searching for the specific LifeTime information-processing algorithm, since information storage and processing are not what uniquely defines Life. The fundamental thermodynamic concept of entropy is interpreted as an information-theoretic term measuring the order of a system, and determining the range of the possible final states that a physical system can attain. Information is stored in a particular system as “order”, as well as in the form of specific initial conditions, and physically processing this information determines its probable future development. This kind of physical information processing is ubiquitous in nature and is thus not sufficient to specifically characterize LifeTime. Clearly, computers and most engineering machines store and process information, but are not alive. We affirm that the concept

LifeTime structurally incorporates a special framework of information processing as an Algorithm with the following properties. First, the Algorithm uses as input the incessant information stream (filtered by sense organs) impinging on any particular individual mainly to evaluate its current deficit from the theoretical optimum in its particular circumstances. This crucially implies that biological systems have access to, and can process information about, their internal state as relevant to their deficit-condition in a particular environment. Second, the Algorithm constantly evaluates the available options to reduce the deficit, evaluating the optimal strategy to reduce the current deficit based on the present state of the environment and taking into account past experiences. Thus, this Algorithm must be understood as modulating the behavior of all Life forms tending to reduce their current deficit. Third, since the deficit defines the status of a particular individual relative to others, and since the Algorithm produces behavior that reduces this relative deficit, it follows causally that individuals constantly attempt to outperform “the others” with respect to relative reproductive success. Finally, the Algorithm mirrors the evolutionary history as reflected by the register of past experiences.

We therefore assert that LifeTime-systems are constantly processing information received from their environment, this term taken in its widest sense, i.e., incorporating the physical habitat, all other Life-forms interacting with an individual, and its internal state. This constant information processing of LifeTime-systems must conform to a special Algorithm outputting behaviors tending to reduce the current deficit as evaluated in their environment. Since essential resources are generally limiting, and since all other conspecifics and heterospecifics are similarly endeavoring to reduce their particular deficits, the Algorithm leads causally to the unceasing competition ubiquitous for all biological systems. That postulating this Algorithm is entirely different from introducing a teleological argument was shown in Chapter 1, when we compared it with Newton’s gravitation.

### *“Natural Computing”: The cell as an information-processing system*

It has been known for some time that what goes on in a cell can be understood in terms of information processing. Although this has been more evident when considering the

DNA molecule, and has given rise to a research domain called "DNA Computing", the idea that all the cellular processes can be understood in this way is less divulged. DNA Computing is a method using DNA molecules as support for computations. This has been experimentally shown to work[cxi]. Here we wish only to remind that protein molecules are similarly a support for computational processes. As D. Bray writes[cxii]: "In principle, any protein that transforms an input signal into an output signal could act as a computational or information-carrying element." And "The imprint of the environment on the concentration and activity of many thousand of molecules of the cell is in effect a memory trace. In contrast to the permanent information encoded in DNA, however, it is a 'random access memory' containing ever-changing information about the cell's surroundings". As in so many other instances, what we are here seeing are descriptions at different scales of analysis. Information processing in living organisms can be envisaged at the macroscopic level of a nervous system, at the smaller level of the DNA or protein molecules, and at an even more fundamental level of the elementary particles constituting these molecules. This last level of analysis must be based on quantum mechanics, and thus must admit *ab initio* all the counter-intuitive results of this approach. In the last few years, the idea that a Quantum Computer may some day become a physical reality has been gaining ground. But, in any case, it is becoming ever more clear that what really may be happening at the most fundamental level in living matter is something that might best be described as quantum computation. We here adopt this position.

### *The quantum mechanical character of the Algorithm*

The Algorithm here suggested is postulated to operate at any level of the LifeTime phenomenon. Fundamentally, however, it must be shown to be active at the cellular level, as cells (or unicellular organisms) constitute the most basic elements in the LifeTime scenario. Individual cells are incredibly complex information processing systems. Only a description at the level of the molecule can provide some insight into this complexity. The molecular timescale is measured in picoseconds or even in femtoseconds – $10^{-12}$ and $10^{-15}$ s, respectively. On such timescales chemical bonds are forged or broken and the physical process called 'life' develops. Cells constantly interact with their environment. Information decoded from the environment, in the form of molecular signals such as hormones or neurotransmitters, lead to cascades of molecular events. Each molecular step of the signaling pathway connects the information stored in the genome with the environment of the cell, resulting in changes of particular physical parameters. Specific changes in cellular parameters, amplified to multicellular organisms, are subsumed under the less than optimal term ‘behavior’ or phenotype. Behavior, such as competing for access to optimal conditions, is what macroscopic humans observe, for instance in animals.

But cellular signaling pathways are not clearly defined linear connections, as such molecular cascades interact and affect each other, proteins that are components of one pathway interact with proteins of a different one, and of course a great number of them is activated simultaneously. All this leads to an intricate network of feedback loops, and thus to clearly non-linear results. To further highlight the intricacy of an individual cell, let us point out that the human genome is now believed to have roughly 40,000 to 100,000 genes! Moreover, the DNA of genes is transcribed into messenger RNA (mRNA) and then translated into proteins. But many proteins are modified after they have been translated, so that one mRNA can give rise to more than one protein. In even the simplest self-replicating organism, *Mycoplasma genitalium*, there are 24 percent more proteins than genes, and in humans there could be at least three times more. We remind further the presence of the internal ‘clock’ (Chapter 4), a molecular oscillator setting the rhythm of the cell. These oscillators are characterized by an intracellular feedback loop in which expression of a group of genes results in production of proteins that then switch off the expression of those genes. But nowhere is this complexity more obvious than in the problem of protein folding.

In the cell, proteins are concatenated by sequentially joining the amino acids specified by the mRNA molecule, in a process termed translation. After folding, the linear amino acid sequence gives rise to the native conformation of the protein. Proteins fold into their native conformation spontaneously, generally in seconds or less, whereas secondary structures such as helices or b turns fold in tens of nanoseconds ($10^{-9}$ s). This folding is the result of well-known physical interactions between atoms of the amino acids, the solvent and extraneous components of the system. How do proteins fold so fast? Suppose we calculate the number of possible configurations a sequence of amino acids can fold into before “finding” its native conformation. That number is staggering.

If to fold proteins have to search their native conformation amongst all those that are possible, the process would take more years than the age of the universe. This is called the ‘Levinthal paradox’. So what mysterious system is capable to reach in a blink what the most powerful computers are unable to achieve even for highly simplified situations?

Whatever happens in a cell, happens at the level of atoms and molecules. So far, only quantum mechanics can describe these interactions. But we humans are strongly biased by a linear, one step at a time, approach to most problems (see Chapter 5). Similarly, computers are essentially Turing machines, and Turing machines process information in a strictly serial manner. Moreover, input (and output) of Turing machines are bits. Bits are either 0 or 1. All this changes in a quantum computer. Instead of bits, here quantum bits or qubits are employed. A qubit is a superposition of the two states 0 and 1, so it is neither of them but in a way, both of them simultaneously[cxiii]. Whereas conventional computers process information encoded in a changeless bit sequence – the program, a quantum computer processes information encoded in a superposition of quantum states. Such quantum states may be the internal electronic states of atoms, or the spin states of atomic nuclei. A quantum software program is a particular quantum state that enables a quantum computer to perform specific tasks. The idea that a quantum computer is at all possible – and extremely simple prototypes have already been constructed and shown to work![cxiv] – is a direct consequence of the quantum picture of reality. In quantum mechanics, reality is at all times the superposition of all possible states evolving in time according to the Schrödinger equation. When a macroscopic (human) observer measures a particular physical parameter this superposition collapses giving a well defined macroscopic result, usually a rational number. Loosely speaking, in the quantum computer a short program, say of 1000 qubits, corresponds to a superposition of all the possible programs, that is, might be capable of evaluating simultaneously $2^{1000}$ programs (about $10^{300}$)! Thus, if and when quantum computers become technically feasible at that scale, humanity will have broken the ‘Turing barrier’, and thus will literally step beyond the limits imposed by its animal condition[cxv].

Things are different in a cell. ‘Reality’ of a cell is the quantum mechanical superposition of the nearly infinite possible states its millions of different atoms and molecules can occupy. But this fantastic mess is a well functioning living cell! We believe that this apparent contradiction disappears when one considers a cell as the continuous output of a gigantic quantum computation. Under this perspective, a cell is at any instant of time a superposition of an enormous number of coherent quantum paths. When macroscopic observers interfere, the ensuing entanglement cell-environment or decoherence results in “that cell under the microscope”. Thus, an external macroscopic observer, who can only measure a few parameters, may register results such as a protein in its native conformation, or changes in a certain pre-selected behavioral form. Moreover, by the measuring apparatus employed, such as eyes or microscopes, the external observer, from the very beginning, filters and biases the result.

So what role is assigned to the LifeTime Algorithm in this picture? Protected from decoherence, a quantum computation does not lead to chaos. Only when a measurement is effectuated, the collapse of the superposition of the possibilities results in a particular measurable macroscopic outcome. But some outcomes are more probable than others. Experiments testing quantum mechanics are usually performed in the gigantic laboratories and particle accelerators of modern physics. When a result of such an experiment is given, it is always stated in statistical terms. The laws of quantum mechanics are not deterministic and can only predict the probability of a given measurement being observed, that is, can only assign different probabilities of observing one or another state of the superposition. This, we argue, is what also happens at the cell level. An Algorithm, a quantum mechanical ‘law’, peculiar and exclusive to living matter, biases the outcome of the interaction of zillions of atoms and molecules in such a way that some results are more probable than others. What macroscopic observers describe as behavior tending to enhance the relative reproductive success of living matter is then such a result.

How can such a hypercomplex system as a living cell consistently perform in this restricted Algorithmic manner? Put differently, how can a cell consistently output behavior enhancing relative reproductive success? One hint of an answer may be found when taking into account the recent subject of ‘quality control’[cxvi]. It is now known that for every vital function a cell has different stringent quality control systems that avoid wrong results be it in DNA replication or transcription, in protein folding, refolding and degrading, or in the start of the cell cycle in mitosis. Put differently, the cell is a magnificent quantum computer the software of which is in some way represented by the Algorithm. This software has incorporated sufficient cell-specific controls and error correcting subroutines to adequately increase its overall reliability. Once it is further considered that, in multicellular organisms, most cells are connected and interconnected with neighboring cells, we arrive at something like a gigantic parallel quantum computing system run by a program consistently outputting this general type of LifeTime behavior.

A final word. Behavior is a term mostly applied to rather complex animals. There, behavior can be studied in terms of appetitive and aversive stimuli. That is, in terms of rewards and punishments. When we finally try to connect the Algorithm with behavior, as we must, it should not be overlooked that this implies extrapolating over many orders of magnitude. The Algorithm is only a cell-level quantum mechanic rule. Ascending from this level to the complete organism, and connecting the Algorithm to macroscopic behavioral forms, is at best a heuristic manner to look at the Life phenomenon. But we seem to be constrained to use such radical shortcuts (see Chapter 7)!

***Trust and order***

The Algorithm steering individuals towards the optimization of their survival and reproduction necessarily refers to a specific environment. Thus, there is still an ingredient that must be incorporated into the LifeTime model. This is what we characterize as a firm trust, an unshakable confidence, in the continuity of currently prevalent environmental conditions. This trust in the future stability of the environment is dependent on the concept of ‘order’. Remark that such a confidence in the stability or the inherent order of the environment amounts to a tremendous simplification of the information received in a particular habitat, as now this habitat becomes “predictable”. We will study this aspect in detail in Chapter 8.

### *Testing the Algorithm*

In order to test the Algorithm we would have to show that there is only one ubiquitous Algorithm or, even better, spell out in mathematical terms its quantum mechanical formula; this obviously we cannot do. Nevertheless, we can show that the Algorithm is permanently active in well-studied organisms; this we do in Chapter 9. In most cases the action of the Algorithm is seen as a steering capability allotting to the individual rewards or punishments according to whether it strictly follows or deviates from its rule. Finally, we point out a number of testable predictions deriving from the Algorithm in the LifeTime model suggesting an explanation for as diverse human phenomena as religious beliefs, placebo effects and self-deception; they will be analyzed in the final chapters of this essay.

### *Concluding remark*

We propose that the Algorithm is an integral component of the structural whole LifeTime. This conceptual model must be comprehended as a totality. If we try to reduce LifeTime to the sum of its components, the result will only be empty circular statements. When preening loose the Algorithm from this non-analyzable[cxvii] whole, it will emerge as a hollow argument. However, this problem is not inherent to the argument itself, but is only a consequence of our difficulty in grasping the unification of Life and Time as suggested in this essay. Of course, we can always reject the entire approach as simply words that unnecessarily complicate things. However, the tradition to ask - and ask again - certain questions is an old one inherited from the Greek. Everyone does not necessarily share this tradition as Herodotus already pointed out in the 5th century BC. "We Greek risk our lives on leaky ships and camels and elephants and whatever to go to the most incredible parts of the earth to ask other people how they live, who they are, what their laws are. Not one of them has ever visited us"[cxviii].

# *7. The Brain*

### *Brain and mind*

In the preceding chapter we stated that biological systems could be regarded as constantly processing information under the regulation of an Algorithm. All cells including, of course, the neural tissue of human and non-human animals carry out this information processing. However, in humans we have to address the further complication represented by 'the mind'. The ambiguous frontier separating the physical brain from the mind is a problem that to some extent remains unresolved. So is the complex relation between the 'intellectual' products of the mind and the 'direct' sense perception of the brain. The same applies to whether the mapping of mentally constructed models of reality reflects reality itself. While acknowledging these difficulties, we can point to some recent experimental results that provide support for the hypotheses put forward in this essay.

The scientific understanding of how the human brain works has progressed immensely in the past few decades. The confluence of cognitive psychology, neurobiology, psychobiology and clinical psychiatry, aided by non-invasive imaging protocols, has revealed in ever finer detail how individual neurons and the various brain modules work together. They produce or influence perception of specific traits such as pain and pleasure, visual awareness, and episodic, semantic, and working memory. In addition, they have provided significant new data on the etiology of different mental illness. A large body of evidence now links the action of several dozen chemical substances, the neurotransmitters, to specific behavior in humans and laboratory animals. Behavior manifesting aggression, fear, pleasure, pain, hunger, sexual drive, drug addiction, and even 'motherhood' have been chemically elicited in experimental animals. Mental illness in humans, disrupting behavior taken as 'normal', has been linked to restricted brain areas, to the action of specific neurotransmitters, and in some cases to precisely identified mutant genes and the impaired proteins into which they are transcribed. Remarkable insight into the working of the brain also stems from modern non-invasive imaging techniques and from the study of the effects of localized brain lesions affecting mental functions. This cumulative increase in knowledge has led towards a clearer delimitation of the large human brain from a restricted subset of the functions that this physical organ accomplishes in the body; this restricted subset of human brain-functions usually being termed 'the mind'.

We confine the use of the term mind to the part of the information processing capability of the brain that reaches conscious awareness. Based on the information flux constantly being supplied by the senses, this conscious and unconscious information processing is carried out by the brain essentially just to keep the individual alive while simultaneously steering it towards optimizing the transmission of its genes into the next generation. Thus the proposed Algorithm should be detectable in human brains, which is the point we here discuss.

Evolution has increased the general information manipulating performance of the human brain, enabling it to solve the life-threatening problems that our hominid ancestors faced during their existence. However, only a very reduced part of this information processing ever reaches conscious awareness. According to Darwin's theory of evolution, the ultimate information processing 'problem' that the hominid brain had to solve was maximizing the relative number of viable offspring that survive, thereby maximizing the number of its genes present in the gene-pool of the next generation.

We elucidate the features differentiating living from abiotic matter by proposing the LifeTime unification. Although we base our analysis on facts, the analysis as such is undoubtedly a conscious intellectual[cxix] information processing operation that therefore must be assigned to the mind. Given the tight entanglement of brain and mind, but keeping an eye on the surprising advances of contemporary neuroscience, we ask: Can modern neuroscience shed light on our conscious, intellectual endeavor? Can facts about the modular structure of the brain, the properties of neurons and their connection, the chemistry and the action of the neurotransmitters, the action of different drugs, help to elucidate the form of the zillions of computations that the mind is simultaneously manipulating when consciously and/or unconsciously processing information? Is it possible to clarify the concept Life by studying the brain solely from an empirical perspective? In one way it is absolutely impossible, whereas from a different viewpoint we obtain a striking confirmation of the presence of the postulated Algorithm.

The emphatically negative part of our answer refers to the question of whether there exists a logical connection between our conscious mental constructions, our intellectual fabrications (a model such as LifeTime, for instance), and the physical substratum of the brain. In more general terms: Does there exist a logical path leading from our mental representations to the physical reality that these intellectual images are assumed to represent? This is a millennia-old question that from Plato to Einstein has mostly been answered in the negative.

## *The unbridgeable chasm separating brain and mind: From Plato to Einstein*

Since the inception of Greek philosophy, the question of the relation between our mental contrivances and the 'exterior' physical reality, assumed to exist and not just be an illusion, has been worked over time and again. This is the case despite the astonishing fact that the modern "solution" was already suggested by Plato in the Timaeus, composed around 358/356 BC. Plato's philosophy started out with what is commonly named his 'Theory of Ideas', presumably taken over from Socrates, but thoroughly criticized, and later in part abandoned by him. This theory establishes a radical and unbridgeable separation between the domain of eternal, simple, and pure intelligible constructs or Ideas, better translated as 'intelligible Forms', and the domain of the complex sensible particulars, forever changing in time. Plato radically distinguished between the different kinds of knowledge about the universe attainable by humans. True knowledge, he claimed, is only possible for an observer capable of directly apprehending the intelligible Forms, whereas ordinary sense-perception produces at best an approximate copy or image[cxx] of the world, similar to the information a painting provides about the depicted real object. In other words, true knowledge of the physical world is exclusively embodied in the intelligible Forms; the unbridgeable chasm between the two domains then results as an unavoidable consequence. But the intelligible Forms are not accessible to common mortals, since their direct apperception remains the exclusive privilege of the gods, and some of their good friends, i.e., the philosophers. As Plato wrote in the Timaeus, the most fascinating of his later dialogues: "We must then, in my judgment, first make this distinction: What is that is always real and has no becoming, and what is that which is always becoming and is never real? That which is apprehensible by thought with a rational account is the thing that is always unchangeably real; whereas that which is the object of belief together with unreasoning sensation is the thing that becomes and passes away, but never has real being"[cxxi].

Thus between the sphere of rational thought and the sphere of "belief together with unreasoning sensation" there can be no connection. One is always in a state of flux, eternally proceeding in time, eternally becoming and passing away, whereas being corresponds exclusively to the intelligible Forms such as life, beauty, or justice that simply are. What knowledge is then possible? Plato, once and for all, brilliantly answered this vexing question by introducing the concept "mediation". He placed between (*mesos*) the eternal intelligible Forms only attainable by the gods, and the ever-changing (*kinêtos*) sense-perceptible world, a mathematical contraption he named the "World-Soul". In the cosmological model so constructed, mortal humans' best chance to acquire a restricted knowledge about the world is to try to figure out the mathematical formulae[cxxii] according to which the World-Soul imposes a partial order in the sensible world[cxxiii]. But questions about the World-Soul, or inquiring why some formula works is useless, with the sole exception of the mathematical formulae governing the movements of the seven planets and the fixed stars[cxxiv]. Assuming that the planets and the stars are divine in nature, their movements must be perfect[cxxv]. Perfection in Plato's system is always directly associated with symmetry, meaning the property of something that allows it to change without changing, as when a perfect sphere is rotated, thereby approaching the perfection of the eternally being, i.e., unchanging (*akinêtos*), intelligible Forms[cxxvi]. The movements of the planets must then adjust to the most symmetric configuration, that is, must be a combination of exclusively circular paths. This "theory" was valid until Johannes Kepler replaced the circles by ellipses in 1609[cxxvii].

Plato's radical separation (*khôrismos*) of pure mental constructs (such as intelligible Forms) from sense-perceptible experiences and observations (measurements, expressed in numbers), each corresponding to a mutually inaccessible domain, only mediated by the mathematical structure introduced by construction into the World-Soul, has remained in fashion until our days. This *hiatus irrationalis* is particularly striking when the mathematical approach advocated by Plato happens to be capable of predicting absolutely new phenomena, about which hitherto nobody had ever dreamed. Such is, to mention just one famous example, the case of Dirac's equations. Very loosely speaking, in 1930 the British physicist interpreted a minus sign appearing in his equations as standing for a completely unknown form of matter, anti-matter. Later experiments strikingly confirmed its existence when Anderson in 1932 discovered the positron, the anti-matter (positive) electron. But how can a mathematical formula, arising in pure intellectual speculation, lead to the prediction and later experimental confirmation of previously entirely unknown physical phenomena? This surprising "unreasonable effectiveness of mathematics"[cxxviii] was also an unresolved problem for Einstein. He once stressed, in a letter to M. Solovine dated May 7, 1952, the absence of a logical relationship between what he called the set "S" of theoretically deduced (i.e. mathematical) propositions and the level "E" of sensible perception (i.e. observed phenomena). In fact, true to Plato he stated that there is no logical procedure leading from the theoretical sphere to what the senses can perceive. "This procedure, looking more closely, belongs as well to the extra-logical (intuitive) sphere because the relation between the concepts intervening in "S" and the experiences "E" are not of a logical nature. The quintessence is the relationship of the eternally problematical connection between what is thought and what is experienced (through the senses)"[cxxix].

In sum, it looks just as if the extra-logical, irrational chasm separating intuitions and intelligible constructions, such as those concerning our subject matter, from their underlying physical sense-perceptible substratum cannot be bridged. Indeed, most philosophers since Plato have systematically questioned the possibility of finding the common denominator of the physical brain and the intelligible mind. But from a modern evolutionary viewpoint this may not be the case, as we will now show.

### *Dopaminergic neurons in the human brain and the Algorithm*

"The capacity to predict future events permits a creature to detect, model, and manipulate the causal structure of its interactions with the environment. Behavioral experiments suggest that learning is driven by changes in expectations about future salient events such as rewards and punishments. Physiological work has recently complemented these studies by identifying dopaminergic neurons in the primate whose fluctuating output signals changes or errors in the prediction of future salient and rewarding events"[cxxx].

So reads part of the abstract of a scientific paper that directly relates the functioning of neurons to the Algorithm. Before discussing this result in greater detail, we first provide some definitions and clarifications. Dopamine is an important neurotransmitter active in different brain structures and thought to underlie a number of behaviors that are related to learning. In primates and humans, dopamine is secreted by neurons in specific parts of the brain to inhibit or modulate the activity of other neurons; particularly those involved in emotion and movement. Some human mental disorders disrupting self-control and working memory crucial to timeliness and goal directed behavior are disrupted by modifications of the dopamine-processing circuits. Further, the widespread range of human conditions encompassed by the term depression[cxxxi] is believed to be partly due to variation in the activity of this neurotransmitter, an observation that has led to the development of some of the approximately 20 drugs partly alleviating this "disorder". These neurons also send projections to brain structures implicated in motivation and goal-directed behavior. In addition, drugs such as amphetamine and cocaine have been found to partly exert their addictive actions by prolonging the influence of the neurotransmitter dopamine on these neurons. Dopaminergic neurons in rats have been shown to be related with the "feeling well" sensation: Rats with implanted electrodes in these neurons press a bar to excite them, consistently choosing this "reward" over food or sex[cxxxii]. In addition, treating these neurons with dopamine-receptor blockers reduces the learning ability of the animal.

Reward is an operational term for describing the positive value a creature ascribes to an object, a behavioral act, or an internal physical state. Rewards may also play the role of positive reinforcer. The reward value associated with a particular stimulus is dependent on the internal state of the animal at the time it encounters the rewarding stimulus and is further dependent on its previous experience with it. The neuronal connection between reward and prediction based on previous experience of a stimulus has been documented in many conditioning experiments. In such experiments, arbitrary stimuli with no intrinsic reward value will function as rewarding stimuli after repeated temporal association with directly rewarding objects. Such arbitrary value-less stimuli may be a sound or a light projected on a screen. The experimental animal must learn to associate them with stimuli that are directly rewarding or aversive. Directly rewarding stimuli are called appetitive stimuli (for example, a drop of tasty juice). Directly aversive stimuli may be some unsavory food, or a disturbing air-puff.

W. Schultz and collaborators propose that reward-dependent learning can be driven by deviations or “errors” between the predicted time of arrival and amount of the reward, and the actually experienced time and magnitude of the reward. The experiment reported by J. Mirenowicz and W. Schulz seems to uncover some aspects of the dopaminergic neuronal substratum of this remarkable phenomenon. A brief summary of their findings follows.

Two monkeys were trained to press a lever to receive the appetitive stimulus, a tasty juice reward, alternated randomly with aversive stimuli, like a mild puff of air to the hand or unsavory saline solution to the mouth. Recordings were performed on a large number of separate dopaminergic neurons under different appetitive and aversive stimuli combinations. In the experiment, it was observed that the dopaminergic neurons responded with a short activation at the exact time when monkeys were presented with appetitive stimuli. Aversive stimuli did not elicit this response. Surprisingly, after repeated pairing (conditioning) of visual and auditory cues followed by reward, dopaminergic neurons change the timing of their activation, from just after the time of actual reward delivery back to the time of the unrewarding cue onset (about a second earlier). That is, after learning, the unrewarding cue predicting a reward activates the neuron before the reward is actually presented. However, when the reward then fails to occur, the activity of the neuron is depressed. Even more surprisingly, it is depressed exactly at the time when the reward should have occurred. In the experiment, this occurred more than one second after the unrewarding cue stimulus. This result reveals that a single neuron can have an *internal representation of the predicted (future-)time of occurrence of a reward*. In contrast, these neurons do not generally respond in this way to “predicted” aversive stimuli.

One can conclude from this experiment that the tested dopaminergic neurons in the brain of these primates do not simply report the occurrence of appetitive events.

They seem to signal the deviation or error arising when an “expected” reward does not materialize at the “predicted” time or in the “predicted” amount. These dopaminergic neurons thus appear to be capable of detecting the *“correctness” of the correspondence between received stimuli and an assumed learned, external “order”*, and signal the deviations from this assumed order. They emit a positive signal (increased measurement of spike production), if an appetitive stimulus is “better than predicted”. No signal (no change in measured spike production) is emitted, if a stimulus conforms to “expectations”, and a negative signal (decreased measurement of spike production), if an appetitive stimulus is “disappointing”, or does not arrive at the “predicted” moment.

In the wording of the previous paragraph we have frequently used quotation marks in order to highlight the language problem, discussed in Chapter 5. It is clear that this way of describing the action of these primate dopaminergic neurons already includes the idea that their activity encodes expectations about predicted external appetitive stimuli (this language problem is also acknowledged by the authors of the papers mentioned above). And we emphasize again that the terms ‘reward and punishment’ as associated with the Algorithm should be understood as being entirely devoid of any attached value. But, as we have expressed in the preceding chapters, there simply may exist no other ways to address these questions, except by clearly circular arguments.

The LifeTime unification is presented as a model that might, at least in part, overcome some of these difficulties. Hence, in the LifeTime scenario it may be less surprising to find in the brain of monkeys individual dopaminergic neurons which already at this primary stage show experimentally measurable modes of functioning resulting from the application of the postulated components structurally incorporated in all LifeTime manifestations. The important result to be underlined here is that LifeTime Algorithmic information processing appears already at the level of individual neurons. Such neurons clearly mark not just the future-Time direction but explicitly show the association of this future-Time with an assumed order of the external world. This order is expected to supply either appetitive or aversive stimuli in a given predictable sequence; a perception of order that must be extracted from the sequence in time of previously recorded experiences registered differently if appetitive or aversive.

### *Dopaminergic neurons and the disfunctioning of the Algorithm*

We model biological systems as LifeTime, structurally incorporating an Algorithm and an assumed environmental order-structure, a feature we call trust-in-order (Chapter 8). It follows that biological systems such as humans should also show in their behavior the properties we attribute to LifeTime. This may be difficult to assess directly, but appears distinctly in some cases of mental 'disorders'. We already mentioned ADHD, the attention-deficit hyperactivity disorder. It affects a surprising 2 to 9.5 percent of all school-age children, depending on the study considered, and moreover can persist into adulthood in as much as two thirds of affected children in some studies. This disorder is characterized by traits that can be interpreted as a polygenic failure in the Algorithm-structural-order component of LifeTime. Russell A. Barkley[cxxxiii] characterizes ADHD as a "loss of behavioral inhibition and self-control", producing the following disruptions in brain function. Diminished sense of time; defective hindsight; defective forethought; poor self-guidance; diminished self-regulation; and impaired ability to break down observed types of behavior into component parts that can be recombined into new kinds of behavior in pursuit of a goal. He writes: "It is my assertion that the inattention, hyperactivity and impulsivity of children with ADHD are caused by their *failure to be guided by internal instructions* and by their inability to curb their own inappropriate behaviors [our emphasis]."

In sum a disfunctioning Algorithm. Finally, it is also worth mentioning that this disorder is rather successfully treated with drugs that inhibit the dopamine transporter, a molecule that protrudes from neurons that secrete dopamine and takes up unused dopamine so that it can be used again.

### *Concluding remarks*

The divide separating the brain from the mind, especially the self-conscious mind remains in essence un-bridged. From Plato to Einstein, what has surprised philosophers is the "unreasonable effectiveness of mathematics". The apparent consensus throughout the centuries has been to admit that the relationship between the sphere of intellectual speculations, e.g. mathematics, and the physical perception of an external reality is of an un-logical or extra-logical nature. Plato's World-Soul, admitting an *ab initio* statistical connection between the two spheres, or similar "solutions", only displace the problem as they inevitably lead to propose as an a priori necessary condition for the acquisition of knowledge that the world is partly ruled by mathematically expressible laws, i.e., a Cosmos. In the final chapters of this essay, we highlight the strong correlation in humans of the world-order they assume (for instance, in the mathematical model they construct to 'explain' the world) and their religious beliefs, the action of placebo effects, and their ubiquitous self-deception. These are types of behavior tending to mask the actual lack of this world-order.

It follows that trust in the statistical stability or general order of the world is a universal behavioral trait. It unequivocally appears in the conditioning phenomenon, in human and non-human animals. Conditioning and trust inherently incorporates the notions of future-Time (the arrow of time) and order, implying the crucial assumption that future environmental conditions will not deviate too much from the registered past conditions on which innate and learned experience is based. Further, it assumes an operative system, related to an Algorithm, that ultimately allows to permanently "steer" Life forms towards increasing the chances of leaving more offspring than "the others". The experimental discovery of such an operative system in single neurons in the primate brain provides support for these ideas.

# *8. Trust-in-order*

> "Our thought is fragmented, mainly by our taking it for an image or model of 'what the world is'. The divisions of thought are thus given disproportionate importance, as if they were widespread and pervasive structures of independently existing actual breaks in 'what is', rather then merely convenient features of description and analysis"[cxxxiv].

## *"Stable" environments*

Over evolutionary time-spans, species become adapted to particular environments. Adaptations enhance the survival and reproductive success of individuals of that species only if the skills and aptitudes selected in the past and incorporated in their genome continue to be beneficial in present and future conditions. This is the case if the inevitable perturbations in the quality of the environment remain sufficiently bounded. The hypothetical optimal condition for an individual, and the deficit arising from the deviation from that optimum, is the input to its Algorithm. The Algorithm is the information-processing rule the output of which results in adaptive behavioral strategies. Hence, it directly follows that a functional Algorithm imperiously requires relatively stable conditions. Indeed, a functioning Algorithm of a particular individual in a particular environment is the hallmark signaling adaptation of that individual in that environment. Hence, according to the LifeTime model, an individual is adapted to a particular environment if and only if its specific Algorithm is functional in that environment.

Humans are characterized by their ability to occupy the most diverse habitats, ranging from the Arctic to the deserts and the tropics. The greater the behavioral flexibility of a species, the more diverse are its habitats as reflected in the Algorithm. Hence, a close relationship exists between the species-specific Algorithm and the range of habitats, to which a particular species has become adapted. This close relationship is directly dependent on specific physical environmental properties subsumed under the concept 'order'.

How can one characterize these environmental properties evidently so fundamental to LifeTime? These properties are reflected in the *order* of the environment. In general, order of an environment implies that its past physical states are connected to its present and, presumably also, to its future states in a "predictable" manner. Thus, order implies that the linear time-sequence registering past environmental fluctuations constitutes a bona fide predictor for relevant conditions likely to obtain in the future. Obviously, this definition of order is nothing but a tautology, moreover dependent on an unambiguous definition of time. Order is a concept in the same category as Life or Time only minimally constrained by stating that its complete absence in an environment excludes the presence of living systems. As the physicist David Bohm puts it: "The notion of order is so vast and immense in its implications, that it cannot be defined in words. Indeed, the best we can do with order is to try to 'point to it' tacitly and by implication, in as wide as possible range of contexts in which this notion is relevant"[cxxxv]. Order, he further remarks, is a concept associated with the notion of limit, and with the Greek concept of *metron*, meaning end-point or limiting point, etymologically related with measure and meter. Consequent with our adopted methodology, in this chapter we address the problem by discussing order from diverse perspectives. The final comprehension of the term is again proposed to derive from the integration of these different aspects into a structural whole that escapes a clear expression in our linear language. This leads us to define a concept we name 'trust-in-order' that will be incorporated as a further integral structural part in the LifeTime model.

***Simplifying the environment.***

Order for a living being such as a human presupposes that information from the world is rearranged, i.e., severely *simplified*, sub-dividing the registered perceptions into independent objects and distinctive events, separated by limiting points in space and time. In other terms, the real world is perceived as being 'coarse-grained'. Events registered by the senses are perceived as transformations of objects. Transformations are invariably perceived on time-scales comparable to the average life span of an individual and compatible with the acuity of its perceptive system. Thus, order is intimately connected with the perceptive equipment of organisms. In humans, it includes the following capabilities: *Vision*. In the visual system, neurons in the primary visual cortex respond best to oriented and moving bars thought to represent an analysis of edges, i.e., limits. Edges in turn define shapes, the next stage in the interpretation of different objects located in space. The compartmentalization of the primate brain further allows filtering out important features such as in face recognition. *Hearing*. Acoustically humans use the minute differential delay of signal perception in the two ears to spatially locate the sound source. *Sense and taste*. A different array of sensors mainly located in the skin and mouth allow humans to gauge temperature, humidity, solidity, and attractive or disgusting taste of potential food. *Olfaction* discerns specific molecules suspended in air with precision. As a pheromone communication system, it has recently been shown to still be surprisingly effective in humans[cxxxvi]. *The immune system*. A hyper-complex immune system can locate and mark for destruction an impressive array of foreign invaders such as virus and bacteria, or cells gone awry such as in a tumor.

In each of these perception categories, humans and non-humans can increase their probability of survival and reproductive success by learning from past experience. But only a vanishing small subset of all the events of the immediate environment can be registered. Registered events are perceived mainly as changes in a given relevant condition and are categorized as either ‘permissible, appetitive or beneficial’ or ‘obnoxious, aversive or dangerous’[cxxxvii]. In practically every case, ‘permissible, appetitive or beneficial’ equates with higher survival and reproductive success, while ‘obnoxious, aversive or dangerous’ generally has the opposite outcome. Categorizing an environment into a reduced set of mutually exclusive categories while ignoring almost all irrelevant distracters is equivalent to drastically *simplify* that environment. Why is the simplification of the information received from the environment so crucial? Why are this drastic information-filter and its resulting bias so fundamental for Life? Because otherwise no deficit gauge is possible, as the hypercomplexity of the environment precludes a continuous detailed assessment of the optimal condition and the deviation thereof. Hence, this prior sense-perceptive simplification of the environment is the absolutely necessary pre-condition for the adaptation of individuals of a species to that environment. We call this simplification ‘trust-in-order’, for reasons we now explain.

***Past experiences are assumed to remain meaningful in future circumstances***

The Algorithm, which operates on the disjunction appetitive-aversive of perceived events, is non-functional if what has been learned or inherited does not similarly obtain in present circumstances. That is, if it cannot be assumed ("trusted") that present experiences will, at least to some extent, conform to the learned paradigm, if what has been learned to be expected as appetitive now turns out to be aversive or, worse, is now totally unpredictable. An assumed world order is then not only an essential presupposition, but also an integral component of LifeTime that further must be postulated to be in some way directly connected to the Algorithm. This correlation of order and the Algorithm becomes manifest as a ubiquitous behavior according to which an individual tends to assign a high probability of encountering only a limited subset of the infinite set of possible environmental circumstances. Put differently, order for an organism is a property directly depending on the particular Algorithm by which that organism processes information emanating from its environment. We term this integral aspect of LifeTime 'trust-in-order'. It appears as a feature of the Algorithm that acts by physiologically 'rewarding' with a 'feeling well' sensation the subset of behaviors adjusting to the assumed order structure, while physiologically 'punishing' in the form of a deleterious alarm-syndrome behaviors associated with deviations from the presumed order.

Thus we define as *trust-in-order* the component of the LifeTime model that accounts for the relationship between an organisms and the predictability of the environment subsumed under the term order. Trust-in-order is an information-theoretic concept that modulates each Algorithm. The Algorithm is the information-theoretic rule by which individuals process the information as perceived in their environment via limiting sense organs, leading to unceasing competition, whereas trust-in-order reflects the specific physical characteristics of the environment in which this unceasing competition is fought out.

As LifeTime and trust-in-order are strictly dependent on the definition of order, considered as a physically detectable quality of a particular environment; we now address this property in detail. However, order is recalcitrant to a definition in terms of simpler self-evident concepts. It thus shares, with time, the character of being in the main an artifact of the way individuals interact with, and conveniently simplify, a hypercomplex world.

### ***Order and probability***

To begin, we must avoid confusing the assumed *order* obtaining in a particular environment with the *probability* assigned to the prediction of its outstanding features in the future, based on learned past experiences. This is so because the concept probability, as applied to a specific part of the world, already assumes strong physical constraints of its properties. The physical world is the sum of an enormously large aggregate of perceived or measured events. The idea of probability as applied to a particular physical system of the world crucially depends on the *a priori* assumption that the long run or average behavior of this nearly infinitely large aggregate of events is independent of the details determining what happens precisely in each space-time location. Precise details and exact determination are always beyond the perceptual capabilities for humans or any other kind of organism. Consequently, only in a reduced subset of systems is it possible to assume that the relative frequency with which a given result is observed will fluctuate within restricted limits near a certain value. The restricted fluctuations of this value (in this reduced subset of cases) are then *a posteriori* interpreted as the probability of the occurrence of the event. Even in the most favorable situation, probability in this sense is nothing but an "abstraction that can only be valid for a limited subset of possible systems, within a certain degree of approximation, in a certain restricted range of conditions, within a limited context, and not beyond a characteristic period of time"[cxxxviii]. Summing up, one should carefully avoid confusing the property of order that may exist in a physical environment, with a probability of observing a particular feature of that environment in future circumstances, as the latter *a priori* already strictly constrains the physical properties of the environment.

### ***Order in binary sequences***

We are interested in elucidating a property called order presumed to be discernible in the arbitrary arrangement on a sequence of distinct events recorded on an irreversible linear past-to-future time axis (‘memory’). Remark that order is an entirely abstract term, a purely mental construct. Thus, we first discuss its most radical abstraction by considering events as binary events spread out linearly on the time-axis of a Cartesian coordinate system. Strictly linear sequences can always be transcribed in binary notation. We further assume that these events happen, or do not happen, with equal probability. A binary string can represent an equally probable succession of events. Independent of what these events are only its happening or not is registered in the sequence. Tossing a fair coin may generate such a string. Heads is 1 and Tail is 0. Suppose we have generated in this way a very long sequence like this:

000110101101111010010100100000010100001111110111111001001001001110 0100...

How can we decide if ‘order’ is present in such a sequence? The information-theoretic definition of order in this case refers to the smallest size of the computer program capable of producing this sequence as output. By definition, if a computer program exists that is substantially shorter than the sequence being investigated, then this sequence is not random but exhibits order. The computer here mentioned is a universal Turing machine, an imaginary device claimed to be capable of performing absolutely any explicitly stated calculation. In other words, when such an overall order is present, the information-theoretic description of the linear sequence of bits (or ‘events’) is shorter in number of 0s and 1s than the brute listing of each and all the bits in the sequence. But, as has been proven by G. J. Chaitin[cxxxix], the immense majority of all sequences, like those generated by tossing a fair coin, are entirely devoid of order, i.e., each sequence is its own shortest description. Thus, the immense majority of binary sequences are completely random, thereby substantiating that order, at least at this level of description, is an extremely rare property.

However, the real world is not a linear sequence of binary events. Let us try to arrive at a different description of the succession of events in time and space and define the order of this succession.

***Deterministic order in classical physics***

In classical physics, time appears as a merely geometrical parameter without distinguishing past from future directions. In principle, classical physical processes are considered invariant under time reversal, and special time-oriented processes describing for instance the apparently irreversible breaking of a glass of wine are attributed to the results of special, very ‘improbable’ initial conditions. However, in this century the belief in strictly irreversible physical processes, such as the breakage of wineglasses, has become dominant. We live, it is claimed, in a unique universe that is the result of a non-repeatable historical process and the outstanding characteristic of a historical event is precisely its uniqueness.

Let as assume we are studying a classical physical system[cxl], composed of $N$ point particles. The instantaneous state of the system is determined by the coordinate $q_i$ of each point particle as well as their momenta $p_i$. This allows us to calculate the energy of the system in terms of these variables. Once this energy, called the Hamiltonian of the system, is known, the motion of the system is determined. Imagine now a space of *2s* coordinates, such that the values of the coordinate qi and the momenta pi of each particle of the system determine each point of this space, called phase space. This means that to each possible physical state of the system corresponds one point $P$ in phase space. As time flows, the initial point $P_o$ describing the state of the system at time $t_o$ follows a particular precise trajectory in phase space, and given this initial state, all future states of the system are exactly known; this is then perfect deterministic order.

Imagine now a great number of similar systems of this kind, slightly differing in their configurations and velocities. This collection of systems will be represented in phase space by as many points. If the initial conditions, the coordinates $q_o$ and the momenta $p_o$ at time $t_o$, are rather well defined, the collection of similar systems will appear sharply concentrated in a region of phase space. We can then speak of a compact ‘cloud’ of points representing these systems and describe the development in phase space of this cloud as a fluid in terms of its density. With time, the cloud will change shape and density. The local density of a particular volume element of the cloud represents the probability of finding the systems in that location of phase space. As the cloud changes size, shape and density with time, systems enter and leave their boundary, and so this probability also changes with time. The surprising property associated with this cloud is that it is incompressible, that is, the volume of the cloud in phase space is preserved in time.

In the classical deterministic case just described, we see that even a large ensemble of similar systems retains properties that restrain the possible future states of the ensemble, even if the initial conditions are not perfectly well defined. Suppose that we start with a compact initial cloud, we can then predict that we will be able to find a given final state with a probability given by the density of the cloud at that time. Clouds that remain compact and dense then represent order, and the incompressibility of the cloud connects the past state to that of the future.

In more realistic models, strict determinism is lost and replaced by clouds that spread out in phase space in such a way that past states do not serve to predict future conditions. This is the case in so-called 'deterministic chaos'. In that situation, the trajectories in phase space of two similar systems, starting from initially very close states, diverge exponentially with time. An ensemble of similar very close initial states, constituting at $t = t_o$ a dense compact cloud, explodes at later times all over phase space and predictability is lost. The equations describing the development of a particular system remain nevertheless strictly deterministic, explaining the name 'deterministic chaos'. This kind of chaos often results if the equations describing the system are non-linear, that is, if feedback loops are present. As feedback loops are ubiquitous in nature, most realistic systems may show this chaotic behavior.

In sum, order in classical physics is a borderline case. This leads again to the suspicion that order in nature is more an exception than the rule.

### ***Topological order***

A branch of mathematics called topology can narrow down the description of order, and the topological objects of interest are topological spaces. Their study originated in the 19th century, when the idea that geometry was the mathematical theory of the real physical space surrounding us was abandoned. Indeed, by the end of that century, mathematicians had considerably widened the scope of "geometry", that now included phase space and many different types of "abstract" spaces such as *n*-dimensional manifolds, metric spaces, Hilbert spaces, projective spaces, and topological spaces. Indispensable for these advances was the development of set theory, as associated with Georg Cantor and Felix Hausdorff. The key concept underlying a topological space is that of a point set, and the concept of points constituting the neighborhood of some point belonging to the set. Note that neighborhood, which we here must try to understand intuitively, is a weaker concept than distance, as for instance in metric spaces: A topology specifies a structural system of neighborhoods but does not quantify distances between points. Points in the set can be associated with events by adding a description to each point. That is, an event is "something" happening or not happening at a point of the topological space. Neighborhood relations then topologically connect different events, and only by these, since the similarity or dissimilarity of events is not a feature specified by these topologies.

Imagine an abstract point set or space of "events". To these point-events will be attached information relating to each event, say a linear sequence of binary symbols. Such a sequence can be considered as determining the essential properties of the event represented by this "point". Each event may or may not be the case, only observation can tell. The overall resulting neighborhood structure then describes transformations of events by a multi-dimensional path through topological space connecting an observed event $\alpha$ with an observed event $\beta$. Connected paths represent continuous transformations whereas discontinuous transformations are transitions between disconnected components in topological space. Remark further that these paths or transformations need not be symmetric, nor does similarity of events imply their proximity in topological space.

We can now search retrospectively for the "history" of transformations in topological space. That is, the history leading from a descriptive sequence associated with a point $\alpha$ to a specific different sequence associated with a point $\beta$ (not similar and not necessarily a neighbor of $\alpha$), if we furthermore arbitrarily include in the descriptions associated with $\alpha$ and $\beta$ a value of a parameter called "time". We thus obtain a continuous or discontinuous history. Adding the number of steps, or time-units, topologically separating $\alpha$ from $\beta$ may enrich the picture. However, "it is important to add here that order is not to be identified with *predictability*. Predictability is a property of a special kind of order such that a few steps determine the whole order (i.e., as in curves of low degree). But there can be complex and subtle orders which are not in essence related to predictability (e.g. a good painting is highly ordered, and yet this order does not permit one part to be predicted from another)”[cxli]. Thus, although a topology specifies a structural system of neighborhoods still nothing allows, in the general case, to predict the path leading from $\alpha$ to $\beta$. Order does not necessarily imply predictability.

### *Adaptation in the LifeTime model and order*

Order, we have seen, is not a property easily assigned to any realistic physical system. Thus we here replace order by a different concept. We call it *trust-in-order*. This component of the LifeTime model is based on three considerations. First, the always limited sense organs of individuals filter the gigantic stream of environmental information, resulting in its drastic simplification. This simplification is the essential condition enabling the action of the Algorithm. The Algorithm is a limited rule processing environmental information. It cannot be envisaged as acting on the nearly infinitely large aggregate of events while taking into account the details determining what happens precisely in each space-time location. The Algorithm previously requires a profound simplification of its input. This input is the deficit of each particular individual in its environment. This deficit cannot be evaluated precisely; a degree of approximation allowing the survival of the individual must suffice. Thus, an organism only registers a limited subset of environmental properties, within a certain degree of approximation, in a certain restricted range of conditions, within a limited context, and not beyond a characteristic period of time. Second, the Algorithm cannot produce its intended result based exclusively on this reduced, simplified subset of environmental features. Enhancement of survival and reproductive success is an information processing operation that requires, in addition, a previous categorization of these simplified environmental features. This can be expressed by assigning a positive value to some of these factors and a negative one to others. Some factors may also appear as neutral. In favorable circumstances, evolution by natural selection fine-tunes these categories. Over evolutionary time, this value system becomes fixed in the genome while neutral factors are simply ignored or the respective sense organs atrophy. The resulting conjunction of an environment sense-perceived as simple, plus a functioning Algorithm, and plus an operative value system, constitutes *adaptation* in the LifeTime scenario. It must be stressed that these components ((i) a simplified environment, (ii) a functioning Algorithm, (iii) an operative value system) are not to be understood sequentially, but as separate aspects of an indivisible whole. This holistic approach is the hallmark of the LifeTime model. Third, the value system is inseparable from the environment filtered by the sense organs. Together, they reflect the elusive concept order. By assigning a positive value to only particular environmental information, and a negative value to others, the individual experiences the environment as ‘ordered’. A functioning Algorithm, on the other hand, requires the consistency of the value assignation. Unavoidably, here we have to introduce the Time element, in the LifeTime model indissolubly unified with Life. The Algorithm must generally remain functional at least over the life span of the individual. Thus not only is the environment perceived as ordered, but as being *consistently* ordered. This consistency, again inseparable from the other aspects (simplified environment, value system, Time), now appears as a general behavior present in all kinds of organisms that we call, for lack of a better expression, trust-in-order.

### *Trust-in-order and behavior*

When particular organisms have become adapted to the environment, this means, in our context, that the Algorithm outputting their behavior includes the information-theoretic features corresponding to that particular environment for optimizing survival and reproductive success. The trust-in-order idea suggests that these features must include a trait by which the organism processes environmental information *as if* individuals trust that their environment, and their past experiences in this environment, will remain meaningful in present (and future) situations. In other terms, although predictability is not a feature normally associated with realistic physical situations, living organisms constantly assume that their drastically simplified environment is in fact predictable. At least, as relates to their Algorithmic enhancement efforts for survival and reproduction success, and for time-spans commensurate with their life-expectation. An example may illustrate this point. Migratory birds must filter the enormous information they receive and extract the necessary signs in a way that allow them to “decide” the correct date for initiating their long and strenuous voyage. Of course, they do not "decide" anything; the perceived signs such as a change in the length of the day trigger behavioral cascades that have proven to be beneficial in the past and on which natural selection has acted. This behavior has been extensively studied[cxlii]. In other terms, as long as this species does not go extinct, the environment presents *for them* a recognizable order-structure.

Should this idiosyncratic order-structure suddenly change dramatically, the correlation between Algorithm and trust-in-order is endangered, threatening the survival of the individual. In our previous example, the migratory bird is absolutely dependent on leaving before snowfall and finding the adequate food supply and resting places, which are environmental *sine qua non* conditions for the evolution of migratory behavior in the first place. This does not preclude that millions of migratory birds such as swallows and martins may die on migration when snow falls early on their migratory routes as observed many times in the Alps[cxliii]. Climatic change does not necessarily lead to extinction because ample genetic variation for timing, duration and direction of migration allows micro-evolutionary responses to selection.

In the real world there may be partial order in a restricted spatial and temporal domain, but there is absolutely no guaranteed ubiquitous order accounting for the outcome of any sequence of events, irrespective of the space and time scales involved. Humans, as yet not extinct but faced by the same vagaries, have developed complex psychological trust-in-order behavioral forms. The most conspicuous is the general trust and confidence that through all history human societies have put on the invisible and inscrutable *guarantors* of world-order called 'gods' and on their earthly representatives: kings, priests, prophets, shamans, magicians, astrologers, and medicine-men[cxliv].

In non-human animals, the trust-in-order idea can be directly tested using the actual behavior when individuals make "decisions" about their future under natural environmental conditions. For example, how should animals choose a future breeding site in order to maximize reproductive success? Monitoring a large number of environmental factors for a considerable amount of time would indeed require capabilities that are akin to those of super-computers and this would be completely unfeasible, even for modern humans. If animals search for habitats that maximize future growth, survival and reproduction, environments where individuals of that species are particularly successful in the current season should preferentially be chosen. Note that this prediction is based on the assumption that the reproductive success and the growth of offspring in a particular site in one year is correlated to a certain extent with the performance of the same individuals in the same site the previous year. This assumption has been supported by empirical findings tested in a number of bird species[cxlv], corroborating the trust-in-order idea. Animals may gather information about the suitability of the environment (for example, the amount of food available, the abundance of predators, parasites and competitors) from the reproductive success of individuals of the same species in that site. Then we should expect non-breeders to prospect a number of potential breeding sites during the breeding season before they actually start reproducing themselves, at a time when reproductive success can be assessed reliably. Young non-breeders actually spend a considerable amount of time visiting several different potential breeding sites exactly at the time when offspring are present and just about to become independent[cxlvi]. That is exactly the time when the reproductive success of current breeders can most readily be assessed. Newcomers (either first time breeders or individuals that have changed breeding site because they have been unsuccessful the previous year) should settle preferentially in sites where others recently have had high success. Such sites are more suitable as a breeding site than any randomly chosen site in a subsequent year. Prospecting breeders indeed tend to preferentially settle in such sites[cxlvii]. Finally, an information-simplifying rule of thumb is that the growth rate of offspring and that the reproductive success is superior in sites where others have had high success. Then we should expect individuals that stick to this rule of thumb have higher success than individuals that are less strict in their habitat choice. Again, this prediction is supported empirically[cxlviii]. In conclusion, the bewildering amount of information about the environment in a particular site can be efficiently simplified and obtained as “public information” from the success of others. Individuals apparently commonly use such information when choosing a future site for reproduction.

### ***Concluding remarks***

In sum, trust-in-order is directly associated with an important *simplification* of the environmental information constantly impinging on the sense organs of any individual. Of course, this biasing filter is only functional, i.e., enhancing survival and reproductive success, in a restricted set of circumstances subsumed under the term ‘order’. The close association of the physical characteristics of this restricted set, the limited information processing capabilities of most individuals, and their competition for reproductive success is what we encompass in the ‘trust-in-order’ component of the LifeTime model.

Here ends the first part of the book with the presentation of the LifeTime model, incorporating as structural indissoluble parts Life, Time, Algorithm and trust-in-order. In the second part we test the LifeTime model in a number of different ways.

# 9. *Of Swallows and Man*

***Testing the LifeTime model*.**

In this and the following chapters we analyze certain testable predictions deriving from the LifeTime model. This model structurally incorporates a number of features: Life, taken as the planet-wide phenomenon; Time, in the restrictive sense of the yet-to-live span of an individual; Algorithm, by which individuals decode and process the information emanating from their environment in a Life-specific way; and trust-in-order, an information-theoretic term modulating the form of the Algorithm in accordance with the perceived order-structure of the environment. In their respective environmental backgrounds, evolution has endowed individuals of all species with adaptations that are means to stake out their situation relative to the hypothetical optimum condition maximizing the number of viable offspring. The presence of the Algorithm causally results in the unceasing competition among individuals to reduce their perceived deficit from optimal conditions. As this permanent effort to reduce the deficit requires resources in addition to those needed just to survive, the Algorithm directly exacerbates the competition between individuals sharing a particular environment. In sexually reproducing organisms, choosy individuals (usually females) often compete intensely for access to attractive individuals of the other sex with superior resources or genes for survival.

Here we test predictions that arise from the LifeTime view by scrutinizing several aspects of the life of two well-studied species: a small migratory bird, the barn swallow, and humans. We contrast a number of aspects of competition for reproductive success for barn swallows and humans and the similarities rather than the differences are a most striking feature. For evolutionary biologists, this is less surprising given the major influence of the environment on the mating system of animals. Before entering this discussion about competition, what has given rise to such competition, and which are the outcomes of such competition, we briefly discuss the importance of genes and the environment in determining the phenotype.

***Genes, environment and the determinants of human nature***

Humans have since long been claimed to be different from any other species of organism in a qualitative way. Obviously, humans are mammals and thereby share an immense number of anatomical, physiological, behavioral, ecological and evolutionary conditions with other primates, but also with other mammals and animals in general. This conclusion has been reached in a no more compelling way than by the studies of DNA sequences of humans and other primates. Compared to our closest relatives among the great apes, we share more than 99% of all letters of the DNA alphabet and their positions in those sequences. Hence, humans have evolved gradually from a long evolutionary history during which we have shared almost the entire evolutionary past with ancestors that we have in common with chimpanzees and gorillas. Clearly, this has immense implications for our understanding of human existence, but also for our attempts to understand human medical, psychological and social problems.

The ways in which human nature is influenced by our biological evolutionary history have been extremely controversial for centuries. The degree of controversy has certainly not diminished during recent decades. Humanities and social sciences have seen their realm of scientific inquiry being snapped up by the biological sciences, first as minor excursions, and more recently by far ranging attempts to understand supposedly entirely human aspects of existence from a biological perspective. A main battlefield has been the dichotomy between genetic and environmental effects on phenotypic traits. The genetic basis of traits can arise from single gene effects such as those determining eye color or quantitative genes such as those affecting height in humans. While single genes usually lead to fixed effects on the phenotypic expression of the genotype, this is not the case for quantitative traits. The *heritability* of a trait is defined as the quantitative measure of the resemblance in appearance between relatives, with a minimum value of zero, when there is no phenotypic resemblance between parents and offspring, and one, when the phenotype of offspring is entirely determined by the genes of the parents. The heritability of a trait thus expresses the proportion of the total variation in appearance among individuals that is determined by genes with an additive effect relative to the total amount of variation. The remaining amount of variation is attributed to such factors as environmental effects, maternal effects, and variation in environmental effects for different genotypes. Heritability is thus a technical term that can be used to quantify the amount of total variation in phenotype that is due to the effects of additive genes. This measure is an important quantity used in animal and plant breeding programs to predict the future phenotypes of lines of individuals that are subject to a certain level of selection in a selection experiment. The heritability only applies to the environment in which it has been estimated, implying that a change in the environment may result in a change in the proportion of the variation that is caused by environmental and genetic effects. For example, height in humans has a large genetic component with heritability being close to 50%. Recent emigration of Asians to North America has caused a considerable increase in height of these Asians in a single generation, which obviously cannot be attributed to an evolutionary change. Rather a change in nutrition is the most likely factor determining this rapid change in stature. That this nutritional effect on height is limited is shown by changes in height among populations of a number of European countries. While several generations of Europeans have been characterized by a continuous increase in height, apparently mainly due to improved nutritional condition, this environmental component has been exhausted for the first time ever, since young Dutch of the present generation have on average not increased in height compared to their parents. Hence, there is no further scope for environmental improvement in height in humans in the Dutch population because the main environmental determinant of height is no longer a limiting factor.

The estimation of genetic and environmental determinants of the phenotype among individuals is usually based on comparison of the phenotypes of related individuals or on attempts to select for increased or decreased expression of a character. Maternal and common environment effects confound any gene-based resemblance between parents and offspring. For example, some females may provide particularly abundant resources for their offspring, such as a larger amount or a higher quality of milk. This may result in improved phenotypes of the offspring, and such effects can be transmitted across generations, if offspring produced by particular kinds of mothers generally perform better, thereby inflating the estimate of the genetic component of variation. Similarly, parents and offspring may tend to end up in similar habitats that are of comparable quality, again inflating the estimate of the genetic as compared to the environmental component. Studies of human heritability are even more restrictive than those of other organisms because true experiments cannot be performed to address questions of heritability. Human studies of genetics are thus often based on identical twins reared apart, since such offspring will share all their genes, but not their post-natal environment. Twin studies are still to some extent potentially inflated because of the common maternal effects during pregnancy. Such maternal effects can be partially removed by concentrating on maternal half-siblings that share the mother, but differ with respect to their father. A different method of studying genetic effects is by way of quantitative trait loci, whereby the identity and the position of genes that affect the expression of a phenotypic trait is located by means of maps of genes on the chromosomes. For those species for which gene maps and long sequences of DNA strings are known, which include many micro-organisms, but also the genome of the round worm *Caenorhabditis elegans* and the fruitfly *Drosophila melanogaster*, and parts of the genomes of mice and humans, the exact location of genes affecting the phenotype of individuals can be recorded.

Every trait of an individual is influenced by gene(s) and the environment because of the nature of development of every trait (ontogeny). Given that both genes and the environment affect the expression of characteristics of all traits in humans and other organisms, it is a misunderstanding that the dichotomy is between the effects of genes and the environment. While most humans are willing to accept the influence of genes on the color of eyes and the height of adults, there is much more reluctance to accept this claim for traits that are related to behavior and mental abilities. It may seem surprising that while most humans are willing to accept the suggestion that anatomy and physiology have biological bases, are subject to selection and micro-evolutionary change, and that this knowledge can be used in medical sciences, the quest for the determinants of mental abilities is still out. Anything evolutionary relating to the brain of humans remains controversial. This ideological schism is no better expressed than in the tremendous debate following the publication of *Sociobiology* by Edward O. Wilson in 1975. The main thrust of this monumental piece of work was that social behavior of animals is based just as much on evolutionary principles as that of anatomy and physiology. This discussion has been nowhere more obvious than in studies of intelligence and IQ. While the mere use of IQ tests and discussion about the determinants of intelligence were politically incorrect in the 1960’s and 1970’s, this attitude has changed recently. The veracity of the IQ quotient as anything but a cultural construct used by suspect scientists has changed by the demonstration of associations between IQ scores and physiological measures of the brain such as its acidity[cxlix].

Recent demonstrations of a negative relationship between IQ and morphological external asymmetries that reflect poor ability to cope with environmental perturbations during development have once more revealed that IQ scores are not exclusively cultural constructs[cl]. Now there is no more discussion of whether mental traits such as IQ scores are heritable; it is only the degree of heritability that is the subject of discussion[cli]. This is an immense leap in approach to biological studies of humans because the discussion is more focused on quantitative than qualitative differences.

In the following section we briefly introduce the barn swallow and certain crucial aspects of its biology that are required knowledge for understanding the following discussion relating to the LifeTime model.

***The life of the barn swallow***

Evolutionary biologists have studied small birds for many decades because it is relatively easy to follow individuals and their offspring throughout their lives. This crucial fact allows assessment of lifetime reproductive success[clii] under natural conditions, and hence the possibility to determine the fitness consequences of particular kinds of morphology or behavior. In comparison, much less is known about the life under natural conditions of the preferred laboratory animals of biology like the nematode worm *Caenorhabditis elegans*, the fruitfly *Drosophila melanogaster,* the frog *Xenopus laevis,* the mouse *Mus musculus* or the rat *Rattus norvegicus*.

We will illustrate a number of important points relating to our main thesis that animals compete intensely with each other for access to limiting resources, thereby differing in growth, survival prospects and reproductive success, using a small passerine bird, the barn swallow as an example[cliii]. Intense competition relates directly to the relative amounts of resources available for individuals differing in phenotype (appearance, behavior and physiology), but therefore also for the perceived deficit between the optimal conditions for growth, survival and reproduction and those experienced. This deficit directly affects the general “well-being” of individuals.

Barn swallows are ca. 20 g passerine birds that live close to humans throughout most of Europe, Asia and North America. Males and females are quite similar in appearance, with a metallic steel-blue upper surface and a white underside. The forehead and throat are covered with red feathers. All tail feathers have a bright, white spot at the base, a trait that is exposed during slow flight. The tail is V-shaped with individuals of the two sexes having central tail feathers of similar length, while males have on average 20% longer outermost tail feathers than females in a Danish population. There is enormous variation in tail length among males, more so than in females, ranging from 85 to 150 mm in a Danish population; the selective advantages of these tail feathers during mate choice will be explained in detail below. Barn swallows are insectivorous birds that catch small insects by direct pursuit. Barn swallows migrate in autumn to their tropical winter quarters and return again the following spring, flying at speeds of ca. 75 km/h. Males arrive to the breeding grounds in Northern Europe on average one week before the females. They will immediately defend a small breeding territory that contains one or more suitable nest sites. Natural nest sites are within caves or large hollow trees, but today almost all barn swallows breed inside buildings such as barns and farmhouses. The close association between barn swallows and humans during millennia has resulted in this species being the focus of a number of human beliefs. Farmers in most of Europe were supposed to open the doors of their barns in spring to allow the swallows to enter their nest sites. Failure to open a door could supposedly reduce or completely eliminate the milk production of cows and the number of calves born. If a swallow nest was destroyed, this could lead to crop failure or the entire farm burning down. Some of this superstition is related to the fact that barn swallows have a red face, supposedly acquired while a barn swallow removed a thorn from the forehead of Jesus on the Cross. Other beliefs are related to the male closely following his mate before and during egg laying. This close pair bond led to the belief that the barn swallow was particularly amorous and faithful. According to an old Danish recipe, if you took the dried heart of a barn swallow, crushed it and added it to the drink of someone you desired, this would cause that person to love you! However, as we shall see below, barn swallows regularly engage in sex with individuals other than their mates. In fact, the close following of the female by the male is a strategy adopted by males to prevent their female from copulating with other males. Since female barn swallows are fertile and can store sperm for more than a week, any male that copulates with a female during that period will have a chance of fertilizing one or more eggs.

Males that spend more time near their mates have females that engage in fewer extra-pair copulation.

After arrival, the male will attempt to attract a mate by an elaborate flight display, song, and by showing off the long outermost tail feathers. The female will follow the male to a nest site, and if the male is accepted, the pair will start to copulate and later build a nest. The small cup-shaped nest contains more than ca. 1400 small pellets of mud that are carried from a nearby pond or puddle during a one week period. Later, straw and feathers are added to the nest, and the female will then lay eggs, one per day, in total 3-7 eggs. The female incubates the eggs for ca. 14 days (in politically correct North America both male and female barn swallows incubate). When hatched, both parents will feed the nestlings for ca. three weeks and after fledging subsequently for another one to two weeks. Since the free-flying offspring cannot be identified from a particular location (as is the case when they are in the nest before fledging), and since many pairs often breed in the same barn, parents that discriminate among fledglings and do not feed any young swallow encountered have been favored. Parents can recognize their nestlings shortly before fledging by individually distinctive calls and thereby avoid wasting effort on parental care of the offspring of the neighbors. Neighboring offspring often beg for food from strangers, but without success. Barn swallows in Northern Europe will raise one to two broods per summer, while birds in Southern Europe can raise up to three broods.

After the breeding season both adults and juveniles will forage in places with large amounts of insects, and they spend the night in large communal roosts that may contain more than 100,000 birds. Migration takes place from August until November, with birds from Northern Europe moving all the way to Southern Africa for the winter; an immense journey of more than 14,000 km twice per year! Individuals are often faithful to both breeding and wintering site in subsequent seasons, and they are thus able to find a particular site again, an even more incredible feat accomplished by this 20 g animal! Since parents and offspring do not follow each other, the juveniles must have an internal migratory program to be able to make their way to the proper winter quarters and not end up in a “wrong” place. In the Middle Ages people believed that small, migratory birds spent the winter on the bottom of ponds and lakes. With the invention of scientific bird ringing in 1899, it became possible to trace the timing and direction of migration, but also to identify the winter quarters of birds. The migratory habits of birds have clear genetic bases. Studies of a small warbler, the black-cap *Sylvia atricapilla*, have shown that the amount of migratory activity and the direction of migration are genetically influenced[cliv]. Crosses between individuals from resident and migratory populations resulted in individuals that were intermediate in migratory activity. The direction of migration has similarly been shown to be genetically influenced. This makes intuitive sense since any individual that migrated in the wrong direction, or flew for too long time, might end up over the ocean with insufficient resources to return. Natural selection is no more strict than in the case of survival during exhausting and dangerous long distance migration such as that from Europe over the Sahara Desert to Sub-Saharan Africa.

Displacement is not restricted to birds, but occurs in many different organisms, including humans. Extensive studies of humans have demonstrated that people have a clear ability to orient towards their home, even when blind-folded and transported to a new location in the neighborhood[clv]. This ability to orient and home has been shown to differ between men and women, with men generally performing more successfully in trials than women. This innate difference in orientation ability related to gender might be directly linked to the general pattern of dispersal in humans, with men on average dispersing a greater distance than women. In addition, this difference might directly relate to a sex difference in activity and foraging patterns, with men in pre-historic times ranging farther than women. This human pattern contrasts to that of the barn swallow, where females generally disperse at a greater distance than males; males on average settle only 3 km from the nest where they were raised, while females move much farther, on average 8 km. Not surprisingly, barn swallows transported away from their breeding site showed a clear sex difference in homing behavior with females returning much faster than males.

In the subsequent two sections we will briefly discuss how recent advances in the study of animal behavior have enlightened studies of human and animal sexual selection, plus human and animal selection of which offspring to raise. Further, in the context of the LifeTime model, these insights highlight the competition characterizing biological systems.

***Reproductive strategies and the fight over control of reproduction***

**Evolutionary psychologists and biologists have during the last few decades started to investigate the functional basis of human behavior in an attempt to infer the importance of the evolutionary past for current human behavior. This scientific endeavor has received a considerable critique from many traditional psychologists and commentators in the humanities and social sciences. Humans have been claimed not to respond as pre-programmed automata because of their free will and the major influence of culture on human activities in all their aspects. However, the effects of culture are not qualitatively different from similar phenomena in other organisms. Most importantly, if such cultural effects were commonplace, we should expect considerable differences in behavior among cultures. This is not the case for many kinds of behavior associated with sexual and social behavior, as we will discuss below. The complex, but sometimes fascinating reproductive and social strategies with their seemingly perfect design features have been claimed to represent phenomena that are far too sophisticated to evolve in humans or any other organisms. However, as emphasized by evolutionary psychologists Martin Daly and Margo Wilson, such reproductive strategies are commonplace in seemingly primitive organisms such as birds, thus posing no problem to the appearance of similar strategies in humans[clvi].**

We will follow Daly and Wilson and use examples from the social and sexual life of our small bird example, the barn swallow, but make parallels to humans to emphasize the similarities rather than the differences between apparently different kinds of organisms. The reason why humans and many small birds share common features of numerous aspects of their lives is that both groups are socially monogamous with the resulting similarities in selection pressures having shaped not only anatomy and physiology, but also behavior. Humans differ from most other primates and mammals in general because the last mentioned usually have single-male or multi-male polygyny with single males or multiple males attempting to acquire a group of females rather than being associated with a single female.

One of the main observations made by Charles Darwin in the last century, also incorporated as a crucial aspect in the LifeTime model, is that individual animals and plants unceasingly compete for growth, survival and reproduction in resource-scarce environments. This intense competition for success in passing on genes to future generations - as compared to other conspecific individuals sharing the same habitat - is nowhere more bizarre and compelling than in the battle for mates and their gametes, even at the expense of survivorship of the individual. The process that accounts for such combat for reproductive success is called sexual selection, the solution to one of the main obstacles to Darwin's theory of natural selection[clvii]. How was it possible to explain the evolution of extravagant characters in males of many animals such as the train of the peacock, the antlers of deer, the horns of many beetles and antelopes, the bright colors of male fish, reptiles, birds and many primates, and the extravagant displays and songs of insects, frogs and birds? These traits are highly unlikely to be adaptations that enhanced the probability for individuals to survive or acquire resources. On the contrary, they are likely to be extremely costly and hence detrimental to the survival prospects of individual males. Darwin suggested that by enhancing the mating success of males, the costs of producing such exaggerated displays could be balanced by benefits in terms of enhanced mating success. Hence such extravagant secondary sexual characters would increase the variation in mating success among males and thus lead to further exaggeration of male sex traits. Two mechanisms were suggested to promote sexual selection. Combat among males for access to mates would result in increased male size, but also evolution of structures that enhanced the ability to win at battle; and female choice of the most adorned males leading to the evolution of exaggerated colors, vocalizations, pheromones and displays of males. Thus the exaggerated feathers of the male peacock are not more fantastic than the mate preference inside the head of females leading to such exaggeration.

Although Darwin's ideas were originally received with skepticism, particularly his ideas about females having "a sense of beauty" for adorned males, these ideas have been vindicated by a large number of studies demonstrating sexual selection to be omnipresent in the animal kingdom. Sexual selection has been demonstrated even in so-called monogamous species such as many bird species despite all individuals eventually being mated in a socially monogamous species with equally many males and females. An experiment was used to test for the presence of such a mating preference in the barn swallow[clviii], which has already been described in some detail above. Males and females are quite similar in external appearance with the exception of the outermost tail feathers which are longer in males than in females; on average, males have 20% longer tails (110 mm) than females (90 mm) in a Danish population of this species. Such a difference in size could be accounted for, if long-tailed males mated earlier than short-tailed males because early breeders raise more broods per season, but also have a greater probability of recruiting offspring into the breeding population, since early fledged offspring have higher chances of survival. Unmated males were randomly assigned to either of four different treatments upon arrival from the African winter quarters. (1) The two outermost tail feathers were cut with a pair of scissors and a 20 mm piece of tail feather added by use of super-glue (males with elongated tails); (2) the two outermost tail feathers were cut with a pair of scissors and a 20 mm piece of tail feather was removed (males with shortened tails); (3) the two outermost tail feathers were cut with a pair of scissors and glued back again (a sham treatment to control for any effects of tail-cutting); or (4) the male was just caught, measured, banded and released again (a control group without treatment). The males were subsequently observed daily and their date of mate acquisition recorded. Similarly, the number of offspring reared during the breeding season was recorded by regular visits to the nests. The experiment demonstrated that male barn swallows with elongated tails on average acquired a mate after 3 days while males of the two control groups took 12 days to acquire a mate and males with shortened tails took more than two weeks to get a mate. This had consequences for seasonal reproductive success, which decreased from more than 10 offspring among tail-elongated males, over 7.5 offspring in control males to only 5 offspring per tail-shortened male. Thus there were immense advantages accruing to males with tails that were just 20 mm longer than their natural lengths, although this was well within the natural range of tail lengths in the population. Seven subsequent experiments have verified this finding, showing that female barn swallows have strong mate preferences for long-tailed males.

Why should female barn swallows care about the length of tail feathers of their partners and not just mate with a random male in the population? The most obvious function of the female mate preference is that females by choosing long-tailed males obtain an advantage in terms of additional resources such as a better territory or a more efficient father for the offspring. However, this does not appear to be the case since territories are very small, only containing one nest site. Furthermore, long-tailed males are not good fathers. On the contrary, they appear to be lazy and provide less assistance in nest building and provisioning of the offspring than short-tailed males, on average a reduction by more than 20%[clix]. Hence, if anything, females pay a cost for their choice of attractive males.

In 1982 William Hamilton and Marlene Zuk proposed a hypothesis that could explain the presence of persistent and strong mate preferences. If only males in prime condition and health status were able to develop costly secondary sexual characters, females should be able to pick genetically resistant mates as sires for their offspring. Hence they could pass on such resistance genes to their young[clx]. Parasites and diseases are ubiquitous in all organisms, and parasites and diseases continuously coevolve with their hosts. This gives rise to the production of better ways of exploiting hosts which subsequently evolve better ways of resisting parasites. According to the proposed hypothesis, females could continuously select resistant mates with extravagant ornaments without depleting the genetic variation in viability, which is the target of the mate preference. Male barn swallows with long tails indeed turned out to have fewer ecto-parasites such as a blood sucking mite and feather lice than did short-tailed males. The basis for this difference in parasitism was not just a difference in exposure to parasites, since nest infection experiments demonstrated differences in susceptibility to blood sucking parasitic mites. More importantly, this difference was genetically based since the parasite burden of offspring resembled that of their fathers, even when the offspring were raised in foster nests with no contact to their original father. This resistance appears to have a basis in immune responses since immune challenge tests have revealed that the ability to raise a strong immune response is considerably better in long-tailed than in short-tailed males[clxi]. Hence, female barn swallows obtain genes coding for stronger immune responses for their offspring by mating with a long-tailed partner.

Strong mate preferences are not restricted to birds, but occur in all kinds of organisms. Although Darwin originally suggested that humans did not have common mate preferences across cultures, research conducted during the last couple of decades has demonstrated mating preferences just as strong as in birds. A cross-cultural study of mate preferences in 37 cultures performed by David M. Buss[clxii] has shown that in all cultures men consistently put female beauty (as defined in the particular culture) as a high priority in a mate. This is the case independently of whether it was Swedes, Zulus or Yanomamo Indians. Similarly women consistently emphasized men's resources as the top priority among more than 100 different features of potential mates. The ranking of the two criteria men versus women was significantly different. Hence, it seems that women prefer wealthy men, apparently in an attempt to be able to raise their offspring without problems, while men prefer beautiful women. The latter preference may be directly related to issues of health because beauty is more important in mate choice in cultures where serious killers such as malaria, schistosomiasis and similar diseases have a greater impact[clxiii]. It is likely that it might be very difficult for individuals to maintain beauty under the continuous onslaught of many serious diseases, with beauty being a health indicator just as in the barn swallow.

Darwin alluded to the cost of secondary sexual characters in his writings, and numerous subsequent studies have demonstrated that males of a diverse array of species suffer such viability costs of their ornamentation or display. The presence of adornment results in increased risks of being eaten by predators and acquiring parasites and diseases. Male barn swallows suffer more from predation by sparrow-hawks than females[clxiv]. Furthermore, male ornaments are costly to produce and maintain because addition of a mere 20 mm piece of tail feather increased mortality by 12%, whereas tail reduction by 20 mm increased survivorship by 5%[clxv]. A reduction in immune function has caused some of these effects of tail length on survival[clxvi]. Tail manipulation affects male flight behavior and the ease at which insect prey are captured in flight, with tail elongation making prey capture more difficult, while tail shortening improves flight. Experimentally long-tailed males have reduced abilities to raise an immune response to a standard immune challenge test. This reduction in immune responsiveness is directly related to a decrease in survivorship. Hence, males pay important survival costs for their ornamentation. These costs of ornamentation reduce the fitness of the average individual, and therefore the average productivity of the average barn swallow. Such costs of ornamentation are, however, still selected by the female mate preference because the costs of ornamentation are by far exceeded by the benefits acquired by the most well adorned males.

The previous examples are all based on visual signals, although there are no reasons to believe that similar arguments cannot be applied to signals in other sensory domains such as smell, vocalization, or even electrical signals in certain fishes, as shown in numerous studies. Humans have a sense of smell, although it has been claimed to be much less important than that of, for example, a dog or a mouse. Recent research based on human preferences for the smell of individuals of the opposite sex has revealed that women prefer men with the smell indicating a genotype complementary to that of their own for one of the major disease resistance gene complexes (the major histo-compatibility complex (MHC))[clxvii]. Claus Wedekind and collaborators let men wear a clean T-shirt at night, advising subjects not to smoke, drink alcohol, eat garlic or use perfume or deodorant. The T-shirts were subsequently collected in plastic bags and the female subjects then had to rank the attractiveness of the smells. Women that did not use contraceptive pills consistently preferred T-shirts worn by men with a genotype that differed from their own. This finding is important because previous research had shown that women were more likely to spontaneously abort embryos with MHC genotypes that arose from fusion of egg and sperm with similar genes. Hence, women might produce offspring carrying different alleles at the MHC-loci due to their preference for men with dissimilar genotypes. Such offspring should, everything else being equal, be better able to resist more diverse genotypes of pathogens and parasites than offspring with similar alleles at MHC-loci. A second finding was that women using contraceptive pills, and hence having a hormonal state that mimicked that of pregnant women, preferred T-shirts worn by men with a similar MHC-genotype as themselves. Again, this finding is very interesting because it is consistent with women in many cultures often staying with close kin such as sisters and mothers during pregnancy. The whole issue of mate preferences for particular smells is also interesting for a different reason as such preferences cannot be attributed to choice by free will. Since the preferences were completely unconscious, preferences must be considered to escape free will and thus be based at a level similar to that of our close animal relatives.

Mate preferences for males with particular phenotypes are not necessarily the end of the game. Monogamous species are not always what they superficially appear to be. Observations coupled with paternity studies have shown that covert sex and extra-marital liaisons are commonplace throughout the animal kingdom[clxviii]. The best way to understand such relationships is that mating systems such as monogamy put severe constraints on female mate choice. Given that there are few very attractive males available, only the first females to choose will have a chance to mate with the most preferred male in the population, while the last female to mate may have no choice at all. However, females are able to adjust their mate choice by copulating with such attractive males if constrained in their mate choice. In the tail manipulation experiments with the barn swallow, tail-elongated males had sex with females other than their mates much more often than tail-shortened males, while it was particularly the females mated to such short-tailed males that engaged in such extra-marital sex. Studies of the paternity of barn swallow offspring revealed that while long-tailed males fathered around 90% of the offspring in their own nest, short-tailed males only fathered around 40%[clxix]. Long-tailed males also fathered more offspring in neighboring nests than short-tailed males, thereby increasing their own advantages of sexual competition. Hence, female copulation with multiple males considerably increased the intensity of sexual selection through an increase in the variance in male reproductive success.

Human extra-marital sex seems also to be widespread. More than ten studies of extra-pair paternity in humans has revealed a median frequency around 10%[clxx]. Studies of sexual habits of students at a US university has shown that men with preferred phenotypes such as symmetric bodies had considerably more sexual relationships during their lifetime than asymmetric men[clxxi]. Hence, mate preferences for extra-pair sex partners in humans may not be so dissimilar from those of barn swallows.

Strong female mate preferences in the evolutionary past are likely to have influenced the evolution of the perceptual system of individuals of both sexes. There are sex differences in the structure of brains in many organisms. For example, the hippocampus area of the brain is used for spatial information and increased allocation of brain space to hippocampal activity has been demonstrated in brood parasitic birds[clxxii]. Females of such birds lay eggs in the nests of other species that subsequently rear the offspring of the parasite. Well-known examples of brood parasitic birds include the European cuckoo and the American cowbirds. Female brood parasites spend the entire breeding season searching for nests of other species in which to lay their eggs. Not surprisingly, female cowbirds have significantly larger brain space allocated to spatial memory than males, whereas that is not the case in a closely related species that is not a brood parasite. Similarly, many small songbirds produce complex songs that generate much attention among conspecific females. While males of some species only produce a single kind of song, other species have extremely variable repertoires that can run into the thousands. Again, such differences in song repertoire size among species are associated with differences in brain space allocated to such activities[clxxiii]. Humans are well known for their sex difference in brain size. Recently, this difference in brain size was attributed to a real difference in the number of nerve cells rather than a difference in gray matter[clxxiv]. Although such sex differences exist, it is not clear to the scientists “what men use their additional brain cells for”. The greater spatial and navigational ability of men as compared to women may be directly related to this sex difference in brain size and number of neurons. We believe that sexual selection is the most likely cause of such a difference.

The evolution of sexual inequality in anatomy and physiology is well understood due to more than a century of study. Sex differences in attributes are almost invariably caused by sexual selection. Sexual differences in phenotypic traits are thus often attributed to sex differences in selection pressures due to sex. Male and female differences in characteristics influenced by quantitative genes evolve slowly because the same genes, arising due to what is technically termed a strong positive genetic correlation, typically influence both male and female traits. Such genetic correlations can be broken up during the course of evolution by sex differences in costs and benefits of expression of a particular trait, hence sex differences in the intensity of natural and sexual selection, but complete sex limitation of traits will typically take thousands of generations. Consequently, sex differences in phenotype are very difficult to change because of the intensity of selection needed to reverse the past course of evolution.

Genes being restricted to the sex chromosomes sometimes influence sex differences. In humans, males have two different sex chromosomes, an X and a Y obtained from the mother and the father, respectively, while females have two X chromosomes, one obtained from the mother and one from the father. While the X chromosome is fully functional, the diminished Y carries relatively little genetic information. Recent studies in human genetics have demonstrated that genes associated with various kinds of mental illnesses, but also aspects of superior mental performance are surprisingly often restricted to the sex chromosomes[clxxv]. The number of such genes recorded on the sex chromosomes is actually much greater than expected by chance, if these genes were distributed randomly across the genome. Men carry a single X that is always expressed. Women carry a double X with genes only being expressed when in their dominant form, or when carrying a double recessive gene. Thus, we should expect that men would express many more extreme phenotypes than women would because not only deleterious recessive genes but also superior recessives would always be expressed in men. This actually appears to be the case, as demonstrated by the recent survey[clxxvi]. To put this simply, there appear to be more idiots and geniuses among men than among women. Such dramatic differences may provide additional fuel for the process of sexual selection.

### *Abortion and parental choice of offspring*

Any parent is well aware of overt conflicts of interest between themselves and their offspring, in particular when the offspring reach the transition between dependence and becoming independent adults. The sometimes dramatic conflicts of interest between parent and offspring from the very start of pregnancy right up till independence are generally less well known. Parent-offspring conflict arises from the fact that offspring often demand a larger share of parental effort put into reproduction than the parent is willing to provide[clxxvii]. Parents can allocate time and resources to reproduction, but always at the expense of other aspects such as storage of resources, future reproduction and survival. Parents thus have to optimize their allocation to reproduction in order to achieve maximum reproductive success for a given level of resource availability. The origin of parent-offspring conflict can most readily be understood from kin selection theory (or the amount of genes shared between parents and their offspring). The offspring carries at maximum 50% of the genes of the mother and in most species on average considerably less than 50% of the genes of the presumed father (for the reasons explained in the previous section). The parent shares 100% of its genes with itself, and the offspring likewise shares 100% of its genes with itself, but maximally 50% with other offspring (identical twins excepted), considerably less if the offspring are half-siblings. Therefore, parents should be less willing to allocate resources to offspring than required by these offspring, and offspring should also demand more resources than their fair share, because any siblings only share a maximum of 50% of their genes. This sets the scene for numerous attempts of manipulation on behalf of the mother and the offspring.

David Haig has identified a large number of embryo-mother interactions in humans and their biochemical bases in a series of studies[clxxviii]. Most of these fetal biochemicals are associated with the transport of additional resources from the mother, while maternal biochemicals are associated with limiting the export of such resources. For example, during implantation, fetal cells invade the maternal endometrium and remodel the endometrial spiral arteries into low-resistance vessels that are unable to constrict. This gives the fetus direct access to its mother’s blood, making the volume of blood reaching the placenta independent of control by the local maternal vasculature. Furthermore, the placenta is able to release hormones and other substances directly into the maternal circulation. The mother-child relationship during pregnancy thus resembles a stalemate of fierce interactions rather than a peaceful association. The physiological barrier between mother and baby is supposedly sealed off with the exception of entry of nutrients and exit of waste chemicals. However, this common wisdom has started to crack with the identification of fetal cells in the blood stream of their mothers[clxxix]. Since cells with Y chromosomes circulating in a woman can only derive from a son, the presence of such cells has been taken as evidence of embryonic cells crossing the embryonic barrier. Such cells can be maintained in the mother for decades, the record so far being 27 years. Even more surprisingly, the presence of high concentrations of fetal cells has been associated with disease conditions such as schleroderma and other auto-immune diseases that occur late in life. The effectiveness of natural selection depends strongly on timing relative to reproduction. Strong selection during old age will have little consequence for fitness, because most reproduction has already taken place. Hence, the fetus’ cells may invade the mother for the immediate benefits of the offspring, as described above, while later negative consequences for mothers of such interactions in terms of increased frequency of disease late in life will have little or no evolutionary consequences.

Most human embryos, and those of other organisms as well, end up as spontaneous abortions[clxxx]. In humans perhaps as many as 80-90% of all embryos never reach term. Similarly high frequencies of abortion have been reported from other mammals, animals in general and even in plants, in which embryo and seed abortion is extremely common. This immense level of abortion reflects a very strong selection pressure against embryos with even minor physical defects. Studies of the genetics of human spontaneous abortions have revealed very high frequencies of chromosomal aberrations and other genetic defects. Hence, these embryos would have had little or no prospect of survival if they resulted in full-born offspring. The selection mechanisms on the part of the mother that discriminate between healthy and defective embryos must have evolved to optimize allocation of limiting parental effort to offspring with a high prospect of survival. This is the tradeoff between quality and quantity of offspring that females of any species face in a reproductive situation[clxxxi]. Any mother with weaker selection mechanisms must have given birth to young that had reduced probability of survival until the age of reproduction, while mothers with stronger selection mechanisms must have suffered from a reduction in lifetime fecundity caused by abortion.

The selection process by mothers (and their relatives) is not completed with the birth of offspring. Infanticide is a common phenomenon in numerous groups of organisms ranging from invertebrates over fish to birds and mammals including humans[clxxxii]. It may seem completely maladaptive to destroy reproductive success if relative reproductive success compared to that of others is the fundamental currency of evolutionary change as represented by the Algorithm in the LifeTime model. Why should mothers or others ever commit infanticide? Two different kinds of infanticide are widespread: In many species mothers kill offspring that are unlikely to survive, to invest reproductive effort only into viable offspring. Scorpions that give birth to live offspring provide a revealing example[clxxxiii]. Newborn scorpions are guarded vigorously by their mother, who keeps them on top of her body: The defensive female scorpion with an entire brood of offspring on the back with the dangerous and poisonous fang dangling above the young is a well-known example of parental care among invertebrates. Young scorpions have to climb on top of their mother and this task is difficult for them. Those who have not made it in a couple of days are weak and often malformed with missing or crippled legs. The mother eventually eats such low quality progeny after a couple of days and tends the remaining brood. Scorpion offspring that had not made it to the back of their mother were reared on their own by a scientist, and the young that had managed to climb on top of their mother were reared likewise. However, only the young that had managed to climb became well functioning adults, while the weak and malformed ones remained weak and malformed when adults.

Males that kill the dependent offspring of a female to enhance their own reproductive success usually commit the second kind of infanticide. Among barn swallows some 10-20% of all males remain unmated for the season, and such males attempt to enhance their reproductive success by copulating with already mated females or by killing the offspring[clxxxiv]. Since a new male is unrelated to the current offspring of a female, the male has no interest in these offspring. Widowed female barn swallows with small nestlings have to spend time warming these, but also experience the conflicting demand to search for insect food for the nestlings. An unmated male that detects an unattended brood of small nestlings will peck at the head of these nestlings and eventually remove them, letting them drop to the ground. Females guard and defend their nests vigorously against such male perpetrators, but are unable to defend the nest contents, which are eventually removed. Similarly, some mated females are unable to defend their nests against infanticidal males because their mates are poor nest guarders. Once the nest contents have disappeared, the female will almost invariably mate with the new male and start a replacement clutch that they eventually rear together. For this kind of infanticide, losing the offspring is certainly not beneficial for the female. However, she has only this option since she cannot guard and feed the young on her own. Even though the average reproductive success of individuals of the population is reduced by infanticide, this is however of no importance to the unmated males involved.

Infanticide is also common in human societies ranging from the mythical histories of the past to present day situations in India and China[clxxxv]. Mothers or midwives habitually have disposed of supposedly non-viable offspring for millennia. Abortion of non-viable or malformed embryos is a widespread practice even in western societies with modern technology. Infanticide by replacement males is equally common across human cultures. Modern western societies display exactly the same patterns with children that have one step-parent experiencing elevated risks of child abuse, violence and death, while children with two step-parents run much higher risks, as shown by evolutionary psychologists Martin Daly and Margo Wilson[clxxxvi].

We have earlier described how sexual signals are important in the choice of partners, and how such signals may become reliable signals of individual quality. This argument can readily be extended to other signaling contexts such as that between parents and offspring. Offspring of many species produce costly signals that are used in communication between themselves and parents[clxxxvii], and such signals appear to reveal offspring health[clxxxviii]. Barn swallow young beg vigorously for food from their parents during a period of three to four weeks when they are completely dependent. Begging continues even after fledging for one to two weeks, and during this period of transition to complete independence fledglings are recognized from their calls by their parents. Offspring begging consists of vigorous calls but also by the display of a bright orange gape. Nestlings with more bright orange gapes obtain a larger share of parental care than nestlings with pale gapes. This was demonstrated by a gape coloration experiment in which some nestlings had a drop of orange food color added to their beak, a sibling had a drop of yellow food color added, and a third sibling just a drop of water. The coloration of the gape is determined by carotenoid biochemicals that the chicks obtain from the yolk of the egg, but also from their insect food. Plants produce carotenoids, and flower-visiting insects that consume carotenoids in pollen may eventually be eaten by an adult barn swallow that feeds these insects to their young. Hence, carotenoids are a scarce resource that birds and other animals only obtain indirectly through their food. Offspring could channel all carotenoids into their bright orange gapes, and thereby obtain more food, if it was not the case that carotenoids are used for generating and maintaining an efficient immune system and protecting the genome from certain mutagenic biochemicals. Studies of chickens, mice and rats have demonstrated that carotenoids enhance immune function, but also function as chaperones of DNA against the mutagenic effects of free radical molecules[clxxxix]. These free radical molecules are reactive biochemicals that readily can cause permanent damage to DNA either in somatic cells or in germ cells, thereby leading to mutations with usually deleterious effects. A number of different mechanisms exist to avoid such permanent DNA damage, that can have serious negative effects on fitness, and the protective effects of carotenoids constitute one such mechanism. For that reason, carotenoids play an important role in maintaining a high level of health. Carotenoids cannot be synthesized by animals, but are consumed by ingestion of carotenoid-rich parts of plants (or algae), or by consumption of other animals that have eaten large amounts of carotenoids such as insects or crustaceans. Carotenoids thus tend to be in very short supply, and investigations of several different species of animals have shown that carotenoids are limiting. Furthermore, immune function may use large amounts of carotenoids in connection with a disease. For example, chickens that have become ill with coccidiosis may loose more than 50% of their stored carotenoids to fight the infection with the products of the immune system. Barn swallow nestlings became momentarily sick by a small injection with sheep red blood cells, which is a novel antigen to the immune system (that the nestlings never previously had encountered and to which they therefore responded strongly). Thereby, they experience an effect similar to the sickness often accompanying vaccination, and showed a reduction in their gape color compared to siblings that only had a control injection with physiological water. This reduction in gape color is likely to have been caused by withdrawal of carotenoids from the gape tissue for use in immune defense. However, this reduction in coloration was not irreversible because nestlings could become brightly orange again simply by administration of a small amount of carotenoids. On that account, the bright orange gape of barn swallow nestlings provides a reliable signal of the health status of chicks because only young that are not currently suffering from infections will be able to allocate most carotenoids to their gape signal. Parents respond to this signal by allocating more food to such healthy offspring that therefore are likely to experience enhanced probability of survival[cxc].

Human babies also produce a number of signals that are involved in communication between child and mother. Just as in the barn swallow these include visual signals such as the coloration and vocal signal such as the rate and quality of cries. Babies’ cries appear to be reliable indicators of their health status[cxci]. Healthy children produce cries with a carrying frequency of around 300-600 Hertz (Hz), although babies vary enormously in the quality of their cries. Many disease conditions such as diabetes, jaundice, asphyxia and bacterial meningitis are directly reflected in the quality of the cries of babies by their frequencies of up to 1000-2000 Hz. Interestingly, mothers respond differently to babies’ cries differing in carrying frequency. Responses to cries with high frequencies range from indifference to direct disgust and abusiveness. Why should the cries of babies with a frequency of 1000-2000 Hz be perceived by adult men and women ranging from highly irritating to intolerable? Such strong negative responses by mothers to babies are obviously problematic for the mother because of the cultural significance assigned to motherhood. The study of human responses to child signals may provide important insights into general health problems, because it provides significant clues to solve psychological problems with an apparently ancient evolutionary past.

### ***Concluding remarks***

As shown, behaviors may evolve that perpetuate the genes of the individual even at the expense of other individuals of the same species. Behavior associated with survival and reproduction is thus often reflected in reproductive strategies that may seem to have design features to enhance the success of individuals. Such reproductive strategies of almost military design are obviously not conscious in the barn swallow, or in humans. The behaviors described in this chapter are remarkably similar in barn swallows and humans, emphasizing a general finding in studies of animal behavior that it is the environmental conditions that shape the evolution of the social system and the mating system. Behavior associated with particular social systems and mating systems are remarkably often repeated in disparate groups of organisms that experience very similar social and sexual conditions, such as barn swallows and humans.

# *10. Coping with Stress*

### *Algorithm, environment and stress*

As shown in Chapter 9, biological systems such as swallows and humans are continually obtaining information from their environment understood as the surroundings and the internal state of the individual. Organisms modulate their behavior as a function of the order-structure assumed to obtain in their environment. This modulation was incorporated into the LifeTime model as trust-in-order, an information-theoretic term indicative of the degree of fine-tuning of the Algorithmic software, equivalent to the adaptation of the individual to its environment. The Algorithm and trust-in-order have the consequence of information being interpreted as either aversive or appetitive. Individuals behave by either avoiding the former or reinforcing the latter, thus fundamentally constraining their options. Importantly, aversive information is interpreted as an alarm signal, and these alarm signals automatically initiate defensive behavioral reactions.

This *modus operandi* can be found from bacteria, to plants and animals[cxcii]. Take for instance the unicellular slime mold *Dictyostelium discoideum*, normally existing as amoeboid cells feeding on bacteria and reproducing by fission. If bacterial food becomes exhausted, these amoebae begin to flow towards each other forming a mass; a process termed aggregation. The aggregated mass of amoebae then forms a cylindrical ‘slug’ which migrates until finding a suitable attachment followed by a process of cellular rearrangement and differentiation in which a multicellular stalk made up of thousands of amoebae becomes surmounted by a globose structure. In the latter differentiated structure some cells further differentiate to become spores. These spores, that can resist long periods of starvation, eventually germinate in more favorable circumstances giving rise to a new generation of amoebae. Hence, food scarcity gives rise to an alarm signal leading to conspicuous consequences in this unicellular organism. A different example can be pointed out in multicellular organisms, where individual cells reproduce by mitosis previously replicating their genomic DNA. These cells have ‘quality control’ systems that detect errors produced during mitosis. This may lead to an alarm signal that stops the progression of the cell cycle. Alternatively, it may lead to cell death by apoptosis (programmed cell death). Progression of the cell cycle and control of apoptosis are thought to act to preserve homeostasis and developmental morphogenesis; depending on the presence or absence of the alarm signal the cell either survives and reproduces or commits ‘suicide’[cxciii].

Clearly, for higher organisms such as barn swallows or humans the web of interactions becomes increasingly complex and difficult to decode. If such a situation is common, adaptive perceptive systems may evolve to *simplify* this otherwise intractable situation, by classifying incoming information as either aversive or appetitive, thereby allowing stereotyped reactions to be readily implemented. For instance, food scarcity triggers differentiation in *D. discoideum*.

Individuals are constantly gauging their position relative to their hypothetical optimum for survival and reproduction. But there is always a deficit, as this optimum is never attained. The postulated Algorithm is the software which, using this deficit as input, directs individuals to constantly strive to reduce their deficit. This measure of deficit can thus be considered an alarm signal. However, reaction to alarm signals can only be sustained for limited periods. Hence, if the alarm signal persists beyond the possibilities of relief a deleterious condition termed ‘stress’ may result.

In humans, distressing alarm signals may not be devalued or removed, as, for instance, in certain mental disorders. In normal conditions, alarm signals produce physiological effects that have evolved for prompt but limited reactions to danger; their continuous action is in most cases directly detrimental to the individual. In these circumstances, the individual may be unable to cope with the stress. Examples of such phenomena are given in the next sections.

### *Challenges in life: The role of stress and anti-stress systems*[cxciv]

The human body contains many types of specialized sensors to monitor variations in critical parameters such us blood pressure, $P_{CO2}$, temperature, glucose levels, urinary distension, signals of tissue injury, with a functioning that is automatic and continuous. Such sensors are connected to particular neuroendocrine systems within the brain that can seize quick and orchestrated compensations when "supra-threshold" changes arise, in order to restore basic conditions of viability. Those neuroendocrine reactions are known as "stress" responses since Hans Selye[cxcv] borrowed the term from physics to exemplify the strain and damage suffered by biological systems exposed to severe and repeated challenges. When compensation is efficient and swift no sign of strain appears other than transient physiological and behavioral activation (changes in blood pressure and heart rate, readiness to muscular action, increase in alertness) that can be quite enjoyable. This is indeed the basis of novelty-seeking and risk-seeking behavior. But when challenge persists without adequate coping, multiple signs of biological strain emerge that may be accompanied by symptoms of chronic fatigue, physical and psychological weakness and disease. Such symptoms depend on the chronically heightened activity of the neuroendocrine systems mediating stress responses.

These neurohormonal devices are known, in fact, as the "stress systems", being widely distributed within the brain and the periphery. Their complexity and the variety of specialized reactions they may trigger is of such magnitude that much current neuroendocrinology and neuroimmunology is devoted to their study[cxcvi]. Although dependent on multiple neural and hormonal subsystems, stress responses are usually depicted as arising from the output of two major cascades. (1) The corticoid reaction starts with the secretion of CRH (corticotrophin releasing hormone) at the hypothalamus. It is followed, in several steps, by hypophiso-adrenal hormonal secretions (with increase of cortisol and adrenaline as main final products). (2) The sympathetic reaction that begins with the activation of central noradrenaline neurons at the locus coeruleus in the brainstem, leading to multiple autonomic changes across the body including a state of heightened arousal in the brain. Both systems are heavily interconnected and mutually dependent[cxcvii]. Damages from stress appear when there is a sustained activation of the corticoid, sympathetic and associated cascades, either because the challenge is too strong to be confronted successfully or there is no escape from it. Thus, a global alarm reaction that is well suited to resist and cope with acute threats becomes self-damaging if it remains chronically activated. Table 1 summarizes compensations triggered by the neurohormonal cascades during challenges.

**Table 1.** Compensations triggered by the neurohormonal cascades during challenges. Modified from Chrousos[cxcviii].

*A) Physical compensations: redirection of energy*

1. Oxygen and nutrients directed to the central nervous system and to the stressed body sites
2. Altered cardiovascular tone: rise in blood pressure and heart rate
3. Increased respiratory rate
4. Increased gluconeogenesis and lypolysis
5. Detoxification from endogenous or exogenous toxins
6. Inhibition of growth and reproductive systems
7. Inhibition of digestion and stimulation of colonic motility
8. Containment of inflammatory-immunological responses

*B) Behavioral compensations*

1. Increased arousal and alertness
2. Increased vigilance and focused attention
3. Suppression of appetite and feeding behavior
4. Suppression of reproductive behavior
5. Dysphoria or euphoria

When dealing with internal challenges the trigger of stress reactions most often does not require detection of threat. However, in organisms with highly developed nervous systems alarm responses triggered by external challenges usually require reliable threat detection. Anatomical and physiological research has demonstrated the existence of preferential, highly efficient brain pathways linking the neural systems that scan signals of danger (e.g. visual, auditory, olfactory) with the stress systems[cxcix]. The function of such primed links depends, moreover, on the action of specific modules that appraise and differentiate between threats. Essentially, those that assess the relevance and the possibility of escape from the danger involved (for instance, they may need to distinguish between novel but neutral scents from threatening or disgusting scents and their potential source). In this process every stimulus is valued on an "aversion scale" which is provided by another dedicated system in the brain[cc]. Such a system is partially intermingled with pain processing centers in the brainstem, but its activity reflects mainly the amount and the quality of "psychological suffering". Stress systems have intimate relationships with the aversion system. In fact, stress reactions are finely tuned to the aversive value of acute challenges, but more typically on a chronic basis. Depending on the positive or negative outcome of the attempts to cope with current threat, aversion prevails with a steady and non-abating activation of stress cascades, or relief emerges leading to a quick close of stress reactions.

### *Social rank and the stressed brain*

In stable social life danger comes more often from competition among individuals than from predators or environmental catastrophes. Social threats adopt many forms and are a rich source of chronic stress. Studies in primates have shown that social and psychological factors have a tremendous impact on patterns of activation of the physiological stress reactions. Robert Sapolsky, a leader in the research of the neurobiology of stress, directed a several years long study on a population of olive baboons living freely in a reserve in Serengeti, East Africa. This is a rich and relatively safe habitat for baboons. They need to spend only 3-4 hours a day foraging and as they organize in troops of 50-150 individuals, there are minimal worries about predation. Infant mortality is quite low. So the external environmental stressors are minor for these animals. Sapolsky[cci] studied many parameters of stress physiology in relation to the social rank of males in the dominance hierarchy (Table 2). In every physiological system examined considerable differences were associated with social rank. Socially subordinate individuals had more pathogenic profiles in adrenocortical and gonadal function, in cholesterol and immune measures and in features of cardiovascular function

**Table 2.** Physiological stress reactions in relation to social rank of olive baboons. Adapted from Sapolsky[10].

1. The adrenocortical axis: dominant males have lower-level basal plasmatic cortisol concentration. They present larger and faster adrenocortical responses to acute challenges but faster recoveries and greater sensitivity to negative feedback inhibition to close the stress reaction
2. The gonadal reaction: dominant males are more resistant to the suppressant effects of stress on testosterone concentration
3. Cholesterol metabolism: dominant males have more HDL cholesterol than do subordinates
4. Autonomic function: dominant males are more sensitive to catecholamines (adrenaline and noradrenaline)

5. Cardiovascular function: dominant males have lower basal blood pressure, a larger and faster rise in blood pressure and heart rate in response to a stimulus and a faster recovery. This is due to the permissive action of corticoids on catecholamine action.
6. Immune profiles: dominant males have more circulating lymphocytes.

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Dominant males thus present more efficient stress reactions: faster responses to acute challenges and quick recoveries once the threat is over. These differences between dominant and subordinate males in physiological measures of stress have been observed in many species including man[ccii]. Victory or defeat in fights or skirmishes is associated with corresponding changes in stress hormones[cciii]. In hamsters participating in agonistic encounters, molecular signs of specific neural activation correlated with victory or loss appeared in several brain regions and circuits that deal with defense and stress[cciv]. Circulating cortisol is the best predictor of dominance in primates: low basal cortisol levels are associated with higher probabilities of initiating a fight, winning a fight, assessing the probability of winning a fight and adjusting levels of aggression when losing a fight[ccv]. Hence, dominant individuals have not only safer levels of stress hormones but more coping resources when they are occasionally defeated during challenges for resources or status. Furthermore, as the chronic activation of stress cascades depress gonadal function, subordinate animals receiving high levels of aggression are less physiologically ready to compete for mates.

Chronically elevated cortisol levels can have detrimental effects not only on immune and reproductive functions and body mass, but on the brain as well. Severe psychosocial stress can result in dendritic atrophy in the hippocampus. When the stress is temporary these effects are reversible but if prolonged they can be permanent[ccvi]. Marked hippocampal degeneration has been found in subordinate animals suffering high amounts of social stress as well as in states of unremitting depression in human patients and in war veterans suffering post-traumatic stress disorders. Such hippocampal damage produces memory and other cognitive deficits as well as a chronic dysregulation of the adrenocortical cascade reaction, resulting in hypersensitivity to challenges that perpetuate higher responses of the stress cascades[ccvii].

***Buffers of social punishment: Anti-stress systems***

**It was readily apparent in these studies that other factors in addition to social rank play a fundamental role in the degree of chronic suffering. Styles of behavior are important: subordinate animals with a high degree of social connectedness did not present the physiological markers of stress, whereas dominant animals in situations of social instability (continuous fights) or with poor social connectedness showed signs of being chronically stressed[ccviii]. In humans, the quality of social support has been shown to be a much better predictor of longevity than typical health-risk factors (tobacco, high blood pressure and cholesterol, obesity)[ccix]. Sexual selection is an important modifying factor: most evidence in mammals shows that males are much more susceptible to the stress of social competition than females[ccx], and males are the sex with most intense competition for mates and mating success. Taken together these studies suggest that certain factors may dampen the damaging activation of the stress cascades, probably through a counterbalancing action of other neuroregulatory systems in the brain.**

Brain chemicals mediating affiliation and social affects seem good candidates for this damping effect. We saw, in fact, that the stress cascades are set into action by noxious stimulation, either directly or through impinging threats. That is to say, by all kinds of aversive stimuli. But animals can indulge in social interactions that generate non-noxious stimulation (touch, warmth, etc.). In recent years evidence has shown that oxytocin systems in the brain may represent an integrator of the physiological, endocrine and behavioral effects caused by non-noxious (non-aversive) stimuli. Oxytocin is released in the hypothalamus in the same nucleus where the stress cascades are switched on. But oxytocin promotes a pattern of effects characterized by a decrease in sympato-adrenal response, enhanced vagal activity, anabolic metabolism, growth stimulation and sedation. In other words, an anti-stress pattern[ccxi]. Although suckling of the nipple mainly stimulates oxytocin secretion as does mechanical vaginocervical stimulation during birth and sexual behavior, there is data showing that somatosensory, non-noxious stimulation such as touch, warm temperature or gentle vibration can produce an increase of oxytocin in the cerebrospinal fluid. Exogenous oxytocin can alleviate alarm calls given by isolated chickens and pups[ccxii]. Endogenous oxytocin mediates bonding triggered by lactation and participates in many types of maternal and sexual behaviors that promote social bonding and affects in rats, voles, hamsters and humans[ccxiii]. Such evidence suggests that oxytocin systems may have an important role in damping the stress cascades. Besides oxytocin, other systems such as endogenous opiates and prolactin participate in basic mechanisms promoting social attachments and establishing social bonds that protect in stressful conditions[ccxiv]. Social activities producing joy such as playing or grooming may be behind the developmental compensatory factors that make certain individuals very resistant to the damage of stressful challenges, despite not excelling in dominance. Activities that increase social connectedness may provide additional resources to resist stress: health-promoting effects of friendship and affiliation to societies of ideological and religious nature may be based on this effect.

### *Controllability and predictability: Relations with aversion and relief*

The feeling of safety is a psychological key that may turn any particular life challenge from an aversive to a relieving tone, with the corresponding switch from stress to anti-stress cascades in the brain. Safety may result from subtle ways of perceiving events. For instance, a good appraisal of dominance hierarchies in social interactions may be a favorable strategy: Behavioral research has widely demonstrated that submission behaviors are efficient safety releasers in animals and man[ccxv]. The tendency to construct and accept the norms embedded in a particular social “order” may provide a protective belt, as signals of safety prevail against signals of danger.

Psychological research has shown that controllability and predictability of events are good buffers of stress. Animals submitted to uncontrollable or unpredictable stressors present more acute signs of physiological and behavioral suffering than when under controllable or predictable stress situations of equal intensity[ccxvi]. If given a choice between strong-predictable aversive events versus weak but unpredictable ones, they select the former; results with humans showed parallel results[ccxvii]. Repeated uncontrollable and unpredictable stressors produce important and long-lasting dysregulations at critical points of the neurohormonal stress cascades: noradrenaline depletion at the locus coeruleus and hypothalamus[ccxviii], and severe disruptions of corticoid receptors at the hippocampus resulting in deficits of corticoid cascade regulation[ccxix]. Some of these changes have been strongly connected with chronic deleterious effects of repeated stress: recurrent depression and accelerated aging[ccxx].

Control and prediction are important coping resources to deal effectively in an uncertain and ever-changing world. Psychological strategies that increase them confer stress resistance whereas those that diminish them enhance vulnerability[ccxxi]. This may be one of the ways to explain why belief (mental tendencies to put trust on regularities) are so necessary, why they can be so helpful in critical circumstances[ccxxii], and why they form so easily often on rather weak foundations[ccxxiii].

There are other psychological inductors of safety feelings. Psychologists, as an alternative strategy to turn off the stress reactions, have studied negation ('denying' that relies on an effective memory suppression of aversive events). However, current explanations on its possible neural and/or endocrinological mediators are mainly speculative[ccxxiv].

### *Individual differences: Genetic make-up and developmental histories*

Typical coping resources that individuals show during their lives are primarily manifestations of the genetic endowment and the marks left by environmental input during development. There are enduring differential styles (temperaments) to confront danger and threat. Children show differential patterns of behavioral and physiological activation that last from 2-months to adolescence[ccxxv]. Lines of animals have been selectively bred to actively cope with stress, replacing passive, highly vulnerable, animals[ccxxvi]. Genetic loci associated with more fearfulness/vulnerability to stress have been detected in mice[ccxxvii]. Moreover, genetic loci associated with novelty and risk-seeking behavior have also been detected in animals including humans[ccxxviii]. Animal lines genetically differentiated for vulnerability to stress present neurohormonal profiles that are distinctive in stress[ccxxix] and in certain anti-stress cascades[ccxxx]. These basic temperamental styles are manifest as typical patterns in every domain of behavior including social interaction.

On the other hand, early experience at critical periods of development can have enormous impact on stress susceptibility. Perinatal aversive stimulation can leave enduring marks increasing stress vulnerability. On the contrary, early regular and gentle postnatal handling, or enrichment, may have long-lasting protective effects[ccxxxi]. This has been demonstrated for several neurochemical systems and for aging-related deficits as well[ccxxxii]. These protective influences derive from an early recruitment of the anti-stress brain systems. The attenuated corticoid stress cascade in rats handled immediately after birth depends on the increased licking and grooming by mothers to the handled pups[ccxxxiii]. In fact, infants that spontaneously were licked and groomed more by their mothers had an attenuated corticoid cascade and were more resistant to aversive challenges.

### *Concluding remark*

Selye once stated "Stress is life and life is stress". This rather vague and general formulation fueled a solid scientific enterprise aiming at disclosing the mechanisms by which organisms deal with and resist life's challenges. Although the whole problem of biochemical and neuroendocrine aspects of stress is far from being understood, an impressive body of knowledge has accumulated showing neuroendocrine and neuroimmunolgical systems specialized in producing stress or anti-stress reactions. It is well known that viability depends on their subtle and continuous interplay.

# 11. Religious Belief

Religion follows in the tracks of biology, even if it is closely related to the aboriginal invention of language, which brought the great opportunity for a shared mental world[ccxxxiv].

## *Language, order, and belief in humans*

Energy dissipating living systems are constantly in a state of flux, far from thermodynamic equilibrium. This state of flux is considered in this study to be an information decoding and processing operation, constrained by the stringent rule of the LifeTime Algorithm. The perceived deficit from their particular optimum, as measured in terms of fitness, constitutes the fundamental input on which the Algorithm acts, leading to competitive behavior to reduce the deficit. Gauging this deficit is achieved by means of a limited sensory apparatus that radically simplifies the world by filtering out all distracters. This simplification is equivalent to the assumption of a property called 'order', the property on hand of which individuals categorize perceived environmental information into a disjunction of opposites, such as relevant or irrelevant, detrimental or beneficial, appetitive or aversive. Hence, a drastic filtering of the *exterior and interior* environment precedes the assessment of the deficit. This information-theoretic simplification of the world, here called trust-in-order, is postulated in the LifeTime model as the indispensable prerequisite for the Algorithmic deficit-reduction effort that uniquely characterizes Life.

Language appeared early in the history of hominids, as pointed out in Chapter 5. Language being composed of linear strings of utterances has the extraordinary property that only a limited set of words and rules for concatenating words allows for a potentially infinite number of distinct information transmitting modules, i.e., sentences[ccxxxv]. Yet to function at all as a communication system, sentences must have the property of being either true or false[ccxxxvi]. Analytic assertions are true by construction and, correspondingly, the information they convey is limited or nil (i.e., they correspond to pure noise). Synthetic assertions of the type 'snow is white' are fundamentally different. Sometimes they can be verified by direct observation or measurement, but mostly their truth or falsity is exclusively based on an act of faith. Determining the intrinsic truth-value of an assertion in a natural language is generally impossible in that language[ccxxxvii]. On the other hand, assigning the truth-value of a sentence on faith alone is equivalent to state that the interlocutors share a common world-view. From a biological perspective, this indicates that utterances signaling a particular condition of a sender can only be consistently interpreted by an interlocutor as true (honest), or rejected as false (deceitful), if both parties share a common world-view[ccxxxviii]. A general endorsement of a *Weltanschauung* has as a consequence a radical simplification of the world, as now particular interlocutors become *predictable*. As shown in Chapter 8, predictability is perhaps one of the strongest constraints that can be imposed on any physical or social situation, thereby entraining its radical simplification.

By the same token, the information exchange between early hominids utilizing a primitive language is functional if and only if the linguistic group shares a common world-view, so that truth-values can be assigned to synthetic sentences. Admitting such a possibility equals to attributing to the *shared* social environment the necessarily required *order,* in the trust-in-order sense of Chapter 8. Consequently, the LifeTime model actually predicts that the following hominid traits may have evolved more or less in parallel: (1) Assigning verbal utterances, ‘names’, to fitness-relevant objects or circumstances. (2) A communication system concatenating these names according to a primitive but shared rule into synthetic sentences. (3) A shared belief system incorporating a presumed world-order. (4) The feasibility of assigning truth-values to synthetic sentences based on that shared world-order. Indeed, the LifeTime model emphasizes that a functioning communication system wherein utterances are not directly associated with a cost presupposes the trust-in-order by which a common world-order can be trusted to reliably obtain in the social environment[ccxxxix].

When linguistic systems evolved towards their presently known complexity, the unavoidable shared belief system and the commonly admitted world-view coevolved, giving rise to new forms of common behavioral patterns. Here we address one of these ubiquitous behaviors: religious belief.

***Religious beliefs in the LifeTime model***

"Should a believer as last resort be compelled to speak of "God's inscrutable design", he is admitting that the only consolation and source of pleasure left for him is an unconditional submission. But if he is ready to accept this [unconditional submission], he might just as well have saved himself the detour" [ccxl]. The detour Freud is referring to in this citation is mankind's timeless quest to extirpate or at least reduce the non-rational element always present in their ubiquitous religious belief-systems. But if in this quest the searcher is led as a last resort to admit God's inscrutable design, to unconditionally surrender to a transcendent authority, then he might have saved himself all the trouble in the first place.

"It is this feeling [of religious 'dread' or 'awe', of something 'uncanny', 'eerie' or weird'] which, emerging in the mind of primeval man, forms the starting point for the entire religious development in history. 'Demons' and 'gods' alike spring from this root, and all the products of 'mythological apperception' or 'fantasy' are nothing but different modes in which it has been objectified. And all ostensible explanations of the origin of religion in terms of animism or magic or folk-psychology are doomed from the outset to wander astray and miss the real goal of their inquiry. Unless they recognize *this fact of our nature—primary, unique, underivable from anything else*—to be the basic factor and the basic impulse underlying the entire process of religious evolution". This long quotation with our emphasis added is from Rudolf Otto's book 'The Idea of the Holy'[ccxli], the subtitle of which is 'An Inquiry into the non-rational factor in the idea of the divine and its relation to the rational'.

Whereas Freud was a convinced and outspoken agnostic and non-believer, Otto was just as strongly a convinced and outspoken Christian believer. Each from his particular *Weltanschauung* points to the same disturbing central element of all human religious experience called by Freud "unconditional submission" and by Otto a "non-rational fact of our nature". According to the LifeTime scenario, both outlooks miss the point.

Strong religious beliefs are ubiquitous throughout history in every known human society. Contrary to the viewpoints of Freud and Otto, the central element of human religious experience is neither rational, irrational nor non-rational, nor is it some kind of unconditional surrender. It simply is the manifestation in humans of the trust-in-order trait of LifeTime. This trust-in-order is literally a fact of nature, an integral part of each LifeTime-form, and as variable among individuals as any other innate trait.

The essential difference between biological and non-biological matter is the multi-dimensional phenomenon LifeTime, incorporating Life, the planetary phenomenon, Time, the future not-yet-dead, the Algorithm, an information-processing rule, and trust-in-order, reflecting information-theoretically a physical property of the environment taken in its widest sense. Biological matter is physically detached from its external environment by means of partially secluding ‘membranes’, resulting in transient distinct individuals. Individuals are said to be adapted if the order-structure their perceptual apparatus decodes in a given habitat is functionally reflected in their trust-in-order trait. Information sense-decoded from the external and internal environment is processed under the relentless rule of the Algorithm, causally resulting in an incessant effort to reduce the deficit from the theoretical optimum. For adapted individuals, deviations from this rule are experienced as being aversive, triggering an alarm signal cascade, whereas submission to the Algorithmic rule is experienced as appetitive, relieving the alarm cascade and thereby enhancing fitness (see Chapter 10). In humans this value dichotomy is further categorized as pleasure or pain, and elevated to the ‘mental’ rank of emotions or feelings, and thus assigned to ‘mind’. Of course, the sensations of pain and pleasure are physiological states of an exclusively physiological basis in humans as well as in all other animals.

The trust-in-order trait becomes manifest in individuals adapted to a given environment in the way they process the information emanating from this environment. It can best be described by stating that they behave *as if* they assume that past experiences remain relevant in the present and future; ‘past’ here understood in evolutionary terms. Thus, appetitive or aversive stimuli are *expected*, and moreover in a predetermined time-sequence, and of a predetermined quality (see Chapter 7). An environment that can be trusted in this way is a far *simpler* environment than one where past experiences are consistently irrelevant to the present or the future. What cannot be trusted, what therefore must by all means be avoided, what produces the strongest aversive reaction, is chaos, complete randomness, the total lack of predictability. The fitness enhancing information processing of the Algorithm is impossible in a chaotic situation; Life cannot persevere in Chaos. Thus, by definition as it were, living matter such as humans require, and necessarily presuppose, a sufficiently non-chaotic environment. Only environments possessing this quality *relative* to a given organism allow the adaptation of this organism to that habitat. Adaptation over evolutionary epochs leads to fine-tuned phenotypes. We call this fine-tuning trust-in-order. Here we argue for a close association of the trust-in-order aspect and religious belief in humans.

First, we analyze the idea of *the holy*, considering it to constitute the central element of religious belief. We do this by relying on the lucid research of Rudolf Otto. Then, two particular religious systems are presented: Religion in ancient Greece and in ancient Mesopotamia. The purpose of these presentations is to highlight the trust-in-order character of these religious systems. They have been chosen because ancient religious systems exhibit the trust-in-order components in a more pristine way than more recently recorded religions, being closer to the ‘aboriginal’ idea of the holy, yet being *written* religions which today can still be studied in reasonably well preserved texts. In contrast, the description of ‘primitive’ religious systems as transmitted by ‘missionaries’ and anthropologists appear as subjectively interpreted systems. They have either have left no written record (for instance, in Africa or Amazonia), or whose records have been destroyed (as in America by the Spanish priests) or only partially deciphered (for instance, the Mayas).

### *Religion, though, fails to disappear*

> Even within a world dominated by self-created technology, humans will not easily accept that constructs of sense reaching out for the non-obvious are nothing but self-created projections, and that no other signs from the universe around are there to be perceived except for the irregularities resounding from the first big bang[ccxlii].

> The justification of the ‘evolutionist’ theory of today stands and falls with its claim to ‘explain’ the phenomenon of religion[ccxliii].

The center of religious experience is the ‘non-rational’ concept of a divinity or god. In spite of their ‘non-obvious’ essence, the gods are provided with attributes that are nothing but exaggerated human traits, such as absolute power, immortality, purpose, and supreme wisdom. In this way the gods become objects of conceptual thought and thus a conscious object of belief. The assignment of human-like attributes to the gods allows the exposition of religious systems by means of a language and much later also in written texts. While mysticism almost constantly refers to the ‘ineffable’, this is not to infer that nothing can be asserted of the object of a mystic experience; if this were so, mysticism could only exist in unbroken silence, which is patently not the case. Moreover, the so-called miraculous is in most cases treated as a breach in a certain causal connection of nature by the will of a god, and thus the miracle is reduced to a linguistically expressible, rationally comprehensible situation. As a final result, the ‘non-rational’ gods appear mainly as rational constructs, comprehensible by human reasoning. How is this contradiction possible? If the gods are rationally analyzable, but found to be non-rational, why has no rational system ever been capable of eliminating the belief in gods? Why has religion failed to disappear? Only if the religious experience is not a primary product of human reason can the ‘unreasonable’ persistence of belief in the gods be ‘rationally’ explained, as then something quite different must underlie this unmistakably human experience. This is the experience of the holy.

### *The holy as the ‘numinous’*

The holy is like Life, Time, order, and other concepts mentioned in this study a word designing an idea recalcitrant to apprehension in terms of commonsensical self-evident notions. Following Rudolf Otto, we first remark that no ethical element is present in ‘the holy’, at any rate it does not constitute the whole meaning of the word; on the contrary, the word requires an altogether different treatment. To emphasize that the holy is given a special meaning, Otto suggested the terms ‘the numinous’ and ‘the numinous state of mind’, which we also adopt. “This mental state is perfectly *sui generis* and irreducible to any other; and therefore, like every absolutely primary and elementary datum, while it admits being discussed, it cannot be strictly defined”[ccxliv].

An early recognized aspect necessarily presumed to be associated with the holy and with the numinous state of mind is the ‘feeling of dependence’, the unconditional surrender of Freud. This surrender refers to a profound feeling of inferiority, entirely depending on other, unreachable superior powers. However, this aspect is not primary but derived. Once the gods have been identified with the numinous, and their rational attributes assigned, a human may interpret the numinous in terms of a creator-creature relation. This relation is, however, a secondary one. The primary relation of humans to the numinous is given the name *mysterium tremendum* by Otto.

### ***The*** **mysterium tremendum**

The adjective *tremendum* is derived from *tremor,* the ‘natural’ emotion of fear. However, when humans face the gods, when experiencing the numinous, the fear is of a special kind. In some languages there exist specific expressions denoting that this ‘fear’ is more than just natural fear. In English, the words that come to mind are ‘awe’, ‘awful’, or the phrase ‘he stood aghast’. Other terms are ‘dread’, as in demonic dread, and ‘shudder’, or to feel horror in the real sense of the word. Interestingly, Otto contrasts the tremor-emotion brought about by the experience of the numinous with “the religious bliss that may come in worship”[ccxlv]. He thus admits the dual effect of the numinous: on the one hand, the tremor, the ineffable shudder, when facing the gods; on the other, the relief that turns into pleasure when submissively prostrating before the gods.

The LifeTime model in fact *predicts* the presence in humans of such a dual behavior phenotype. Behavior conforming to the Algorithm and trust-in-order conjunction is experienced as appetitive and results in the psychological and physiological sensation of “feeling well”, whereas behavior straying from this mold is interpreted as aversive and becomes psychologically and physiologically manifest as “painful” (tremor)[ccxlvi]. The substantially enlarged information-processing capabilities of the human brain, including the difficult concept of self-consciousness, provide the computational autarchy leading to the possibility of so-called free-will decisions. Since such decisions are modulated by physiological inputs, it follows that the Algorithm and trust-in-order causally results in a psychological and physiological “feeling well” sensation when humans “freely” submit to this innate rule. It remains to be shown that the gods and their ‘numinousity’ are, at least in part, a manifestation of the

Algorithm/trust-in-order conjunction as experienced in conscious humans; this will be attempted below.

A further element is added to the *mysterium tremendum*: Otto calls it 'overpoweringness' or 'majestas'. He refers to the sensation of might, power, and absolute overpoweringness of the gods as compared to their inferior creatures. It is the 'being but dust and ashes' and nothingness of man, his 'creature-feeling' or, more precisely, his complete 'feeling of dependence'. Otto further remarks that it is also a general trait of all forms of mysticism to proclaim the nothingness and the impotence of man as set off against the overpowering might and majesty of the gods, the mystic self-depreciation. Of course, the slightest conscious reflection of the human condition immediately leads to this drastic contrast: the world presents all the qualities Otto calls overpoweringness. In animals, the Algorithm simply produces unceasing competition for enhanced survival and reproductive success. Not so in conscious humans:

> Thus consciousness does make cowards of us all;
> And thus the native hue of resolution
> Is sicklied o'er with the pale cast of thought[ccxlvii].

Humans possess a sophisticated information transmission system in the form of an early, primitive language and millions of years of evolution gave rise to innate associations between names or special oral utterances and the overpowering aspects of the ephemeral place of humans in the order of things. Remember that the divergence between hominoids and the Old Word monkeys took place about 25 million years ago, while the ape-human split probably occurred as far back as 6 to 8 million years ago[ccxlviii]; in contrast, all of recorded human history covers a mere 5,000 years.

The next step in the analysis is the term *mysterium*. Otto quotes Tersteegen: *Ein begriffener Gott ist kein Gott*, "A God comprehended is not a God". What is a mystery? Evidently, a mystery is the non-comprehended, the 'wholly other'. The environment in the largest sense (the world and "the others") completely escapes all attempts of comprehension by primitive[ccxlix] humans. Especially so when the time-element is also considered. Independent of whether 'time' is a human artifact or a physical reality, everything that a human consciously faces lies in the future, exclusively the future is important, meaningful, worth worrying about[ccl]. But the future is precisely by definition the unknown, that is, the mystery par excellence, which to be sure directly points to the close connection of religion with divination, astrology, pre-destination and similar destiny-scouting attitudes. Note further that it is precisely this 'mysterious' future-time that is incorporated as a structural element in the LifeTime model.

As in Otto's approach all that is to be comprehended is exclusively God, and as God appears as the *mysterium tremendum*, the scientific quest for an understanding of the numinous is doomed to failure, as it equates with an attempt to rationalize religion, and religion, he claims, is non-rational. "[These comprehension efforts] are the source from which springs, not religion, but the rationalization of religion, which often ends by constructing such a massive structure of theory and such a plausible fabric of interpretation, that the 'mystery' is frankly excluded"[ccli].

On the contrary, "the feeling or consciousness of the 'wholly other' will attach itself to, or sometimes be indirectly aroused by means of objects which are puzzling upon the 'natural' plane or are of a surprising or astounding character"[cclii]. The gods, and the numinous, are innate mental structures "not only because our knowledge has certain irremovable limits, but because we come upon something 'wholly other'"[ccliii].

What is this 'wholly other'? In the LifeTime model, Life-forms adapt to specific environments in two ways: by evolving idiosyncratic Algorithms and idiosyncratic trust-in-order structures. By the first, they are as it were ceaselessly driven towards enhancing their fitness. By the second, to an unshakably trust[ccliv] in the perseverance of the perceived physical order-structure relevant to their particular needs for survival and reproduction. This trust-in-order aspect of the Algorithm must be understood information-theoretically, as a consequence of the way in which individuals are constantly filtering and simplifying the incoming information from the environment. As a result, instead of a Chaos the environment becomes a Cosmos. In a simplified Cosmos, individuals can categorize physical stimuli from the environment as either aversive or appetitive. In humans, the indispensable bias filtering the incoming information presumably lies at the origin of such 'mental' artifacts as time, life, order, and the numinous 'wholly other'. The filter, however, is not arbitrary, as it has been fine-tuned by millions of years of evolution; it will remain valid until the extinction of the species.

Otto goes as far as to write: “The intimate interpenetration of the non-rational with the rational elements of religious consciousness may be elucidated by taking another familiar case, in which a universal human feeling, that of personal affection, is similarly interpenetrated by a likewise thoroughly non-rational and separate (*sic!*) element, namely, the sex instinct”[cclv]. And he adds: “Another point in which the ‘erotic’ is analogous to the ‘holy’ is in having in the main no means of linguistic expression but terms drawn from other fields of mental life”[cclvi]. “The consciousness of a ‘wholly other’ evades precise formulation in words”[cclvii]. In other terms, Otto seems finally to admit that ‘the sex instinct’ and ‘religious belief’ are similarly rooted in biology; we heartily agree!

***Religion as a system structuring and cementing hierarchies***

Religion is a system of rank, implying dependence, subordination and submission to unseen superiors. As Otto explains, it is overpoweringness that defines the gods. Gods are honored by submission, as to a powerful father figure that grants protection and ensures security. For instance, the word ‘Islam’ means surrender to the will of Allah. The gods appear systematically as father, pastor, shepherd, dispensing justice and limiting fighting and antagonism among depending inferiors, i.e., humans. They further settle and form the basis of the “highly developed awareness of authority within a complex system of rank that is well established in all primitive societies”[cclviii]. Power structures are ‘vertical’, tending at the summit towards a unique figure: king, pharaoh and, ultimately, the dominant god. As shown in Chapters 11.1 and 11.2, the gods fight vigorously and brutally until that one of them attains the summit of the hierarchy. This verticality is reinforced by the gods generally inhabiting high mountain places, their symbols being pyramids, ziggurats, impressive church towers or mosque minarets. The word ‘altar’ comes from the Latin *altus*, high. The priest and the king increase their ‘highness’ with special hats and crowns, whereas kneeling or prostration expresses submission. Signals of holiness or highness are usually expensively decorated emblems that share the property of being costly with reliable signals in animals and plants.

We have emphasized the enormous complexity of the human social environment. Religion, as Burkert points out, is a way to reduce this complexity, of making social environment workable and cementing its power structures. “Religion operates to stabilize the accepted order, praising its highest starting point”[cclix]. “Praise is the recognized form of making noise in the presence of superiors”[cclx]. “Neither Hammurabi nor Darius, nor a Sassanid king nor Constantine relied on prayer alone to establish their kingships; but it was from religion, from the authority and power of the god that they sought legitimization”[cclxi].

Biology has provided many examples of social organization in a great variety of species[cclxii], and the considerable costs of sociality in terms of predation, disease, parasitism and social competition must be balanced by greater benefits for sociality to remain evolutionarily stable. Conceivably, religious beliefs constitute a prerequisite in the development of social structures in humans. In this context, we emphasize the importance of oaths for the establishment of human social organization (see Chapters 11.1 and 11.2). Burkert asks: “Why must people have religion? In the ancient world, the obvious answer would have been, for the validation of oaths”[cclxiii]. Social organization in humans and non-human animals is dependent on information exchange that may be either honest or deceitful. Plausibly, very early in their history, the conjunction of a primitive form of language, religion and social organization became cemented by a primitive form of oaths. Oaths make fellow men predictable and give stability to a commonly held world-view. As previously mentioned, the establishment of truth-values is the *sine qua non* precondition of communication. Oaths guaranteed by dire curses enforced by the gods precisely achieve this end. However, this requires a common belief domain. By this means oaths become essential for the establishment and maintenance of hierarchies. “Taking an oath means a radical ‘reduction of complexity’, in an effort to establish universal meanings and create a world of sense that is dependable, with clear divisions between true and false, right and wrong, friend and adversary, ally and foe”[cclxiv]. In other words, the oath is an indispensable element in the assumed “trusted” order-structure of that part of the environment represented by “the others”. Not surprisingly, committing perjury is still today considered an extremely serious crime that is punished severely in most legal systems[cclxv].

### *Concluding remarks*

We have shown that the mental phenomena subsumed under the title ‘religious beliefs’ most probably became incorporated in the genome of our early hominid ancestors. This is shown both by the ubiquity of religious beliefs, and the surprising fact that religious beliefs have withstood unscathed millennia of criticism, remaining entirely aloof of the non-rational label affixed by philosophers and other agnostic critics. We argue that the basis of religious belief is a trait – we call it trust-in-order – inherent in all Life-forms, an essential component of the features that essentially distinguish living from abiotic matter. This trait or phenotype becomes idiosyncratically manifest in humans in a ‘rationalized’ power-submission structure. This structure can be found everywhere in the living world, but it takes in humans yet two other forms. These are placebo effects and self-deception to which we turn our attention in the next chapters. However, first we show in Chapters 11.1 and 11.2 how the predictions of the LifeTime model find support in two of the most ancient written religious testimonies.

## *11.1. Theogony as the Establishment of Order from Chaos*

Here we analyze one of the earliest complete written testimonies of Ancient religious beliefs. We present this analysis with the aim to highlight certain aspects deriving from the LifeTime model, especially as referring to the trust-in-order aspect. Based on written records from ancient Greece, it is easier than elsewhere to carry out such a test, especially because we are in possession of a brief and remarkably structured text which could well have been written down as early as the eighth century BC: Hesiod's *Theogony*.

The collapse of Mycenaean civilization in the twelfth century BC marks the beginning of an obscure period for Greece, from which the first works to emerge were those attributed to Homer, the *Iliad* and the *Odyssey*. These were oral epics, which, it is believed, were given a definitive version in the course of the eight century, and were written down later, in the sixth century. The account which gives us the most convenient and adequate access to the cosmogony known to the ancient Greeks is still Hesiod's *Theogony*, which is prolonged into social and anthropological areas in the *Works and Days*. They were probably written between 730 and 700 BC; and this is why we can suppose that these two poems were composed directly in written form.

We now have a very much better idea of what to believe with regard to the introduction of writing into ancient Greece. At the time of the Mycenaean civilization, a syllabic writing was used to consign administrative documents onto clay tablets preserved in the royal palace. Chadwick and Ventris were able to decipher this writing, called Linear B, in 1953. After an eclipse of more than four centuries following the collapse of the Mycenaean civilization, the use of writing was reintroduced into Greece at the beginning of the eighth century BC. The Greeks borrowed the Phoenician consonantal alphabet, which itself was a variant of the West Semitic systems, invented in the second millennium; but the Greeks wrote down vowels beside the consonants in combination with which they were read. This innovation brought about a veritable revolution in reading: whereas a consonantal syllabary is necessarily reserved to a small group of professionals, who are able to compensate for the deficiencies of the notation of consonants alone, reading now became - at least in theory - an activity accessible to all people who enjoyed some degree of leisure. It was at the moment when this unknown type of writing was introduced that Hesiod's *Theogony* was composed; it thus remains the oldest religious text in ancient Greece to have been written down directly. The *Theogony*, moreover, is prolonged by the *Works and Days*, which applies to the world of human beings what the *Theogony* says about the birth of the gods.

The *Theogony* explains how, starting from Chaos, the order, which now reigns over all things, was established. As its title indicates, this poem describes the generation of the gods on the model of the generation of human beings. The goal is the perpetuation and propagation of life in a context in which the future is more and more foreseeable, because more and more ordered.

The poem opens with a long prelude in which Hesiod tells how, when he was grazing his lambs at the foot of Mount Helikon, the Muses revealed their truth to him, in order that he might glorify “what will be and what was”, and celebrate the race of the immortals. Hesiod asked the Muses, who are the daughters of Zeus and Mnemosyne (=Memory), to tell him what happened in the past, and what caused the establishment of the current order of things. If the future is invoked, it is because it must prolong the continuity of this order by guaranteeing it. Let us see how this order was established.

At the origin, we find a trio of powers: first Chaos, then Earth and Eros. The starting point is Chaos. In order to imagine Chaos, we must hypothesize that the elements existed, but had no stable, regular link between them. By definition, Chaos appears as the absence of all distinctions in time and space; an absence which renders all thought, discourse, and action impossible. The discourse on the establishment of an order begins with an initial distinction within time: first there was Chaos, then Earth and Eros. Nothing is said of a distinction within space, but we now find ourselves with three names, which refer to three distinct realities.

From Chaos, Erebus and Night are born. From Night come Ether and the Light of day. For its part, Earth gives birth to a being equal to herself, the starry Sky (=

Ouranos). She also bears the Mountains, and Pontos, the furiously swollen Sea. We note that from the very beginning, the appearance of the new divinities is described by means of verbs associated with the ideas of generation and childbirth. Nevertheless, all these generations initially take place without the help of Eros; that is, without the intervention of sexual union between a male and a female principle. Several new elements appear at this stage: (1) The temporal relation (first *x*, then *y*) becomes a relation of causality (from *x*, *y* is born). The vocabulary of engendering makes its appearance, but without any mention of copulation: the generations succeed one another spontaneously, without the intervention of Eros. At this level, the process of maintaining these entities takes place almost automatically. (2) The number of entities, which have a proper name, increases. (3) Oppositions arise between these entities: Night is opposed to the Light of day, like darkness to light; the Sky is opposed to the Earth, as upper is to lower, and above all as male is to female. Opposition is a highly effective principle of distinction, since only two classes are able to exhaust all the realities belonging to the same genus.

When Eros becomes active, a biological process, which implies sexual union, takes over. Yet everything is not yet arranged; far from it! The first marriage - that is to say, the first sexual union between Ouranos (the Sky) and Gaia (the Earth), results in excessive proximity between these two principles, which blocks the process of generation. From the embraces of Sky and Earth are born Ocean, the Titans (Coios, Crios, Hyperion, Iapetos) and the Titanides (Theia, Rheia, Themis, Mnemosyne, Phoibe, and Thetis). The last of the Titans is Cronos. Finally, Gaia bears first the Cyclopes (Brontes, Steropes, and Arges), then the Hecatonchires (Hundred-handed ones): Cottos, Briareos, and Gyes.

What can we say about this stage? (1) The two primordial divinities, like those who come after them, have a sex attributed to them: they are either masculine or feminine, since it is sexual generation that henceforth explains generation. (2) The number of entities endowed with a proper name increases. (3) One name stands out from this group: Themis, who represents the immanent justice that corresponds to the order of the world. At this stage, however, Themis does not yet play any active role. (4) Until this point, competition had not come into play. When it does appear at this stage, it neither concerns sex nor nourishment, but power. There are two reasons why this is so: the gods are too few for there to be a real choice between sexual partners, and they have no need of food. The only issue that matters is who will lead; and Zeus will give a definitive answer to that pressing question.

Ouranos, who conceived hatred for his children as soon as they were born, prevents them from coming into the light of day by keeping them closed up and hidden within the womb of their mother, the Earth, as he lies stretched out on top of her. This excessive coupling blocks the whole process of generation, and is equivalent to a return to Chaos. So as to re-start the process of generation, which is equivalent to re-establishing some kind of order—the order that, until this point, has manifested itself in the production of new beings by mean of sexual union—the Earth decides to intervene. This happens by re-establishing, by violence, an initial distinction between sky and earth, upper and lower, light and darkness, male and female. The Earth creates a metal sickle, which she gives to Cronos, to castrate his father.

Cronos accomplishes this deed. The blood that spurts from Ouranos' wound falls upon the earth, where it gives birth to the Erinyes, the Giants, and the Melian nymphs. Aphrodite is born from the foam that escapes from Ouranos' testicles, which have fallen into Pontos (the Sea); Eros and Himeros (Desire) immediately join her. The violent establishment of distinction is thus mitigated by union, which is made possible by the birth of Aphrodite, associated with Eros and Himeros. This permits an acceptable distance between opposites. It is thus not surprising that there now follows more than 250 verses which describe the birth of the Olympian gods, who will be the principal actors in the struggle for power which follows.

The competition for power takes up where it left off. Cronos' castration of Ouranos has earned him the right to reign over the world of the gods, and in order to maintain his power, he swallows his children as soon as his wife Rheia gives birth to them. Once again, we see the process of generation being blocked; in order to master the future, Cronos tried to stop it. Yet Rheia manages to hide Zeus, her youngest child, in a cave in Crete, by substituting for him a stone, which Cronos swallows without noticing the change. Once Zeus grows to adulthood, he tricks Cronos into vomiting up his brothers and sisters, and this deed earns him sovereignty over the world of the gods.

From this point on, all the actors (except Typhon; we will see why later on) are united for the battle which now follows. Zeus must ensure his power by reducing the opposition of the old gods in the course of a series of battles. These take place in two phases: in the first, Cronos appeals to the other Titans to revolt against Zeus, who has all kinds of difficulty resisting them. On the advice of Gaia, Zeus rescues the Hundred-handed ones from the subterranean world where he had imprisoned them, chained up by Cronos. With their help, the Titans are crushed by Zeus and thrown into the Tartarus. Later on, Zeus must confront a new threat in the person of Typhon, youngest son of Gaia, who united with the Tartarus. In the already-organized world, Typhon represents the return of primordial Chaos, to which all things would be returned if he managed to defeat Zeus. Typhon is quickly stopped by Zeus' thunderbolt, and thrown into the Tartarus. From his remains, there arise fierce and unpredictable winds that are the origin of many scourges on earth and on sea; this indicates that the forces of disorder can never be definitively and totally defeated. As in Plato's *Timaeus* (the oldest cosmology in ancient Greece, where 'necessity' always opposes the work of reason), Chaos is vanquished, but it does not disappear, insofar as the order which is established is not complete. Zeus then contracts a series of five marriages, which constitute a kind of conclusion to this story of the establishment of a lasting order.

The first marriage seals the order of succession once and for all. Zeus takes as his first wife Mêtis ('crafty Intelligence'). Zeus, however, fears his wife may give birth to “a violent-hearted son who would be king of men and gods”. So, at the moment when Mêtis is about to give birth to Athena, he swallows both mother and daughter (born from Zeus’ head), on the advice of their grandparents, Gaia and Ouranos. He thereby puts a definitive end to the cycle of successions. Believing he is preventing the birth of a son, he renders inoperative the crafty intelligence (Mêtis) which could have inspired either that son, or any other. From now on, no ruse can threaten the established order by unexpectedly threatening the foreseeable course of the future. Zeus thus succeeds in dominating the future, not by stopping it, like Ouranos who stayed joined to Earth, or like Cronos did in the case of his children. Instead, he renders crafty Intelligence impotent, which alone was capable of threatening the organizational principle of this future, by assimilating it. It is precisely because Zeus has this future under control that he can claim to be king of the gods.

Next, Zeus marries Themis ('Equity'), who incarnates stability, continuity, and regularity. From this second marriage there are born the Hours (Horai): Good Order (Eunomiê), Justice (Dikê), and Peace (Eirênê), who watch over the fields of mortals; and the Parcae (Moirai), who indicate each person his or her portion, as well as the limits that they must not cross. By marrying Themis, who is immanent justice, and rules over all reality in a natural way, Zeus can beget the Horai, who represent the regularity in nature and society. The most suggestive divinity among the Horai is Dikê, the justice of men. She points out those who have committed a fault, and indicate that they must pay for it. The Horai are associated with the Moirai, who ensure order by assigning a determinate lot to each person, which he must not seek to modify.

Zeus' third wife is Eurynomê ('the far-stretching Law'), daughter of Ocean, who gives him as daughters the three Graces (Charites): Beauty (Aglaê), Pleasure (Euphrosynê) and Abundance (Thaliê). These can be considered the fruits of a just, lasting order. Zeus thereby shows that he is the guarantor of the well being which flows from acts, which correspond to the process made foreseeable by the order so established.

Zeus then takes Demeter as his fourth wife. She gives him his daughter Persephone, who would later be raped by Hades. This rape symbolizes death and rebirth, which apply not only to the vegetable world, but also to the animal world, in a form that is less than clear. Finally, whereas the fourth marriage guarantees the survival of the species in the body, his last marriage with Mnemosyne (Memory), who will give birth to the Muses, will ensure the perpetuation of renown in memory, which characterizes the reign and the will of Zeus. By his fourth marriage, Zeus shows how he can effectively oppose that which can destroy the idea of the perpetuation of life. He attacks death, which is denied by the ideas of survival and renown.

Zeus thus confirms the privilege he has conquered, and his will to have the frontiers and limits respected, by which each of the gods has had his or her domain and rank attributed. Zeus now takes as his official wife Hera, who will give him his children Hêbê, Ares, and Eilythuia; but he will unite with several other goddesses, with whom he will have other children. Starting with this last marriage, Zeus appears exclusively as a promoter of the phenomenon called life. And as he has established it, he vouches for this order, which makes possible the perpetuation and the propagation of life.

The *Theogony* can be considered a hymn in honor of Zeus, or rather in honor of the establishment of order which Zeus establishes once and for all, and which human beings must follow. Whereas the *Theogony* shows how society may become pleasant under the reign of justice, the *Works and Days* describe what happens when justice is no longer present in society. In general, justice can be held to be the order which reigns in the city of men; an order which is equivalent to regularity and stability in human relations.

The *Works and Days* is composed of two parts. The first teaches, in the form of myths or moral precepts, that no one can deceive Zeus, for fear of engendering evil, and that injustice means man's destruction. The second part offers a solution to escape from the unhappy situation in which evil and injustice can plunge mankind: work the land, as the gods had ordered.

The maxim according to which no one may deceive Zeus on pain of engendering evil is illustrated by the myth of Prometheus and Pandora. In that myth the ruse, which allows man to feed upon the meat of sacrifices, is associated with the mortality of the human species, which perpetuates itself by the sexual union of men and women. Moreover, the maxim according to which injustice means man's destruction is illustrated by the myth of the races, in which justice is opposed to insolence (*hubris*). There then follows an admonition directed to kings and to Perses, the theme of which is still justice. The hour of punishment always comes, for two divinities watch over it: Justice and Oath. Even if Justice is fooled, Oath may rush after the perjurer and punish him who had sworn to be just.

There then follows the second part, in which the theme is the following: “Work!”. Work ensures life, for gods and men honor work. We must know under what conditions the gods make work fruitful, and learn how we must behave towards other people. Then come the enumeration and description of the great labors of the fields. Advice on agriculture is followed by advice on navigation, the choice of a wife, moral conduct, and religious practice. Finally, comes the enumeration of the various days of the month, and the work reserved for each of them. Unlike the *Theogony*, the *Works and Days* are interested in people who are mortal beings, who must fight against death by appealing to the twin functions of nutrition and childbirth. Thus, there is necessarily fierce competition between them, the object of which is the search for food and the choice of a sexual partner. Within the framework of an agricultural society such as the one Hesiod describes in the *Works and Days*, such competition can take place in order only if two factors are made to intervene. These are work, which permits the constant, regulated production of food; and marriage, which establishes rules for the choice of a sexual partner.

The most important word in the *Works and Days* is *dikê*, or justice, which may be interpreted as order within society. It is not the last word, however. The last word is *horkos*, or oath, begotten by Struggle to be the scourge of perjurers. Oath is the god in charge of collecting sworn words, and punishing whoever violates them; for this reason perjurers are called *epiorkoi*, "those upon whom there is *horkos*" (*Works*, v. 219). We should note that the birth of Oath is situated very high up in the genealogy of the gods, since it descends from Night, the daughter of Chaos. We can therefore understand that even the gods are subject to the oath, by the intermediary of an ordeal by the waters of the Styx (*Theogony*, v. 782-806). The guilty god is struck with starvation for a year, and is deprived of contact with the other gods for the following nine years. Among humans, this oath is characterized as follows: "And finally, Oath, worst of scourges for all earth-bound mortals who deliberately swear falsely" (*Theogony*, v. 231-232). The oath is the last safeguard, which forces gods and humans to ensure the reign of justice. Only justice can maintain order at all levels of reality. This is the order which, at the end of a long struggle, Zeus has established definitively against the still-active forces of Chaos.

It has often been claimed that human beings cannot help but feel a sense of anxiety in the face of ever-threatening Chaos. In other words, human beings must find a guarantee for the maintenance of order, which is all that permits the perpetuation and propagation of individuals and hence life. Humans in ancient Greece must have imagined that this order was established and maintained by an overpowering being (i. e., the divinity (whether plural or unique)). It is this feeling of dependence that underlies the religious phenomenon. Dependence, however, is inseparable from submission, which implies obedience to this superior being (be it plural or unique). This obedience alone makes possible the maintenance of order which humans call justice; and in the last analysis, only the oath can ensure its undivided reign. Perhaps, as Walter Burkert suggests, it is necessary to suppose the existence of a divine world in order to ensure the efficacy of oaths, on which all human relations, especially social, economic, and political ones, are based[cclxvi].

# *11.2. Order and the Gods in Ancient Mesopotamia*

### *The general character of early Mesopotamian religion*

The Hellenistic term ‘Mesopotamia’ designates the territory “between the rivers” Euphrates and Tigris, approximately corresponding to modern Iraq. Settled as early as the 6th millennium BC, it produced a civilization the influence of which stretched from the Mediterranean to the Indus valley. In the late 4th and early 3rd millennium BC this civilization consisted of a number of principalities in the Euphrates valley, grouped around a center with religious and political significance. Although we merely have glimpses of this earliest period, it appears that recurrent rivalry between these centers led to frequent political changes. The population was largely agricultural, but we also find early evidence of industry and commerce, sometimes over large distances. The prominent influence exerted by religion on almost every aspect of Mesopotamian civilization can be gleaned from numerous cuneiform clay tablets, steles such as border stones, the famous law codices (see below), plus diverse epigraphic material. Written in Sumerian and Akkadian the clay tablets so far unearthed now reach almost half a million. Many are damaged or incomplete, and their interpretation is not made easier by the complicated writing system in which each grapheme can take on different values, either as a phoneme or as an ideogram. Many tablets are only dated approximately, and the origin of many of them cannot be physically located, as looters may have dug them out. This enormous material provides a consistent overview of the religious conception of the world-order in early Mesopotamia, as the main lines of this religious system apparently remained basically unchanged in the millennia after the invention of writing around 3,400 BC. And it should not be forgotten that in this case we are actually dealing with the *original* texts, whereas in almost all other cases ancient religious systems have reached us in much later copies of manuscripts (parchment, papyrus), sometimes separated by millennia from their inception[cclxvii]. Here, we give a succinct sketch highlighting the intimate relationship between order and the gods in Ancient Mesopotamia.

The period of the entry of the non-Semitic Sumerians into the valley of the Tigris and Euphrates is still beyond exact historical research, but we know that great cities and elaborate religious cults were already present before 3,500 BC. At about 3,300 BC the Sumerian religion has already an elaborate pantheon of literally thousands of deities and an intricate theological system. This immense Sumerian theological system played a fundamental role in the religion of the entire Near East for millennia. Later, the Semitic invaders who in several waves took over Mesopotamia, preserved it in innumerable Akkadian translations, and its influence is evident even in the much later Greek and Hebrew world-views.

Ancient Mesopotamians understood their gods as power, as a vital force causing all being, thriving and flourishing. The nearest term with which one might wish to characterize this experience of the godly is the “numinous”[cclxviii]. The name and the external form of the numinous experience tended to overlap. Thus, the name and the phenomenon (for instance, the visible sun) became in a way one and the same, e.g., the same Sumerian word (u t u) denotes simultaneously the visible sun and the power of the sun god. Thus, the earliest gods were “emblems”, only later did they take on a “human” form (see below). But already as such emblems they led armies to victories or were brought out to witness the making of oaths and guarantee the punishments announced in the accompanying curses.

Several clay tablets containing examples of a literary form known as “cult dramas” connect the powers of fertility to its divine representative. Others recite the yearly lamentations of the death and disappearance of the power of fertility at the onset of the dry season, or narrate the primeval contest for world order against the forces of Chaos. The great age of this world-view is attested by the Uruk vase[cclxix], dated to the final quarter of the 4th millennium and thought to depict the rite of the sacred marriage that must be understood as the numinous experience of the basic life-sustaining activities. The beneficial presence of the numinous divinity was secured by fashioning images of the gods, which in turn were provided with suitable habitation in the form of temples; the word for temple and house are the same both in Sumerian and Akkadian. The earliest forms of Mesopotamian religion thus appear as worship of the powers of fertility and yield that sustain and ensure human survival and reproduction. It shows the cyclical time-concept of ancient Mesopotamia and points to the close association of the presumed world-order and the gods, that is, points to the fundamental role of the gods in sustaining and guaranteeing human survival and reproduction.

"The fourth millennium, as far as we can grasp it from contemporary sources and later survivals, informed ancient Mesopotamian religion with its basic character: the worship of forces of nature. These forces were intuited as the life principle in observed phenomena, their will to be in this particular form. As the most characteristic trend of the millennium we may posit the selection and cultivation for worship of those powers which were important for human survival - powers central to early economies - and their progressive humanization arising out of a human need for meaningful relationship with them. This led to a growing preference for the human form over the older non-human forms as the gods within human patterns of family and occupation. The dominant form is the son and provider. Whose life from wooing to wedding to early death expresses the annual cycle of fertility and yield"[cclxx].

***The layered structure of the divine hierarchy***

The religious world-view of Ancient Mesopotamia soon changed, as continuous warfare and competition between the city-states was added to the ever-present fear of famine. The ruler, exalted above men, fearsome as warrior and awesome in power now appears in art representing war and victory, while the epic tale in the literature appears as a new form. Parallel, the religious concept of the numinous acquires its added characteristics of '*majestas*', might, power, and the absolute overpoweringness of the gods as compared to inferior human creatures (see Chapter 11). Mirroring human social organization, the highest authority in the Mesopotamian universe was the assembly of gods, presided on the top by a layered triad of supreme divinities. The innumerable gods appear as local rulers and they are provided with individual figures and names. Their respective places in the order of things creates the layered structure of the Cosmos where, from the sky downward to the earth inhabited by humans, each layer is the particular domain of one powerful deity. This simplified, layered, easily imagined structure replaces the complex, incomprehensible real world, and the believer is released of anxiety as now everything in the Cosmos acquires its assigned role and place. Importantly, the earthly organization of human society mirroring the divine organization finds herein its justification, but also is prescribed its duties: the king not only rules, but his primordial obligation is to assure justice for all.

First, we briefly outline the most important gods and indicate their location in the divine hierarchy. It must be understood that the pantheon is imagined as an "assembly of gods" where, sometimes only after a ferocious fight, a king-like deity reaches undisputed preponderance.

*The god An.* An ranked as the highest among the gods. His name is the Sumerian word for sky. An is the numinous power in the sky, the source of life-spending rain and the basis for the calendar and therefore of time, since the night-sky, through its changing constellations, determines the times of the year. Its spouse is the earth Ki, on whom he engendered all life-sustaining vegetation. In fact, An is a major source of fertility, the "father who makes the seed sprout"[cclxxi], engenderer not only of vegetation but also of demons and, crucially, of all the other gods. The universe conforms to An's will, he is the power that lifts existence out of anarchy and chaos and turns all into an organized Cosmos. As the ultimate source of authority, An is closely associated with the highest authority on earth, with the king. He is the god that confers kingship, but at the same time demands the ritual service from the king, as shown in these lines where An agreed to make Shulgi (2094-2047 BC) king:

Let Shulgi, king with a pleasant term of reign,
perform correctly for me, An,
the rites instituted for kingship,
let him direct the schedules of the gods for me.
Let him offer up to me the things for the New-moon day
and the things for the New Year (festival).
Let him present (?) to me salutations, petitions,
and plaints —
abundance breaking through the earth like grass and herbs,
I have verily (?) added on for him![cclxxii]

In sum, An is heaven, but also the force that brings the world out of Chaos and makes it an organized Cosmos, as he represents the power that ensures obedience to the order laid down in laws and social customs, that is, by the king. And he similarly ensures the maintenance of the laws of physical nature; in short, he guarantees the world-order.

*The god Enlil* is next in rank after An, the name meaning “Lord Wind”. He is the moist spring wind bringing nature back to life. His duty is to enforce the decrees of the assembly of gods. This picture in time took the form of a human administrator ruling over the complexities of the world, making all major decisions. Enlil is simultaneously beneficent and hostile, as of course the wind also is. So he may be the benign zephyr or the destructive storm and, in a passion of fury, send the Flood to destroy mankind. The story of the Flood, much later retaken almost *verbatim* in the Hebrew Bible, is told in the Akkadian myth “The Story of Atrahasïs”, dating to the 3rd millennium. Mankind, created by the gods to relieve them from fatiguing daily work, such as digging irrigation channels or working the ground, multiplied so rapidly and became so noisy that Enlil could get no sleep. Furious, Enlil sends the deluge, but one very wise man, Utanapishtim (the Mesopotamian Noah), advised by Enki (see below) built a large boat, loaded it with his family plus pairs of animals of all kind and, after seven days and nights of flood, was saved to re-start mankind and the animal world. This perplexing temperament, and the intermediate location between sky and earth, gives to this god his specific character, and mankind can never be fully at ease with Enlil, can never know what he may have in mind.

*The goddess Ninhursaga* is, with An and Enlil, the third member in the triad of the most powerful deities. The names of this “Lady of the stony ground”, or “Lady of the foothills” signal her domain: the foothills, rich with trees, plants, metal ores, and wildlife. But she also appears as mother and birth giver, “the Lady who gives birth”, personifying the power of the womb, the power to make embryos grow and to give a distinctive form to the offspring:

Mother Nintur [another name of the goddess], the lady of form giving,
working in a dark place, the womb;
to give birth to kings, to tie on the rightful tiara,
to give birth to lords, to place the crown
  on (their) heads, is in her hands.[cclxxiii]

*The god Enki* (Akkadian *Ea*) is the last divinity we here mention, as he appears as the persistent rival of the reigning triad An, Enlil and Ninhursaga. He personifies the numinous power in the sweet waters in rivers, marshes and rain. He of course personifies the power to fertilize. Further, when water moisturizes clay, it acquires plasticity and the capability to exhibit different forms. So, he is the god of “shaping”, the god of artists and craftsmen. But water also cleanses, and thus Enki is the god of ritual lustration and purification from polluting evil. Purification rites used to purify the king from the evil threatening him during an eclipse resort to his domain. Finally, Enki personified intelligence and knowledge, the image being flowing water avoiding obstacles rather than conquering them, or as water flowing over the field, irrigating it, then trickling away and disappearing.

*Lesser gods.* An, Enlil, Ninhursaga, and Enki are the supreme deities, in charge of making the great existential decisions, “the powers in the principal cosmic elements: the skies above, the storms ruling the atmosphere, the rocky ground, and the flowing fresh waters”[cclxxiv]. Among a second, intermediate tier of lesser gods are: Sin, the power of the moon, Utu/Shamash the power of the sun, Adad, the power in thunder, and the many-sided goddess Innana/Ishtar, manifest in the planet Venus. They are seen as grandchildren and great-grandchildren of An, not matching the main divinities in authority.

### ***The establishment of cosmic order in the* Enûma elish**

Probably composed during the middle of the 2nd millennium BC, the famous ancient Mesopotamian ‘Epic of Creation’, known by its first words in Old Babylonian Akkadian language as *Enûma elish* (‘When above’), narrates the origin of the basic powers in the universe and how the present world-order was established. It consisted originally of six tablets, the longest containing 161 lines, to which later a seventh tablet, a hymn on the divine names, was added. The composition is a product of the priests of Babylon, in which the local god Marduk is glorified as the only deity who was able to defeat Ti’amat, the dragon of Chaos. The poem begins with the description of the primordial watery Chaos, when not even names could be given to anything, the unmistakable sign of complete anarchy:

When heaven above was not (yet even) mentioned,
firm-set earth below called by no name;
(when) but primeval Apsû, their begetter,
and the matrix, Ti'amat—she who gave birth
  to them all—
where mingling their waters in one;
when no bog had formed,
  (and) no island could be found;
when no god whosoever had appeared,
had been named by name,
  had been determined as to (his) lot:
then were gods formed within them.[cclxxv]

In the beginning, only two entities existed: Apsû, the deity of the sweet underground waters and Ti'amat, representing the salt waters of the sea. These waters were mingled in the primeval Chaos, a situation mirrored in Genesis 1, 2: "And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters". The 'deep' (T$^{e}$hom in Hebrew) is etymologically related to the term Ti'amat. As Jacobsen further points out, the *Enûma elish* also "underlies Hesiod's *Theogony*"[cclxxvi].

Of this fascinating poem, which archeologists have found on different tablets in longer or shorter versions, we here only point out two aspects. The epic of creation relates a long and brutal struggle whose final victor is the city-god of Babylon Marduk. At the time of its composition, the city of Babylon became the center of an empire including most of Mesopotamia. No local city-king could be legitimized over a large territory unless this particular city-god was elevated to the supreme place in the divine hierarchy, acquiring the power to decree fates and work miracles, again providing evidence for the close association between the religion-based world order and the political order. Thus the principal goal of the *Enûma elish* is Marduk attaining the position of permanent king of the universe, corresponding to the transition from temporary kingship to permanent kingship in Mesopotamia. On the other hand, it narrates the creation of order replacing the primeval Chaos, and entrusts Marduk, and his earthly representative the king, with the fundamental responsibility of maintaining this order. We here only point out this interesting aspect: After Marduk defeats Ti'amat in violent battle, he splits (divides) this watery deity in two and of one half of the corpse makes the heavens. Note again the resonance in Genesis 1, 6: "And God said: Let there be a firmament in the midst of the waters, and let it divide waters from the waters". We simply mention that the poem continues describing the creation of the universe, of mankind, and of the order that now permanently is presumed to replace Chaos.

"As a view of world order, [*Enûma elish*] is in many ways impressive. It sees the universe as grounded in divine power and divine will: even those wills traditionally felt as older, more authoritative, or hostile, are unified under the leadership of a single ruler who governs through consultation, persuasion, and conviction. It is religiously of great profundity, leading in its picture of Marduk toward aspects of awe and majesty. Moreover, it is intellectually admirable in providing a unifying concept of existence: political order pervades both nature and society. Finally, it is humanely satisfying: ultimate power is not estranged from mankind, but resides in gods in human form who act understandably. The universe is now moral and meaningful and expression of a creative intelligence with valid purpose: order and peace and prosperity" [cclxxvii].

***The preconditions of order: Justice and binding oaths***

Religion is a manifestation of the imperious need for a simplification of the environment. Ancient Mesopotamian religion furnishes the basic ingredients for such an environmental simplification in at least two instances: the king as lawgiver and law-guarantor, and the establishment of the binding oath.

Kings as lawgivers are known from so-called codices, the oldest dating from king Ur-Nammu of Ur (2112-2095). The most famous one, of course, is the impressive stele of king Hammurabi (1792-1750), now in the Louvre[cclxxviii]. This stele was found by the French expedition in 1901 AD in Susa (now in modern Iran) where it had been taken as a trophy by the Elamites after one of their incursions in Babylonia. Fragments of other copies, also on clay tablets, have been found. In the prologue the king refers to himself as "king of righteousness", protector of the weak, the widow and the orphan. Hammurabi set copies of his impressive legal system in many places, calling on all that had a just cause to bring it before the courts, giving assurance that justice will be dispensed. At the top of the stele he appears in submissive attitude before the sun god Shamash, the god who sees everything and is thus the deity of justice. A later tablet of the 8th century illustrates the principles by which rulers are supposed to be guided:

If the king does not heed the law, his people will be destroyed;
his power will pass away.
If he does not heed the law of his land, Ea, the king of destinies,
will judge his fate and cast him to one side.[cclxxix]

The importance of oaths, and their relation to the gods, has already been pointed out. The Hammurabi code implies that no agreement of any kind is valid without a duly attested written record, including the indispensable oath guaranteeing compliance. The religious element enters into these transactions in that the oath is always taken in the name of a god, followed by the description of the terrible punishment awaiting the perjurer, a punishment the invoked god is assumed to guarantee. Further, innumerable boundary stones, recording sales of fields or granting privileges, contain inscriptions that usually conclude with dire curses in the name of the gods for anyone daring to alter the agreement. Likewise, Hammurabi's stele ends cursing anyone attempting to destroy or damage the text. Why are oaths so important? Because otherwise it is impossible to distinguish deceptive from honest signals. As in other animal species, honest signs must be costly lest they turn out to be ineffective. Collectively, trusting the oath - and the automatic divine punishment striking the perjurer - are necessary pre-conditions for the maintenance of the social structure, since by distinguishing honesty from deceit they create the intelligibility necessary for its functioning.

### *Concluding remarks*

Of course, religious beliefs in ancient Mesopotamia were infinitely more complex and rich than suggested here. Nevertheless, these short notices clearly indicate the close relationship between belief and the biological traits causally deriving from the LifeTime model. The ancient inhabitants of the land between the rivers were faced with an incomprehensibly complex physical and sociological environment, and they radically simplified the otherwise unmanageable information stream constantly impinging on their senses, allowing them to function, survive and reproduce. This is precisely what religious beliefs achieve when a community generally embraces them. At that stage, trust-in-order overlaps with trust in the gods and their promise to maintain the overall structure of the world, leading to "order and peace and prosperity"[cclxxx].

# 12. Placebo and Related Phenomena

### The immune system and health

The ubiquity of religious beliefs in human societies and their prominent effects on human existence is more than a mere cultural phenomenon, as there are underlying functional benefits associated with such beliefs (Chapter 11). Thus, in the previous chapter we emphasized the close connection between religion and "feeling well". In this chapter we argue that an important, but sometimes over-looked origin of religious beliefs, and in fact of any psychological state leading to "well being", is its effect on health status and hence fitness. Here, we investigate the role of stress on immune function and health, and the effect of "feeling well" on health status, also in the case when there is no obvious reason why there should be a change in the perception of self. This is the effect of placebo on health status.

The immune system of humans (and other vertebrates) is an incredibly complex system that allows identification and subsequent destruction of foreign living organisms entering and parasitizing individuals. Hence the immune system is a mechanism that allows discrimination between self and non-self and the destruction of any foreign invader. Given that resources are limiting for many organisms, and that plant and animal tissue consists of highly concentrated nutrients, it may be no surprise that more than half of all species are parasitizing others. They live in or on other organisms from which they extract resources for their own benefit for at least part of their life[cclxxxi]. Parasites comprise numerous microorganisms such as virus, bacteria, fungi, and unicellular animals such as those causing malaria, but also many species of parasitic worms such as tapeworms and round worms, blood-sucking mites, and insects such as fleas and lice. Parasites are by definition detrimental to their hosts by their exploitation of resources that could otherwise be used for growth, survival and reproduction. Any potential host that is able to avoid being exploited by debilitating parasites will thus experience an advantage relative to its less fortunate companions. Mechanisms of host defense against parasites include avoidance of becoming infected such as choice of habitats with no or few parasites, the prevention of parasites from entering a host and various mechanisms of parasite removal. Scratching and similar kinds of physical removal of ectoparasites is commonplace in humans and many other animals. A number of primates habitually eat plants with particular pharmacological properties when experiencing the signs of severe parasite infections[cclxxxii]. Chemical compounds of such plants have been shown in tests to have negative effects on parasites, and native humans often use similar plants in traditional medicine. However, the immune system is by far the most sophisticated defense mechanism in humans, but also in other animals.

The immune system consists of the innate part and the so-called cell-mediated part[cclxxxiii]. These components produce a number of different types of cells and chemical substances that are involved in recognizing and subsequently mass producing cells and biochemicals that recognize the surface properties of potential attackers, and thereafter capturing and destroying cells with these properties. Given the immense diversity of microorganisms surrounding us, it is no surprise that the number of different types of immune defense cells circulating in an ordinary human runs into the billions. Once the immune system has experienced contact with a particular breed of parasites, circulating memory cells will allow rapid identification of any subsequent invasion and lead to extremely rapid mass production of defense cells. Hence, any subsequent infection is followed by a secondary immune response that is very fast at neutralizing the invaders.

The immune system is a multi-function device that is able to cope with invasion by an immense diversity of pathogens and parasites because the different cell populations are able to raise fast and efficient defenses to virtually any novel challenge. The immune system by its mere extent is costly to produce and maintain. A different measure of the cost of the immune system comes from studies of autoimmune diseases, which may arise from components of the immune system attacking self rather than invading parasites. Typical autoimmune diseases in humans include multiple sclerosis, juvenile diabetes and rheumatoid arthritis, and similar diseases occur in other organisms. Autoimmune diseases are much more common in women than in men, and women generally have stronger immune defenses than men. Autoimmune diseases are much more common in industrialized societies where the immune system rarely is challenged by a diversity of parasites and pathogens that are characteristic of developing countries and the conditions of human evolutionary past. Hence the immune system of people in industrialized societies may become relatively specialized with particular clones (or types) of white blood cells predominating at the expense of others[cclxxxiv]. Circulating white blood cells are composed of numerous cell clones of similar identity, although the factors determining the abundance of these clones remain unknown. However, recent experiments on mice have shown that the proportion of the different clones shifted in ways consistent with competition among clones for a limiting resource. The final population of white blood cells of a mouse reached ca. 50 millions, independent of whether a single or multiple clones were used[cclxxxv]. These findings suggest that the different clones of white blood cells, which have different functions of recognizing particular kinds of invaders, change in abundance, and that one can only dominate at the cost of another. Such dominance of specific types of immune defense cells increases the risk of attack on self rather than invading microorganisms.

The immune responses of humans and other organisms have strong genetic components with individuals differing in their ability to resist parasites relative to their genetic constitution. This is for example the case for partial resistance to malaria and schistosomiasis. However, just as for any other trait, parasite resistance is not solely a question of genes, but also a question of environmental conditions. Several aspects of immune function are condition-dependent with individuals in prime condition being better able to cope with infections than less fortunate humans. A major component of death caused by relatively benign diseases in developing countries is due to poor nutrition and the resulting weak immune responses. Numerous experiments on non-human animals also testify to the importance of a nutritious diet for the production of an efficient immune response[cclxxxvi].

Most tellingly the immune system has been termed our sixth sense[cclxxxvii]; a most appropriate name given its crucial role in sensing the potentially dangerous entry into the body of alien invaders. Just as the immune system is not isolated from the influence of genes or nutritional status of the individual, so it is not isolated from the general condition and well being of the individual, as shown below. The efficiency of the immune system depends to a high degree upon the mental state of the individual and its ability to cope with stress. Such interactions between mental status and immune function are mediated by biochemicals produced by the immune system and other endocrine organs.

### *Well-being and immuno-competence*

Stress is not a state confined to modern city-dwelling humans. Although numerous definitions of stress exist, many biologists agree on defining stress as the physiological state that results from an incongruence between optimal and experienced living conditions for that particular individual, causing temporary or lasting damage (see Chapters 9 and 10). As conditions deteriorate, the costs of maintenance of normal physiological processes will increase, and a smaller proportion of available energy can be utilized for growth, survival and reproduction. Situations of sub-optimal environmental conditions are commonplace for all living organisms for part or all of their lives, and a number of different coping mechanisms have evolved that adjust the allocation of limiting resources to essential activities that ensure a high survival probability of the individual. Coping mechanisms include the production of so-called heat shock proteins that protect the individual from severe risks of physiological breakdown, and the production and release of stress hormones such as corticosterone that result in increased foraging activity and facilitate allocation of resources to maintenance. Stress also has important effects on immune function by detracting from the resources otherwise allocated to running an efficient immune system[cclxxxviii]. Stressful situations are thus often associated with increased susceptibility to infections. Most humans are familiar with this situation when a particular heavy workload or severe personal problems often seem linked to the acquisition of a cold, influenza and similar kinds of infection.

The immune system is influenced by feedback between mental state and health state. The pattern of connectivity may render interpretations of the possible causal relationships difficult, particularly in humans where experiments are often not possible. However, the feeling of well being either based on the state of self or that induced by an inactive substance, such as a placebo treatment, can directly affect the probability of recovery, as we will discuss further in the remaining parts of this chapter. Some of these effects may act directly through belief and self-deception, as is presumably the case for placebo effects, perhaps mediated by changes in stress status, as indicated by recent studies of the relationship between exposure to music and subsequent immune status.

## *The functional significance of music*

Music plays an important role in all known cultures and has done so for millennia. Primitive instruments date back at least 40,000 years, and the tones of a primitive flute of that age are remarkably similar to those produced by modern instruments[cclxxxix]. The functional significance of music for human beings remains obscure, although the association with festive and religious activities may suggest that music has played a key role in creating or emphasizing particular moods for a very long time. Recently, research has demonstrated that students listening even for only a few minutes to classical music have greater scores in standard intelligence tests than controls without the musical exposure[ccxc]. The direct mechanism for this effect remains to be determined, although a hypothetical one is through improved immune function. This can be inferred from studies showing that parasites may seriously impair the learning ability of children. Administration of anti-worm medicine to children and subsequent tests of learning ability revealed a clear difference between the treatment and the control group that only received the placebo treatment[ccxci]. Hence academic performance of children in school seriously depends on their current health status. Numerous experiments performed on rodents that differ in their parasite infection status have demonstrated equally dramatic differences in learning performance.

Which are the direct mechanisms leading to differences in performance in standard intelligence tests associated with exposure to music? Music can have beneficial effects on immune function and hence potentially ward off infection. A study by Francis Brennan and Carl Charnetski exposed volunteers to 30 minutes of muzak (so-called elevator music), jazz, clicking or other noises, or simply 30 minutes of silence[ccxcii]. The circulating level of immunoglobulin A (an important protein involved in the immune response of humans to ward off infections) was tested before and after exposure. Volunteers that listened to muzak or jazz experienced significant increases in immunoglobulin levels of on average 14% and 7%, respectively. Controls that were just exposed to silence demonstrated no change, while the immunoglobulin levels of volunteers exposed to noises plummeted on average by a staggering 20%. Such effects are likely to be mediated through the influence of sounds on the perceived level of stress. Hence, relaxing music may not only make people feel good, but can readily improve their immune function, perhaps by modulating their levels of stress.

There may be other aspects of music further influencing well being. Seemingly they result from associating the musical experience with the essential order-structure always assumed to be in place, and whose absence is a major factor of stress. Clearly, when past experiences cease to be meaningful in present circumstances, a crisis originates, leading to tremor and anguish, i.e., to stress.

### *Placebo effects*

Placebo is a Latin term for the medicine-like control treatment containing a physiologically inactive substance such as calcium that is used in tests of the efficiency of new types of medicine. The use of a placebo treatment and a real medical treatment in a double blind design allows distinction between true pharmacological effects and psychological effects. Obviously, the reason for having double blind tests in the first place is that the human mind can be trusted to supply the “facts” that would tend to support the hypothesis, even when there was no real evidence for any effects. Interestingly, comparison of the health status of volunteers receiving the placebo treatment and those receiving none at all often differ dramatically, with purely psychological effects causing an improvement in health status[ccxciii]. Unfortunately, many medical experiments do not contain a second control group receiving no treatment at all that would allow a stringent comparison of the effect of treatment with a completely inactive substance and no treatment whatsoever.

Until quite recently, all medical activity by humans must have been in the main based on placebo effects simply because doctors had little effective medicine to offer. An exception is the use of medicinal plants and other substances that appear to be used in connection with certain diseases and infections in other primates and even in mammals outside the primates[ccxciv]. Perhaps more surprising is the observation that American doctors through the 1940’s handed out sugar pills in various shapes and colors, apparently in an attempt to induce placebo responses in their patients. The literature on placebo effects is extensive although it is only relatively recently that scientists have started to gain a scientific interest in the placebo effect as such. Hence, placebo has changed status from a pure control treatment to a potential treatment of its own.

In this section, we will present a few examples to illustrate the effects that pure placebo may have on the recovery of patients, but there exist innumerably more examples than those reported here. A study of arthroscopic knee surgery in which patients with sore, worn knees were subject to either scraping out the knee joint, washing out the joint or doing nothing except from a placebo treatment demonstrate surprising effects. Patients that received the placebo treatment were also anesthetized, received three little cuts in the knee as if to insert the instruments used in the two other kinds of treatment and the medical doctors then pretended to operate. Two years after surgery, all three groups of patients reported significant relief of pain and swelling, and surprisingly patients that underwent the sham operation had improved just as much as patients receiving the real treatments[ccxcv].

Placebo treatment also appears often to have strong effects as causing pain relief. Treatment of depression with modern anti-depressant drugs and placebos has recently been suggested to be about equally effective by a review conducted by Irving Kirsch[ccxcvi]. The purely mental nature of conditions was equally clear in a study of non-orgasmic women by Eileen Palace[ccxcvii]. Placebo was used as a direct treatment to restore sexual arousal. The patients were connected to a biofeedback machine that they were told measured the blood flow of their vagina, which is an index of sexual arousal. The women were then shown sexual visual stimuli that are known to arouse most women, but had no effect on the patients. The experimenter played a trick on the women by sending within 30 seconds a false feedback signal showing that their vaginal blood flow had increased, while in actual fact there was no change whatsoever. Almost immediately upon hearing about this “false” response, the women became genuinely aroused.

Placebos were originally thought to work through the release of endorphins which often are likened to the body’s own, natural morphine-like substances. However, this does not appear to be the sole explanation. An additional reason why placebos can work appears to be explained by expectancy theory, which is part of cognitive psychology. This theory concerns what the brain believes to happen in the immediate future and the effects of this belief on changes in physiological state. Expectancy involves associative learning by conditioning similar to the treatment of Pavlov's famous dogs when hearing the sound of a bell (see Chapter 7). The medical treatment that humans receive during life can be likened to conditioning trials. The doctor's white coat, the voice of a caring person, the smell of a hospital or a practice, the prick of a syringe or the swallowing of a pill have all acquired a specific meaning through previous experience, leading to an expectation of pain relief. Similar effects may work just as well through experience with medicine men or others who are known in a particular culture to be responsible for curing ailments. Although most treatments by medical doctors in the Western world are associated with active biochemicals or other components, if a patient receives a pill without any active substance, he may still experience the therapeutic effect. However, the strength and persistence of placebo effects that often occur almost immediately, with no conscious record of the associated events, suggest that they be directly wired into the brain.

The general finding of beneficial effects of placebo controls, which is prevalent in much of the pharmacological literature is consistent with mental state and belief being sufficient to significantly improve health status. Thus the Latin meaning of the word placebo, which is "I shall please", is much closer to the real effect of the treatment than one might have imagined!

### *Placebo, self-deception and belief*

Placebo appears to be more than a curiosity of experimental design in pharmacology, but rather a very general demonstration of the importance of beliefs for human well being. This also puts placebo effects and religious beliefs (Chapter 11) into a completely different perspective, simply because the presence of strong beliefs can have important consequences for health and hence for the probability of survival and reproduction.

The persistently strong effects of placebo that we have discussed earlier in this chapter can arise from expectations about certain events happening in particular contexts, based on previous conditioning. If the remission of pain or other signs of poor condition is so forcefully achieved through placebo treatment, we can wonder whether strong beliefs in general will cause an increase in health status. Several medical studies have investigated the relationship between strong religious belief and health. These studies tend to support the prediction that the two are closely associated. For example, a recent study in North Carolina found that individuals who participated in religious activities were 40% less likely to have high blood pressure than matched controls[ccxcviii]. Similarly, humans that are strong believers also tend to be less frequently depressed, have stronger immune responses and to deal better with addictions than non-religious controls[ccxcix].

Humans like individuals of any other organism may be closer to or more distant from the optimum environmental conditions for survival and reproduction. Believing being close to such optimal conditions through self-deception may be experienced as resulting in a feeling of well being. The mental state associated with conditions of plenty is “feeling well” and having the ability to cope, while adverse conditions result in an experience of the opposite. Human self-deception distorts reality and the memory thereof by emphasizing the good times and diminishing the bad ones (see Chapter 13). Furthermore, the previous discussion of placebo effects with their almost instant nature of pain relief suggests that self-deception plays an important role in maintaining a state of “well-being”, even when reality may look far from ideal. Placebo-related phenomena and religious beliefs can be considered ways in which such mental states of plenty at least partially are achieved. Belief may subsequently have an effect on the possibility of achieving such states of plenty, indirectly through the effects on immune function and health status, and more directly on the actions taken to achieve and maintain such states.

Coherent with the LifeTime model, we suggest that the “feel-good” factor, the placebo effect and the ubiquitous religious beliefs all arise as a direct consequence of individuals achieving a superior physiological state by having an experience *as if* being closer to optimal conditions than is actually the case.

## ***Concluding remarks***

The effects of mental status on general health are not necessarily confined to humans. Many studies have shown that parasite infections are closely associated with dominance rank, low ranking individuals suffering disproportionately from poor health[ccc]. Although these studies generally have been interpreted as suggesting that stressful conditions accompany sub-ordinate social status, the alternative interpretation is that the mental status of individuals directly affects their immune status and hence their risk of contracting serious parasitic infections.

We have described the association between environmental conditions, immune function and health status by arguing for a direct, strong effect. Stress, which reflects a deficit in condition relative to a hypothetical optimum, generally has immuno-suppressive effects and thus can cause a deterioration of health. Placebo effects, which turn out to have strong impact on well being, may arise as a consequence of endorphin release and associative learning arising by conditioning. The strength and persistence of placebo effects, which are based on expectancy of what will happen in the immediate future, suggest that the responses are firmly wired into the brain. Mental qualities such as a strong belief in medicinal practitioners, but potentially also in other superiors with "power", and the effects of such a belief structure on immune function, should enhance abilities to cope with the near future, in particular under adverse environmental conditions. The future-orientation of these mental mechanisms of coping with disease, pain and other adverse conditions are consistent with the LifeTime scenario.

# 13.Self-deception

### *What is self-deception?*

In the preceding chapters, certain human and animal behaviors directly emanating from the LifeTime model were analyzed. Here, another phenomenon that is predicted by the LifeTime model is scrutinized: Self-deception. We recapitulate that the LifeTime model unifies in a structural whole four basic elements. (1) Life, the planet-wide phenomenon; (2) Time, in the future not-yet sense; (3) Algorithm, by which environmental information is processed in view of optimizing reproductive success as compared with “the others”; and (4) trust-in-order, an information-theoretic feature encompassing a filter of information that simplifies the ‘world’ and, based on the filtered information, determines the magnitude of the deficit from the hypothetical optimum as pertinent for that particular individual. These features appear as clearly discernible in animals such as the barn swallow, as shown in Chapter 9. Thus, barn swallows compete for territories and mates, members of a monogamous pair compete for reducing their share of costly biparental care, males guard ‘unfaithful’ mates, and unmated males recur to commit infanticide to enhance their reproductive success. All this apparently without ever reaching ‘conscious awareness’: As LifeTime-forms, swallows, under the control of the LifeTime Algorithm simply act out the LifeTime script.

The main difference between barn swallows and humans lies in the fact that humans may become, at least in part, consciously aware of their deficit in a particular situation. A perceived discrepancy between actual state and the optimum that maximizes growth, survival and reproduction may cause stress-induced immuno-suppression[ccci]. In the LifeTime scenario, an inferior position is assessed as an alarm signal that elicits an enhanced effort in agreement with the Algorithm. However, unless this alarm signal is of short duration, its permanence will result in severe stress. Consequently, diverse coping-mechanisms have evolved, allowing individuals to optimize their reproductive success even when faced with adverse conditions. Here, we propose that self-deception is such a mechanism.

Self-deception is the mechanism by which humans deceptively distort or mask information about their own true status to obtain an advantage in competition for limiting resources. This mechanism effectively enhances fitness of the self-deceiving individual. This fitness enhancement is directly correlated with the superior social position that an individual may achieve by masking his true status for others. What in the first place has led to the evolution of self-deception in humans, and in all likelihood also in other animals, is the ubiquity of deception commonly found in all biological systems[cccii].

Humans never consistently achieve optimal conditions. A permanent deficit is thus a constant fact of life. The larger the consciously perceived deficit, the more pernicious is the stress induced by this unavoidable and inescapable situation. The LifeTime model predicts that a behavior masking the conscious awareness of this deficit will be selectively favored (1) if it relieves the otherwise severely fitness reducing stress. It will also be favored (2) if it enhances social status relative to “the others” by better deceiving them, thereby leading to individual gains in social and sexual competition. This behavior is what is called self-deception. Thus, self-deception refers exclusively to the sham deficit-reducing, stress-relieving mechanism operating in a particular individual in a social context.

Self-deception reflects the deceptive behavior towards self to enhance fitness by hiding the fact that self is deceiving. Hence self-deception relates to fitness domains such as sexual and social competition where individuals exaggerate and perform other self-deceptive activities so as to enhance their fitness at the expense of others with less developed self-deceptive faculties. Self-deception is a natural extension of mind reading, or actually being mind read, since self-deception hides for self and thus also for others (but does so in an exaggerated way) what are the status and the qualities of self. Self-deception as we know it is an entirely human phenomenon, although there are no reasons to believe that similar phenomena may not also occur in other animals, as we will argue later in this chapter.

Self-deception refers to the hiding of the truth from conscious awareness to facilitate hiding it from others. Conscious awareness of attempted deception is reflected in particular modes of voice, sweaty hands and similar behaviors that form the basis for the ability of the lie-detector to reveal cases of deception. Such signs of deception can become completely hidden if the deceiver is unconscious of his deception. In other words, the nervous behavior associated with conscious cases of deception is completely eliminated. Cases of self-deception do not include evident cases of deception, but cases where the true motivation for a particular act is hidden for the deceiver and thereby for others. Hence deceivers may upon challenge of their “true” motives by others reveal convincing alternative explanations that are immediately available. Such examples include well-known excuses for most people: “It was not my intention, since I thought that ...”. The true extent of self-deception and its role in human evolution remains obscure although Robert Trivers has suggested that the advent of language greatly increased the possibilities of deception and self-deception[2]. The ability to use sophisticated language allows humans to deceive others in a number of different ways because information about events distant in time and space cannot readily be controlled. This is already clearly illustrated by the first written accounts of human activities on ancient Mesopotamian clay tablets, where curses and oaths are common ingredients of any commercial transaction (see Chapter 11.2). Although these curses and oaths implied that the gods would interfere in case the contract did not materialize, the mere fact that the curses and oaths were included in these contracts implies that contracts were not fulfilled in all cases. The evolution of abilities to pay particular attention to pieces of potentially deceptive vocal communication in humans must have accompanied the early evolution of language, and this in turn must have facilitated mechanisms such as the ability of signalers to conceal such information from self and thereby from others.

Examples of self-deception are commonplace in human social contexts, exaggeration providing a well-known case; repeated tales of accomplishments becoming exaggerated almost by default. A famous example concerns the Indian rope trick during which an adult man is playing a flute, which results in a rope rising into free air. A small boy suddenly appears, climbs the rope and disappears into free air. Many accounts of this trick have been reported, although none have been verified on photographs, video or just by known eyewitnesses. If self-deception is playing a role in reports of the Indian rope trick, we should expect that old accounts should be more exaggerated. Indeed, that appears to be the case according to an investigation by Wiseman and Lamont of the 21 reported cases[ccciii]. While more recent cases involve reports of the rope rising and the boy climbing, older cases concern the boy disappearing in free air and subsequently turning up by the side of the flute player.

### *How to identify self-deception*

Self-deception involves the simultaneous maintenance of truth and distorted reality in the mind of an individual. Hence there is basis for an almost split and schizophrenic mind, with separate private and public parts that interact in complicated ways. Self-deception thus leads to the evolution of entire belief systems with self-serving biases that are hidden from both self and others to make it more difficult to counter them. How can we identify self-deception? A remarkable example of self-deception is presented by Ruben Gur and Harold Sackeim of physiological responses of humans upon hearing a human voice[ccciv]. Gur and Sackeim suggested that three criteria must be fulfilled to allow a behavior to qualify as self-deception: (1) True and false information is stored in the same person. (2) The false information is stored in the conscious mind, while the true information is stored unconsciously, thereby keeping information away from the conscious mind. (3) Self-deception is motivated with reference to others. We adopt this definition of self-deception in this chapter.

Gur and Sackeim measured the galvanic skin response, which is a physiological measure of skin potential. A person usually responds more strongly to hearing his own voice compared to that of others, with the reaction to own voice increasing the longer one listens, while the opposite is the case for the voice of somebody else. The galvanic skin response provides a measure of *unconscious* self-recognition, while self-reporting of whether an individual just heard his own voice or that of somebody else provides information on *conscious* self-recognition. A number of people were tested for self-recognition, and subjects fell into four different categories: (1) Individuals that made no mistakes. (2) Individuals that denied their own voice some of the time. (3) Individuals that projected on somebody else their own voice some of the time. (4) Individuals that both denied their own voice some of the time and that projected their own voice some of the time. When the physiological galvanic skin response was recorded, it turned out that the skin and hence the unconscious mind knew better than the conscious mind. Subjects denying their own voice showed a strong physiological skin response. Subjects projecting their own voice showed the weak skin response typical of hearing the voice of somebody else. For most mistakes it was obvious that the part of the brain that controlled speech and hence consciously communicated the origin of the voice had it wrong, while the unconscious part controlling the skin had it right. Thus contradictory information is stored in the brain, as required by the first criterion for documentation of self-deception. Furthermore, the second criterion was fulfilled because subjects were conscious of their verbal assessment, but not of the physiological skin response. The third requirement is that the errors made should be motivated with respect to others. This was also the case since those who projected themselves onto somebody else's voice were those who spent more time in front of mirrors and listened more to their own voice, as reported in a questionnaire. Humans that have succeeded in a task are more likely to project themselves onto others, while those who have failed tend to do the opposite by shrinking the presentation of self, albeit being unconscious of this process. The direct benefits of self-deception seem obvious from these findings. Self-deception will promote a state of induced well being that will allow an individual to cope with difficult situations. Furthermore, any success achieved by these means will tend to result in self-deceptive individuals projecting themselves onto others, thereby preparing the ground for further self-deception. In other words, self-deception will appear to be a self-reinforcing process.

### *Categories of self-deception*

Self-deception comes in a frighteningly large number of disguises. This should be no surprise given that humans have been perfecting hidden belief systems for themselves and others for millennia, with only the most ingenious cases of self-deception not being countered. The most exaggerated animal and plant signals have evolved in social contexts of conflict such as that between potential mates, between parents and offspring, and between predators and prey. The great diversity of signals and the incredible intricacy of design of these signals bear direct testimony to the high level of conflict. Psychologists have classified the different kinds of self-deception into a number of categories, and we follow one of these categorizations of self-deception in the following exposé of the various facets of human self-deceptive strategies[cccv].

Humans have a prominent tendency to present themselves as beneficial and effective in the eyes of others, thereby appearing *beneffective*. In general, humans tend to exaggerate their own role when something turns out in a beneficial way, while habitually denying any personal responsibility for harm or even that a certain act of was clearly harmful. Beneffectance is ubiquitous in human activity. It provides the basis for quarrels between car drivers involved in accidents: "You hit me because you entered the main road without first paying attention!" "My view was obstructed by an illegally parked car, and my car therefore entered the main road very slowly and carefully." The tendency to deny responsibility for harm done to others is often emphasized by a switch from an active to a passive voice, while own accomplishments are emphasized by the use of an active voice. No wonder that the police requires assessment of these kinds of situations from witnesses that are not directly involved in order to be able to determine what really happened.

A second kind of self-deception is the ubiquitous tendency to *exaggerate*. We already mentioned above the case of the Indian rope trick. Re-telling of humanitarian acts particularly if involving kin or clan members invariably leads to exaggeration, with memory slipping in a particular direction, seemingly based on a preference for exaggerated stories by the story teller and the listener as well. The common and banal aspects of life that are found everywhere are not the kinds of events that will keep an audience listening. Historians, journalists and others habitually handling human reports of accounts are engaged in an uphill struggle against the self-assembling cover of such exaggeration accumulating like geological sediments. The truth can often only be approached by carefully removing layer after layer of exaggeration. Exaggeration, in particular when self and close associates are involved, appears to be a ubiquitous human characteristic that generally improves the perception of self by others. This must have been the driving force in the first place. Obviously, such exaggeration is habitually completely unconscious. If audiences, be they one person or many, continually are exposed to tales of exaggerated achievements, this will give rise to a certain level of skepticism on the part of receivers. Perception of tales will often be based on filters that tend to devalue exaggerated stories. Hence, competition among individuals will select for an increase in exaggeration, just to allow to be heard, but given that tales are more or less automatically devalued, a certain equilibrium level of exaggeration will be an automatic consequence. However, given the ubiquity of exaggeration, biased twists to tales of self-accomplishment and humanitarian acts of associates must have had and still have clearly enhancing effects on the social status of persons involved.

If people continuously deceive themselves into believing that their own role in humanitarian or personal acts is better than it really is, while the role of others is diminished, this will require continuous *rewriting of the past* to ensure a superficial illusion of consistency. A notorious example is the way in which politicians continuously change their mind and only persistent digging and exposure of often contradictory statements by journalists reveals the true extent of the level of self-deception. These behavioral patterns are probably no more exaggerated in politicians than in other humans. They only become very obvious when exposed in a newspaper or on television. Often humans will rewrite their past in a way that adds details to information that is currently being presented. Examples from psychology experiments[5] demonstrate that humans habitually alter their memory of others, in particular if the new information is personal and derogatory. Memory can be counted on to supply new pieces of evidence for current information; "new" memories automatically appear out of the blue. This illusion of consistency of the past must have evolved in a context where the assumed role and achievements of self was difficult to harmonize with a derogatory reality. Exaggerated versions of self-accomplishment led to success and such success and leadership was cemented by an imaginative memory.

The *perception of human relationships,* that being married couples, friends or colleagues, is fraught with self-deception. When such relationships are strained during incidents of disagreement, there is a dramatic asymmetry in the perception of self and others. Both believe that one is an altruist, while the other part of the relationship exhibits extreme, perpetually recurring selfishness. They only disagree over who is altruist and who is egoist. Such biased views of human relationships are put no more succinctly than in the Bible by the statement that we always see the splinter in the eye of a brother, but not the beam in our own![cccvi] Again, this type of self-deception relates directly to a past evolutionary history of frequent deception, with not even the most angel-like persons passing the test of scrutiny by close friends!

Humans habitually see what they want to see. Numerous prime examples of such *perceptual bias* exist. People continuously tell about "the good old days", easily forgetting the bad sides of the story. Perceptual defense is no more persistent than when self is involved. Humans need much more information to be able to see the negative sides of their own activities, while positive sides are readily perceived at the slightest hint. This occurs in everyday life as well as in experimental manipulations performed by psychologists[cccvii]. An associated human behavior termed perceptual vigilance refers to the perpetual assessment of any fact being presented with respect to self. It is just as if self is a professional lawyer continuously building a legal case to prove that self is beneffective, altruistic, helpful to others, and rarely selfish and harmful. Again, self-deceptive perceptual defense and perceptual vigilance relate directly to the continuous assessment of humans by others for signs of deception and the relative standing of self in the local community.

Self-deception has only been studied in humans, but may also occur in other organisms, as suggested by Robert Trivers. The reason for this expectation is that individuals of non-human animals often find themselves in extremely tense and stressful situations, being closely scrutinized by opponents or interactors for signs of cheating. Although signals often are assumed to be reliable indicators of the qualities of individuals because signals are costly, but more so for low than for high quality individuals, there is ample scope for cheating and deception. As long as signals on average are reliable, with occasional cheating, it will pay receivers to respond to signals as if they were revealing the qualities of signalers. Any ability on behalf of signalers to act in a self-confident way independent of the inherent true underlying quality may have important fitness payoffs. A male that is evaluated by a female that he has courted, or by an opponent that he is currently facing off, will have a greater chance of giving a convincing image of his high self-esteem with a certain level of self-deception. This will be the case as long as this does not become seriously incongruent with the faculties of that individual. Hence we may expect that self-confidence is just another quality of signalers, being expressed in its most extreme form by individuals of the highest underlying quality. In other words, the reason for self-deception being exaggerated and being effective in signaling contexts is that it can be viewed as a second layer of signaling in its own right. Self-deception neither implies nor requires “self-consciousness”, as some readers might expect from previous descriptions of self-deception in humans. The only requirement is that the behavior of an individual may reflect directly its true underlying qualities or faculties, or alternatively these qualities being superimposed by features of high self-esteem or similar kinds of self-assertive behavior.

### *The function of self-deception*

The function of self-deception seems clear as long as it provides an advantage to the individual by hiding important information about the qualities of self from self. Although no formal analyses have been made of the occurrence and magnitude of self-deception in different social contexts, it seems likely that these mainly relate directly to significant fitness domains: Deception and self-deception are more likely in contexts where major gains can be achieved. Hence sexual and social contexts appear to be the main breeding grounds for self-deception. This also explains the fact that self-deception and many of its signs appear to be much more common among men than women, since men are involved in much more severe sexual and social competition than women. Men boast much more than women and men appear to be more beneffective than women.

The conflict of sexual interest between males and females in many species (including humans) has been likened to a salesman (a male) attempting to provide an offer that a customer (a female) cannot refuse. The evolutionary reason for the allocation of these roles in the first place is that females in general will benefit very little from copulating with additional males. A copulation with any additional male carry few benefits in terms of quality or quantity of offspring produced, but potentially many costs in terms of venereal diseases, waste of time and risk of abuse. Males, on the other hand, will continuously be able to increase their reproductive success as the number of sexual partners increases. Hence females will tend to be reluctant to accept an approach by a male because “the true interests” of the male are not obvious (or too obvious!). Males will tend to be persistent because males that are generally more persistent will be more successful, particularly if females evaluate male quality from persistence. Interactions between the salesmanship of men and the sales resistance of women in sexual contexts include the continuous exaggeration of the achievements and qualities of self by men and the devaluation of these signals by women. Men will invariably appear to present themselves as better, more intelligent and wittier than their competitors. They appear not to be promoting their own qualities directly, but mainly doing so indirectly through the context of social interactions and the statements of other, presumably more objective persons; the only problem being that these statements and their generally positive stance cannot readily be controlled. Evolutionary interpretations of beneficence, chivalry, bravery and good citizenship suggest that such apparent aspects of altruistic behavior often appear to be used in a social context to impress others[cccviii]. Even the famous example of the hero Mr. Darcy in Jane Austen's novel "Pride and Prejudice" leaves a small sign of his beneficence so that his love Elisabeth will notice his superior character[cccix]. If this had been a true case of altruism, there should have been no reason to notify anybody else of this apparent act of chivalry in the first place! Apparent acts of altruism may benefit the actor, as demonstrated by an experiment on charity conducted by Claus Wedekind and Manfred Milinski[cccx]. Seventy-nine students were enrolled by giving them a pot of imaginary money. They could donate one or two francs to individuals whose record of donation was known to them. The experimenters added an additional four francs to the money received from each donation. In the experiment students could therefore increase their fortune by building on the assistance of others. The students only knew the 'charity score' of each individual, which increased by one point when donating money, but decreased by one point when not doing so. However, the students did not know whether a potential receiver had helped them earlier on in the game. Intriguingly, students with high charity scores were more likely to receive money from other participants, and this was independent of whether or not they had previously helped their helpers earlier on in the game. In other words, there was a net benefit of being generous.

Given that human pre-history and history consist of a long line of social interactions and alliances associated with competition for limiting resources and social status, it seems likely that self-deception has played a crucial role in forming and maintaining such social relationships. Dominance relationships caused by differences in social status may be cemented by unconscious acts of self-deception on behalf of both the dominant and the subordinate interactor. Robert Trivers and Huey Newton provided a very detailed analysis of an example of such a dominance relationship and the associated self-deception by the two interactors[cccxi]. This example concerns the infamous case of flight 90 from Chicago to Tampa on 13th January 1982, based on an analysis of the tape recordings from the black box. This flight ended in complete disaster killing all 78 passengers and the pilot and co-pilot. Weather conditions were bad even for winter with an extremely icy runway, and the vested interests of pilot and co-pilot in the flight apparently differed considerably. While the co-pilot was relatively young and inexperienced, the pilot had, besides his higher rank, also considerable experience and the associated higher social status. When the take-off was being planned and executed, this dominance relationship between the two pilots was obvious from their conversation. The pilot apparently fooled himself (i. e., deceived himself) into believing that the weather was not too bad for the flight, while the co-pilot was overall more realistic about the entire enterprise. The pilot reported no ice and snow on the wings before take-off, while the co-pilot tended to view the situation slightly differently by emphasizing the greater amount of snow and ice of a thickness of a quarter to half an inch covering the entire wing. It was only when the pilot realized the problems of gaining lift during take-off after passing the time limit for aborting the flight, and the co-pilot expressed this explicitly, thereby causing the pilot to leave his state of self-deception, that both realized their grave situation. At this stage, the airplane had started to lose height and the disaster was imminent. Just a few moments later the plane crashed without ever reaching any important altitude.

With this example in mind, how can we explain the evolution and the maintenance of such apparently maladaptive behavior? Self-deception in the context of both the building of a sexual relationship and the interaction between individuals differing in dominance status may have been generally beneficial during much of human evolutionary history. The function of self-deception can be viewed as a way of acting without this action reaching conscious awareness, so that the perception of self by others is improved because the level of deception is hidden for self to better hide it from others. In other words, self-deception may act as a way of achieving important gains such as establishing a sexual or social relationship that may have important future payoffs in terms of fitness. The use of deception in social contexts must have been difficult (and increasingly difficult as mental abilities increased during evolutionary time) due to the ability of receivers to scrutinize others for signs of nervousness and similar revealing types of behavior. Hence, any behavior that could be hidden from self in the unconscious mind that would allow self to appear as more beneficial, altruistic or of higher moral standing would be at a selective advantage.

Self-deception may also have been an important means for humans to act as coherent groups. The roles of different group participants relative to their social status may have been facilitated by self-deception because the immediate benefits of such cooperation is not necessarily evident for any of the participants, neither from the perspective of the dominant nor from the perspective of the subordinate participant. Why should the dominant individual allow the subordinates to take a share of the resources, and why should the subordinates participate in a particular dangerous act, when not receiving their fair share? The evolution and the maintenance of cooperation is facilitated by participants increasing their stakes relative to what has been offered by the other party[cccxii], and such an increase in stakes may have been impossible, or less likely, if the true roles of participants had been honestly revealed and perceived. The immense stress experienced by individuals of a group attempting to achieve a very difficult task, such a killing a large prey or winning a fight with a superior enemy could only have been facilitated by self-deception by the group leader. He may not have been perceived as convincing by band members if being reliably conscious of his own faculties. Also self-deception may have been beneficial on behalf of the subordinate participants, who may have acted differently only because they experienced a deceptive view of their own abilities, those of their leader and those of the enemy. Thus tasks that could only be achieved with great difficulty by individuals consciously aware of their actions may often have been facilitated by a certain level of self-deception, given that this did not lead to disastrous over-optimism such as that experienced by the pilots of the Chicago flight.

Self-deception may finally have played an important role in coping with adversaries of life in terms of physical and psychological pain. Individual humans differ considerably in their ability to sustain pain, and such differences may be important during recovery from illness and surgery (or wounds), but also in production of cognitive coping mechanisms. A study by Jamner and Schwartz[cccxiii] assessed the level of self-deception among 64 subjects using a standard personality inventory, and the individuals were subsequently classified as high, medium and low self-deceptors. Levels of perception and judgment of pain were subsequently determined using electrocutaneous stimulation applied to the forearm. The minimum level of perceivable pain was the same in the three groups of subject. However, there was a large difference in the ability to cope with pain. High deceptors were consistently superior in tolerating pain than low self-deceptors. Similarly, the pain threshold was on average more than twice as high for high than for low self-deceptors. Finally, discomfort associated with pain was twice as low for subjects categorized as high as compared to low self-deceptors. The fitness benefits of self-deception being associated with ability to sustain pain may seem very obvious: Being able to cope even in the presence of a severe wound may mean the difference between life and death.

Depression is a very common disease that affects a large number of humans in industrialized societies, and immense losses are incurred in terms of both individual suffering and economic loss. In particular women suffer from depression to a higher degree than men do, but the reason for this gender difference in disease prevalence remains unknown. The causes of depression are not clear, although attempts to interpret depression from an evolutionary perspective suggest that it is linked to the often dramatic incongruence between personal abilities and the potential achievements that could be made by individuals living in the global village[cccxiv]. Today every young human living in the industrialized world is confronted with global achievements in sports, arts, science, and business, while the human psychology has evolved in small groups of perhaps a few dozen individuals, in which everybody potentially could be considered valuable individuals with useful skills of general usefulness. Consistent with this suggestion, several studies have investigated the relationship between severity of depression as measured by the Beck Depression Inventory and a measure of the level of self-deception. Interestingly, a negative relationship has consistently been found, suggesting that it is the non-depressed humans that have a more distorted view of reality[cccxv]. In other words, individual humans with a realistic view of the world and its problems run a higher risk of becoming depressed because of the frightening facts of the human condition. A self-deceptive view of the world is distorted, but in such a way that it is bearable for the individual. This also raises a possible explanation for the higher frequency of depression in women as compared to men. If men have evolved a higher degree of self-deception associated with their more intense sexual and social competition, men may have become less susceptible to the depressing facts of life than women. Hence, it is the smoke screen of self-deception that renders men relatively immune to depression, while the lower level of self-deception in women directly gives rise to a realistic view of the world and the depressing inferiority of self relative to the potential optimum. Humans habitually have a more or less intense level of inner speech by which the individual assesses and evaluates the world and thereby potentially mediates self-consciousness[cccxvi]. Depressed humans with an undistorted view of reality have a high level of inner speech, while non-depressed individuals with a distorted, self-deceptive view of the world have little inner speech[15].

If self-deception is a common means by which humans achieve various benefits, why do not others more readily identify cases of self-deception? Occasionally, a person may discover that he was misled into a situation of believing somebody who upon close scrutiny turned out to be a deceiver, mainly because of the efficiency of self-deception. While the behavior and the faculties of that individual in actual fact may have remained unchanged during a long-lasting social interaction, the revelation of deceit may only have come by as a consequence of self-deception on the part of the person being deceived coming to an end. Why is it the case that people let themselves be cheated over and over again? Miracle men can promise wonderful solutions to complex problems that ordinary people cannot solve even with their most whole-hearted efforts, and humans readily accept such miracle solutions over and over again. Belief in miracle solutions testifies to the extreme efficiency of self-deception as a means of gaining an edge in a difficult situation of social or sexual competition. We suggest that the beneficial effects of self-deception in social interactions for gaining increased status or limiting resources by far outweigh the costs of deceiving self. Furthermore, the beneficial effects of self-deception in terms of the ability to sustain physical and psychological pain may render certain humans better able to cope with the hardships of their existence.

## *Concluding remarks*

Self-deception is a ubiquitous human behavior that penetrates all social and sexual interactions, as shown by the examples discussed above. It has mainly evolved in the context of social and sexual competition. Self-deception is more than an idiosyncratic subject of social and evolutionary psychology because it may have tremendous influence on the achievements of individuals and their ability to cope with the harshness and the deficits of their existence.

This chapter has mainly dealt with self-deception in its own right, but it also plays an important role in understanding the phenomena investigated in Chapters 10, 11 and 12. For example, self-deception makes individuals believe that things are better than they actually are. This relates directly to the effects of well being on immune function and health status. Similarly, self-deception plays an equally crucial role in understanding placebo and self-healing. Such effects can only arise in a context where self is unconscious about the actual mechanisms at work. The role of self-deception in religion is certainly no less than in any of the previously mentioned contexts. Finally, the general perception by humans of their "true" status in their particular social context is masked by a smoke screen of self-deceptive phenomena that include hope, love, nationalism, racism and many others. These different phenomena obviously interact in a number of intricate, synergistic ways.

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This chapter on self-deception ends our tests of the LifeTime scenario. We have analyzed the mechanisms of social and sexual competition as an evolutionary force in barn swallows and humans and how this relates to the concept of LifeTime (Chapter 9). The role of religion in human society and the mechanisms that have given rise to religious beliefs were related to the LifeTime concept in Chapter 11. The beneficial effects of placebo and belief in maintaining health and hence providing an advantage in social competition was discussed at length in Chapter 12. The role of self-deception in human existence was treated in Chapter 13. We consider that the last four chapters support our claims about the LifeTime concept. They show ways in which the LifeTime concept has affected the evolution of mechanisms that relate directly to the irreversible arrow of time, the ubiquitous discrepancy between actual and optimal conditions for growth, survival and reproduction, and the resultant perpetual competition for social status and limiting resources.

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[i] The classical study still is E. Rohde, *Psyche*, 2nd ed. 1898, reprinted by Wissenschaftliche Buchgesellschaft, Darmstadt (1980).

[ii] To avoid a frequent confusion, we remind that the split between brain and mind introduced by Descartes required connecting the appearances of the external world (phenomena) with their internal, mental, representation. Thus, Descartes was led to redefine the term "idea" as (conscious) mental representation.

Previously, “idea” was used in the entirely different sense of Plato’s “theory of ideas”, where “idea” stands for an immutable perfect form such as the good, beauty, and others.

[iii] *[...] sed quid clare et evidenter possimus intueri, vel certo deducere, quaraendum est; non aliter enim scientia acquiritur.* Descartes, *Regulae ad directionem ingenii, Regula III* (published posthumously in 1701). Loosely translated: “...no other way to acquire [the kind of knowledge called] science [is possible] except from what can [initially] be perceived as clear and evident, or deduced from it with certainty.”

[iv] A conclusion concordant with Aristotle’s view expressed in *Posterior Analytics* 100b.

[v] The author of the ‘ontological argument’ for the existence of God was (Saint) Anselm, Archbishop of Canterbury (1033-1109).

[vi] But already anticipated in Plato’s *Timaeus*. See L. Brisson & F.W.Meyerstein, *Inventing the Universe*, State University of New York Press, NY (1995).

[vii] For Aristotle (but not for Plato, see previous note) not only are fire, air, water, and earth entirely different substances, but matter is further radically subdivided into supra- and sub-lunar, another postulate demolished by Galileo.

[viii] The dogma of transubstantiation, approved in the Council of Trent in 1551-1552, holds that in the Eucharist the substance, though not the appearance, of bread and wine becomes Christ’s body and blood.

[ix] See P. Redondi, *Galileo Eretico*, Einaudi, Rome (1983). Redondi shows that after 1633 Galileo still maintained a Copernican viewpoint but totally abandoned his previous atomistic theory of matter.

[x] For a divergent opinion, see C. S. Calude & F. W. Meyerstein, *Chaos, Solitons and Fractals* **10**, 1075-1084 (1999).

[xi] C. A. Hutchinson III *et al.Science* **286**, 2165-2169 (1999).

[xii] M. K. Cho *et al.*, *Science* **286**, 2087-2090 (1999).

[xiii] The “selfish genes” metaphor provides another example.

[xiv] Last but not least, in E. O. Wilson’s excellent book *Consilience*, A. Knopf, NY (1998).

[xv] As in: “There may be Life on Mars”.

[xvi] In fact, we will argue that this capability represents the adaptation of the individual to the environment in which it is capable of gauging this deficit.

[xvii] The Algorithm may, in some circumstances, output the ‘suicide’ of a living cell, as for instance in the phenomenon of apoptosis, or the destruction of the offspring of an individual, as in infanticide.

[xviii] Classifying external stimuli into only two categories, aversive or appetitive, represents another instance of the drastic simplification of the environmental information impinging on the sense organs of a given individual. Of course, aversive/appetitive can be replaced by positive/negative, on/off or, better, by 0/1.

[xix] IBM is reported building a gigantic ‘petaflop’ computer, nicknamed ‘Blue Gene’, to try to model protein folding. Cost: around US$100 million.

[xx] For instance, the relentless competition for survival among *individual* neurons in the brain has recently been attested at the molecular level (A. Chenn and C. Walsh, *Science* **286**, 689-690, (1999) and N. Šestan *et al.*, **286**, 741-746 (1999)).

[xxi] In chapter 5 another limit, our common language, is analyzed.

[xxii] Violent environmental fluctuations, as registered more then once on this planet, led to massive extinction.

[xxiii] Readers interested in the relationship between stress, ecology and evolution may consult the following recent books: A. A. Hoffmann & P. A. Parsons, *Evolutionary Genetics and Environmental Stress*, Oxford University Press, Oxford (1989); R. Bijlsma & V. Loeschcke (eds.) *Stress, Adaptation, and Evolution*, Birkhäuser, Basle (1997); A. P. Møller & J. P. Swaddle, *Asymmetry, Developmental Stability, and Evolution*,Oxford University Press, Oxford (1997); A. P. Møller, M. Milinski & P. J. B. Slater (eds.) *Stress and behavior*, Academic Press, New York (1998).

[xxiv] For depression and religious beliefs, see K. A. Alvarado, D. I. Templer, C. Bresler & S. Dobson-Thomas, *J. Clin. Psychol.* **51**, 202-204 (1995), G. J. Kennedy, H. R. Kelman, C. Thomas & J. Chen, *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **51**, P301-308 (1996), H. G. Koenig, L. K. George & B. L. Peterson, *Am. J. Psychiatry* **155**, 536-542 (1998), M. A. Musick, H. G. Koenig, J. C. Hays & H. J. Cohen, *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **53**, S218-227 (1998) and W. J. Strawbridge, S. J. Shema, R. D. Cohen, R. E. Roberts & G. A. Kaplan, *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **53**, S118-126 (1998). For immune response and religious beliefs, see for example L. Kamen-Siegel, J. Rodin, M. E. Seligman & J. Dwyer, *Health Psychol.* **10**, 229-235 (1991) and H. G. Koenig, H. J. Cohen, L. K. George, J. C. Hays, D. B. Larson & D. G. Blazer, *Int. J. Psychiatry Med.* **27**, 233-250 (1997). See also K. S. Markidis, *J. Gerontol.* **38**, 621-625 (1983), W. J. Strawbridge, R. D. Cohen, S. J. Shema & G. A. Kaplan, *Am. J. Public Health* **87**, 957-961 (1997) and H. G. Koenig & D. B. Larson, *South Med. J.* **91**, 925-932 (1998) as examples of studies demonstrating an association between religion, life satisfaction and life expectancy.

[xxv] A. Harrington (ed.), *The placebo effect*, Harvard University Press, Cambridge, Mass. (1997); M. Enserink, *Science* **284**, 238-240 (1999).
[xxvi] V. Apanius, *Adv. Study Behav*. **27**, 133-153 (1998).
[xxvii] R. Trivers, *Social evolution*, Benjamin/Cummings, Menlo Park (1985).
[xxviii] See L. Brisson & F. W. Meyerstein, *Puissance et Limites de la Raison*, Les Belles Lettres, Paris (1995).
[xxix] See G. J. Chaitin, *The Limits of Mathematics*, Springer-Verlag, Singapore (1998).
[xxx] G. A. Wray, *Science* **279**, 1871-1872 (1998).
[xxxi] See F.W. Meyerstein, *Complexity* **4** (4), 26-30, (1999).
[xxxii] Gravity is not included, as there is still no satisfactory Quantum Gravity theory.
[xxxiii] In space-times of 10, 11 or 26 dimensions, depending on which theory you favor!
[xxxiv] There seems to be nothing more "complex" than the universe that, to our knowledge, is not alive.
[xxxv] "Shortly" is evidently a relative term. It points to an additional difficulty: The tight connection of the considered space-time scale of a description with the description itself. Assuming that the description of a phenomenon is space-time scale-invariant is a very strong and in most cases untested assumption; it probably reflects innate prejudices relating to an assumed world-order.
[xxxvi] A. R. Rogers in G. Cardew (ed.) *Characterizing Human Psychological Adaptations*, Ciba Foundation Symposium 208, p. 231 (1997).
[xxxvii] The environment of an individual must be understood as including, besides the physical environment, also the other members of the species, such as kin, mates, offspring, and other conspecifics, plus the predators, parasites, symbionts, and prey directly affecting its reproductive success. But also the internal physiological state of the individual is, in a way, part of its environment - in the widest sense of this term - as it similarly affects its optimizing efforts.
[xxxviii] A. Luther, R. Brandsch & G. von Kiedrowski, *Nature* **396**, 245-248 (1998).
[xxxix] W. D. Hamilton, *J. Theor. Biol* **7**, 1-52 (1964).
[xl] R. L. Trivers, *Q. Rev. Biol.* **46**, 35-57 (1971).
[xli] E. Sober & D. S. Wilson, *Unto others*, Harvard University Press, Cambridge, Mass. (1998).
[xlii] This effect is demonstrated in a model by G. R. Price, *Nature* **227**, 520 (1970).
[xliii] Maxwell's demon is an imaginary creature to whom Maxwell assigned the task of operating a friction-less door in a partition dividing a volume containing gas at uniform temperature. Temperature is a (macroscopic) statistical value, while the different (microscopic) gas particles have all different energies, i.e., different velocities. The door is opened by the astute demon so as to enable fast molecules to move (say) from left to right through the partition. In this way, without expenditure of external work, the gas on the right could be made hotter than before and that on the left cooler so that now thermodynamic work can be extracted at no cost. How can the demon undauntedly violate the second law? In fact he cannot do his trick cost-free, that is, without increasing the entropy of the system, as what has been overlooked is the energy cost associated with measuring (decoding) the energy (velocity) of different particles. Landauer then established that the entropy increase of the system derives from the irreversible loss of information resulting from the demon's need to set back his instrument to zero between any two measurements. So, even with a perfect instrument, no demon can disregard the second law.
[xliv] Maxwell's "demon" was proposed as a violation of this sacrosanct principle.

***xlv***
*References*:

A. Babloyantz, *Molecules, dynamics and life*, Wiley-Interscience, New York (1986).
D. R. Brooks & E. O. Wiley, *Evolution as entropy. Toward a unified theory of biology*, The University of Chicago Press, Chicago and London (1986).
P. Coveney & R. Highfield, *The arrow of time*, Allen, New York (1990).
L. Glass & M. Mackey, *From clocks to chaos. The rhythms of life*, Princeton University Press, Princeton (1988).
D. Jou, J. Casas-Vázquez & G. Lebon, *Extended Irreversible Thermodynamics*, 2nd edition, Springer, Berlin (1996).
P. T. Lansdsberg (ed.), *The enigma of time*, Adam Hilger, Bristol (1982).
G. Nicolis & I. Prigogine, *Self-organisation in non-equilibrium systems*, Wiley-Interscience, New York (1977).
I. Prigogine & I. Stengers, *La nouvelle alliance, Métamorphose de la science*, Gallimard, Paris (1979).
I. Prigogine & I. Stengers, *Entre le temps et l'éternité*, Fayard, Paris (1988).
A. Winfree, *The geometry of biological time*, Springer, Heidelberg (1980).

A. Winfree, *The timing of biological clocks*, Scientific American Library, W. H. Freeman, New York (1987).

[xlvi] J. T. Fraser (ed.), *The Voices of Time*, Penguin, London (1968).
[xlvii] Note, however, that all the terms here employed: foresight, to plan ahead, (future) challenges, and others, already incorporate entirely the linear, asymmetric time concept.
[xlviii] M. J. Berry *et al.*, *Nature* **398**, 334-338 (1999).
[xlix] L. Brisson & F. W. Meyerstein, *Inventing the Universe*, State University of New York (SUNY) Press, New York (1995).
[l] J. Aschoff, *Naturwissenschaften* **41**, 49-56 (1954).
[li] G. Tosini & M. Menaker, *Science* **272**, 419-421 (1996); M. Menaker, L. F. Moreira & G. Tosini, *Braz. J. Med. Biol. Res*. **30**, 305-313 (1997).
[lii] Y. Liu, J. Loros & J. C. Dunlap, *Proc. Natl. Acad. Sci. USA* **97**, 234-239 (2000).
[liii] D. A. Oren & M. Terman, *Science* **279**, 333-334 (1998); S. S. Campbell & P. J. Murphy, *Science* **279**, 396-399 (1998).
[liv] E. Gwinner in D. S. Farner, J. R. King & K. C. Parkes (eds). *Avian Biology*. Vol. 5, Academic Press, New York (1975), pp. 221-285.
[lv] R. R. Baker & M. A. Bellis, *Human sperm competition*, Chapman & Hall, London (1995).
[lvi] M. Hau, M. Wikelski & J. C. Wingfield, *Proc. Int. Orn. Congr*. **22**, 1720-1739 (1999).
[lvii] M. Hau, M. Wikelski & J. C. Wingfield, *Proc. R. Soc. Lond. B* **265**, 89-95 (1998).
[lviii] T. H. Clutton-Brock, *Am. Nat*. **123**, 212-229 (1984); T. Pärt, L. Gustafsson & J. Moreno, *Am. Nat*. **140**, 868-882 (1992).
[lix] L. Gustafsson & T. Pärt, *Nature* **347**, 279-281 (1990).
[lx] C. FitzGibbon in T. Caro (ed) *Behavioral ecology and conservation biology*, Oxford University Press, New York (1998), pp. 449-473; M. Alvard in T. Caro (ed) *Behavioral ecology and conservation biology*, Oxford University Press, New York (1998), pp. 474-500.
[lxi] M. Wilson, M. Daly & S. Gordon in T. Caro (ed) *Behavioral ecology and conservation biology*, Oxford University Press, New York (1998), pp. 501-526.
[lxii] A. Kacelnik in G. R. Bock & G. Cardew (eds) *Characterizing human psychological adaptations*, John Wiley & Sons, Chichester (1997), pp. 51-70.
[lxiii] Ecclesiastes 3, 1. After the quoted lines, Ecclesiastes continues thus:
2 A time to be born, and a time to die; a time to plant, and a time to pluck up that which is planted;
3 A time to kill, and a time to heal; a time to break down, and a time to build up;
4 A time to weep, and a time to laugh; a time to mourn, and a time to dance;
5 A time to cast away stones, and a time to gather stones together; a time to embrace, and a time to refrain from embracing;
6 A time to get, and a time to lose; a time to keep and a time to cast away;
7 A time to rend and a time to sew; a time to keep silence and a time to speak
8 A time to love, and a time to hate; a time of war and a time of peace.
[lxiv] See, for instance, J. Alcock, *Animal Behavior*, Fifth edition, Sinauer, Sunderland (1995).
[lxv] Always admitting as a postulate that there is a finite limit to the speed of information transmission, assumed by Einstein to be the speed of light in vacuum. Parenthetically, the world would be very different if instantaneous information transmission was attainable. This point has a present-day correlate: In our world "news" are (almost) instantaneously known, a circumstance that has profoundly affected human society.
[lxvi] See also Chapter 2.
[lxvii] R. Omnès in J. J. Hallivell *et al.*, eds., *The Physical Origins of Time Asymmetry*, Cambridge University Press, Cambridge (1994), p. 272.
[lxviii] K. Peach, *Nature* **396**, 407-408 (1998); H. R. Quinn & M. S. Whitherell, *Scientific American*, October 1998, 50-55 (1998).
[lxix] The experience of 'time' as a presumably fitness-increasing trait can be shown to be disrupted in mental disorders such as schizophrenia and in a syndrome called "attention-deficit hyperactivity disorder (ADHD)". This shows two things: (1) there is genetic variation for these traits, and (2) in some forms of mental diseases it alters the most fundamental views of the patient about the relation of Life and Time. We take this as a further proof that our commonsense understanding of Life and Time are in the main mental artifacts. For instance, as N. C. Andreasen writes in *Science*, **275,** 1590 (1997): "A person with schizophrenia has a fundamental deficit in taking measure of time and space and in making inferences about interrelationships between self and others, or among past, present, and future [...] Patients with ADHD show a global deficit in dealing with time. They cannot easily learn from past mistakes, accurately

evaluate their present efforts, realistically plan for the future, or organize and execute tasks that require an orderly temporal sequence". (See also the commentary by P. W. Gold, *Science* **281**, 1149 (1998)).

[lxx] The possibility of one's own imminent death is almost never freely acknowledged in public. For instance, friends and relatives always "console" someone terminally ill by pretending that things will improve, that he will "soon" be better. Further, someone "terminally" ill - but we are all terminally ill from the very day we are born! - should not complain about his impending demise as this is felt to be "disagreeable" or "pessimistic". In the same vein, no one is allowed to speak of the "short" period of one's remaining life, good "optimistic" manners demand that one considers the rest of one's life as an almost infinite time-span. This attitude further leads to expressions which, under close scrutiny, are utterly absurd, such as "wasting one's time", "not having time", and so forth.

[lxxi] Actually not circular but cycloidal. Geometrically, the cycloid is the path traced out by a point on the circumference of a circle that rolls without slipping on a straight line. Thus the cycloid is the geometrical representation of the cyclical eternal repetition of the same.

[lxxii] The oldest part of the Hebrew Bible, attributed to "J" , the redactor referring to God as Jehovah (or Yahveh) and dated the 9th century BC, that is, before the great Babylonian exile, starts in Genesis II, 4b: "in the day the Lord God (Yahveh) made the earth and the heaven....", followed by the narration of Adam and Eve, etc. Redactor "E", referring to God as Elohim, active about a century later, starts his sequential narrative with Abraham. The much later composition of the seven-day creation story in Genesis I, attributed to the priestly redactor(s) "P", reflects the linear-time approach favored by the post-exile priest-caste. See J. Bottéro, *La Naissance de Dieu*, Gallimard, Paris (1992).

[lxxiii] Apparently this represents the first known example of the idea of history, as in more ancient king-lists or laudatory inscriptions one cannot discern the will to represent the past historically. Of course, mythical narratives may have a historical core, but they are not composed in a historical frame.

[lxxiv] "For the living know that they shall die: but the dead know not any thing, neither have they any more a reward; for the memory of them is forgotten". *Ecclesiastes* 9, 5.

[lxxv] As in the *Phaedo.*

[lxxvi] T. F. Münster, K. Schiltz & M. Kutas, *Nature* **395**, 71-73 (1998).

[lxxvii] N. S. Clayton & A. Dickinson, *Nature* **395**, 272-274 (1998).

[lxxviii] And thus some form of self-consciousness? A difficult question indeed.

[lxxix] G. Steiner, *No Passion Spent,* Yale University Press, New Haven (1996), p. 28.

[lxxx] Isn't it surprising that people, having at their disposal only a limited repertoire of words, and a limited grammar, are nevertheless capable of grasping the meaning of an infinity of different sentences?

[lxxxi] S. Pinker, *The Language Instinct*, Harper-Collins, New York (1995), p. 84.

[lxxxii] We here admit this universal translation possibility as a 'fact' with the strong caveat that frequently only the essential meaning is what survives such translations in the most favorable case. Poetry can at best be re-created, but hardly ever directly translated. Authors who abandon a clear and simple way of writing preferring a 'richer' alternative - we mention below the cases of Heidegger and James Joyce - are in more than one respect un-translatable, that is, their "official translations" are established in spite of an irretrievable loss of original intent. A notorious historical example are the successive translations of the Old Testament, beginning with the *Septuagint* in the third century BC, followed by Jerome's *Vulgata*, the *King James Authorized Version*, and 'modern' renditions.

[lxxxiii] In fact, communication systems in nature are frequently non-linear. For instance, animals smelling the odors they encounter in their surroundings are "reading" messages chemically encoded in three-dimensional molecular structures. This non-linear "language" system is widely employed at all levels amongst all kinds of Life forms. It has also recently been shown that this system is still active in humans, although at an unconscious level. See K. Grammer, *Ethol. Sociobiol*. **14**, 201-214 (1993). K. Grammer & A. Jutte, *Gynäkol. Rundschau* **37**,150-153 (1997). S. W. Gangestad & R. Thornhill, *Proc. R. Soc. Lond*. B **265**, 927-933 (1998).

[lxxxiv] L. Wittgenstein, *Tractatus Logico-Philosophicus* (1921), 5.6. Translation from the German, here and below, is somewhat *ad hoc* ours; numeration and emphasis are Wittgenstein's.

[lxxxv] Translation H. Tredennick.

[lxxxvi] For a detailed analysis, see F. W. Meyerstein in F. W. Meyerstein, ed., *Foundations of Big Bang Cosmology*, World Scientific, Singapore (1989).

[lxxxvii] M. Gardiner, *aha! Insight*, Freeman, New York (1978).

[lxxxviii] Translation H. Tredennick.

[lxxxix] But, what does "true" mean? And what is a "fact"? According to the scholastic definition, truth in this sense is *adaequatio intellectus et rei.* This granted, how can we establish the adequacy, the commensurateness, of the ideal intellect and the real things? So *truth* and *fact* are again examples of those difficult circular terms that bedevil a study of the kind here attempted. According to the philosopher W.

V. O. Quine, the *truth* of a linguistic assertion stating a *fact* cannot be established within the framework of that language: a meta-language is required, thus leading to an infinite regress.

[xc] L. Brisson & F. W. Meyerstein, *Puissance et Limites de la Raison*, Les Belles Lettres, Paris (1995).

[xci] By default, as it were!

[xcii] *Vernünftige Wesen*, Kant.

[xciii] The question remains controversial and at the forefront of present-day investigation (*Science* **282**, 1441-1458 (1998), in particular pp. 1455-1458).

[xciv] Before this discovery, a 1.8 million-years-old stone tool industry had been uncovered in the Olduvai Gorge, Tanzania, and 2.3 million-year-old artifacts are known from Omo (Ethiopia) and Turkana (Kenya). And very far from these East African sites, in the Longgupo cave in Sichuan, China, hominid remains closely resembling the Olduvai fossils, also associated with complex stone artifacts, have been found and dated to be of about the same age (H. Wanpo *et al.*, *Nature* **378**, 275-278 (1995)).

[xcv] W. H. Kimbel *et al., J. Hum. Evol.* **31**, 549-561 (1996); S. Semaw *et al., Nature* **385**, 333-336 (1997).

[xcvi] M. J. Morwood *et al.*, *Nature* **392**, 173-176 (1998).

[xcvii] H. Thieme, *Nature* **385**, 807-810 (1997).

[xcviii] For detailed studies, see G. Roux, *La Mésopotamie*, Seuil, Paris (1985-1995), J. Bottéro, *La plus vielle religion*, *En Mésopotamie,* Gallimard, Paris (1998), J. Bottéro, C. Herrenschmidt & J.-P. Vernant, *L'Orient Ancien et Nous*, Albin Michel, Paris (1996)¸ H. Frankfort, *Kingship and the Gods*, University of Chicago Press, Chicago (1948-1978), T. Jacobsen, *The Treasures of Darkness*, Yale University Press, New Haven and London (1976), E. Doblhofer, *Die Entzifferung alter Schriften und Sprachen*, Reclam, Stuttgart (1993), W. von Soden, *Einführung in die Altorientalistik,* Wissenschaftliche Buchgesellschaft, Darmstadt (1985).

[xcix] Similar to the use of Latin in the Middle Ages.

[c] Here is a beautiful example from the seventh century BC:

> Like locusts devour....lice and caterpillars
> may they cause your towns, your land and your district be devoured.
> May they treat you as a fly (caught) in the hand ;
> may your enemy squash you.
> Just as urine stinks,
> just so may your smell be before
> god and king and mankind.
> As for you, may they strangle you, your women,
> your sons and your daughters with a cord.

Quoted in E. Yamauchi, *Persia and the Bible*, Baker Books, Grand Rapids (1990-1996).

[ci] "The attempt of human consciousness to find a lodging in the given world—an attempt which we call 'myth' ", G. Steiner, *op. cit.*, p. 109.

[cii] In Ancient Mesopotamia, the oral word carried considerable weight: Just mentioning the name of the god in the recitation of the mythological poems was considered to have a thaumaturgic use and - presumably with some success - was employed in the healing of diseases.

[ciii] Approximately in the spirit of the emphasis McLuhan laid on the *media* in which a social group, beyond the directly spoken language, preferentially exchanges information.

[civ] Why no vowels? A possible explanation is that the omission of vowels permitted to write a text independent of its idiosyncratic dialectal pronunciation, and so one and the same writing system could be applied in a much larger geographical area (J. Montserrat, personal communication).

[cv] The Phoenicians are a West-Semitic people recorded already in the third millennium BC (in Byblos, today in Lebanon); they inhabited the biblical Canaan (Tyros, Sidon), founded Carthage (9th century BC) and fought the Romans in the Punic wars.

[cvi] R. Landauer, *Physics Letters A* **217**, 188-193 (1996).

[cvii] Note that the unquestioned admittance of the real number system leads to many unsolved 'problems'; see F. W. Meyerstein, *Complexity* **4** (4), 26-30 (1999).

[cviii] G. J. Chaitin, *Algorithmic Information Theory*, Cambridge University Press, Cambridge (1987).

[cix] R. Landauer, *op. cit.* (abstract).

[cx] E. Sober & D. S. Wilson, *Unto others*, Harvard University Press, Cambridge, Mass. (1998).

[cxi] L. M. Adleman, *Science***, 226**, 1021-1024 (1994).

[cxii] D. Bray, *Nature*, **376**, 307-312 (1995).

[cxiii] A qubit is typically a microscopic system such as an atomic or nuclear spin or polarized photon; actually, any 2-state quantum system can be used to represent 0 and 1. But a qubit must be understood as the superposition of a continuum of intermediate states, which are superpositions of 0s and 1s.

[cxiv] The literature on quantum computation is growing enormously! We just mention one paper by D. Gottmann & I. L. Chuang, *Nature* **402**, 390-393 (1999). Note that 'teleportation' discussed in this paper refers to another purely quantum aspect of reality. In teleportation, the state of a qubit can be transported instantly over any distance, based on the property of quantum 'entanglement'. A. Einstein, who believed that the quantum mechanical picture of reality is incomplete, criticized this strange quantum behavior. But decades of work and experiments have shown unambiguously that in fact the basic constituents of the world behave in this counter-intuitive manner.

[cxv] But this will not happen soon. The power of a quantum computation lies in the possibility of interference among the multiple paths the quantum system can take from a prepared input to an output that can then be measured. This means that in quantum computation one has access to information in a massively parallel manner. To work, however, the initial superposition of quantum states must evolve coherently according to a certain chosen algorithm. In the read-out terminal, the different states interfere and a result of the calculation is obtained. But the rub is to maintain this coherence. In order to achieve this, during all the process the different quantum paths must be completely isolated from their macroscopic environment. Otherwise, the outer world will become 'entangled' with the calculation, and the ensuing decoherence simply wipes out the result.

[cxvi] *Science* **286**, 1881-1905 (1999).

[cxvii] 'Indissoluble'.

[cxviii] Quoted in G. Steiner, *No Passion Spent*, Yale University Press, New Haven (1996), p. 235.

[cxix] *Intellect*: faculty of reasoning, knowing and thinking (*The Oxford Dictionary of Current English* (1993)). This "definition" sheds only a meager light on the term so "defined"!

[cxx] Image in Greek is *eikôn*, the verb *eikô* meaning to resemble, and thus Plato named the knowledge accessible to humans an *eikôs logos*, a copy (model) of reality, that is, at best, a verisimilitude.

[cxxi] *Timaeus* 27d-28a. For translation and commentary, see L. Brisson & F. W. Meyerstein, *Inventing the Universe*, State University of New York (SUNY) Press, New York (1995). See also F. W. Meyerstein in F. W. Meyerstein, ed., *Foundations of Big Bang Cosmology*, World Scientific, Singapore (1989).

[cxxii] The mathematical character of the World-Soul order meshes with Plato's repeated emphasis that only sense-perceptible observations expressible in numbers, that is, measurable, can lead to verisimilitude, to plausible models.

[cxxiii] Plato's World-Soul provides the mathematical *guarantee* for whatever order can be found in the physical world, thus replacing a variegated Pantheon of gods constantly interfering and messing up humans' destiny (as in Homer). In fact, Plato's *demiurge*, the "mythical" constructor of this partially ordered universe, after installing the mathematical World-Soul between the two otherwise unbridgeable domains, retires to his usual abode, wherever that may be, never again to return nor interfere.

[cxxiv] The only other mathematical explanation of physical facts known in Plato's time, and widely used in the *Timaeus*, was the discovery that musical harmony is determined by arithmetic and harmonic proportions (fixing the ratios of the lengths of the cords of a consonant lyre). These neatly showed how mathematics provided the mediation-bridge between the intelligible sphere of music and the sense-perceptible sphere of a physical instrument. Note that this "mediation" is entirely "unlogical" since no "logical" explanation of this fact is deemed to exist. Note further the incredibly audacious extrapolation from such a meager factual basis to a complete cosmological model that, nevertheless, has stubbornly stood the test of time.

[cxxv] In Plato's time the seven known planets were: Sun, Moon, Mercury, Venus, Mars, Saturn and Jupiter. Plato referred to them as *planêtês* meaning erratic or vagabond, since their movements apparently did not conform to strictly circular motion. Thus he put before the astronomers the hard task to figure out how a combination of only circular movements could describe the observed celestial displacements of the seven "erratic" heavenly bodies.

[cxxvi] This is another astonishing aspect of his program. For Plato, only when *symmetry* - sameness under change mirroring the intelligible Forms - obtains in some physical system is knowledge about that system possible. Early in the 20th century, the German mathematician Emily Noether established a fundamental theorem, today known as Noether's theorem, postulating that the fundamental conservation laws in nature (energy, momentum, etc.) are nothing but reflections of previously assumed underlying symmetry postulates. These underlying symmetries may, for instance, refer to the general structure of space-time (isotropy, homogeneity, etc.). Without such conservation laws, however, our possibility of understanding the physics of nature would be severely undermined.

[cxxvii] Kepler explicitly stated that his approach was based on Plato's *Timaeus*. See J. V. Field, *Enrahonar* **23**, 7-33, Universitat Autònoma de Barcelona (1995).

[cxxviii] E. Wigner, in the often cited article *"The Unreasonable Effectiveness of Mathematics in the Natural Sciences"*, wrote: "The enormous usefulness of mathematics in the natural sciences is something

bordering on the mysterious and there is no rational explanation for it". *Communications on Pure and Applied Mathematics* **13**, 2 (1960).
[cxxix] Facsimile and translation of this letter in A. P. French (ed.), *Einstein, A Centenary Volume*, Heinemann, London (1979), p. 271.
[cxxx] W. Schultz, P. Dayan & P. R. Montanue, *Science* **275**, 1593-1599, (1997). See also the experiments by J. Mirenowicz & W. Schulz, *Nature* **379**, 449-451 (1996).
[cxxxi] A condition marked, among others, by symptoms of disruption of the "feeling well" sensation. In depression, accessible rewards are not "emotionally felt" as such, that is, their reward value is modified. According to the LifeTime model, this directly affects the functionality of the Algorithm, as the Algorithm essentially operates by means of rewards and punishments.
[cxxxii] I.e., resulting in a Algorithmic disfunctionality impairing survival and reproductive success.
[cxxxiii] R. A. Barkley, *Sci. Am.* September 1998, 44-49 (1998).
[cxxxiv] D. Bohm, *Wholeness and the Implicate Order*, Routledge & Kegan Paul, London (1980), p. 27.
[cxxxv] D. Bohm, *ibid*, p. 115; moreover, his remarks on probability theory in this context are of particular interest.
[cxxxvi] Human males can smell the fertile state of human females, whereas the perception of the odor of sweat of human males is altered in ovulating human females. K. Grammer, *Ethol. Sociobiol*. **14**, 201-214 (1993). K. Grammer & A. Jutte, *Gynäkol. Rundschau* **37**,150-153 (1997). S. W. Gangestad & R. Thornhill, *Proc. R. Soc. Lond*. B **265**, 927-933 (1998).
[cxxxvii] It has been suggested (see for instance J. P. Ridge, E. J. Fuchs & P. Matzinger, *Science* **271**, 1723-1726 (1996)) that the immune system is activated only by antigens associated with a danger to the organism (the 'Danger model'). The distinction between self and non-self in this view is considered to be an artifact, at least as referred to the immune system.
[cxxxviii] D. Bohm, *Causality and Chance in Modern Physics*, University of Pennsylvania Press, Philadelphia (1957), p. 165.
[cxxxix] G. J. Chaitin *Algorithmic Information Theory*, Cambridge University Press, Cambridge (1987).
[cxl] That is, we are not studying the system from a quantum-mechanical viewpoint, nor are we considering any relativistic corrections. Thus "the system" is macroscopic, the speeds considered are much smaller than the speed of light, and gravitational sources affecting the system are weak. Further, thermodynamically the system is considered isolated from the rest of the universe. Thus it clearly appears that these considerations are only valid "for a limited subset of possible systems, within a certain degree of approximation, in some restricted range of conditions, within a limited context, and not beyond a characteristic period of time".
[cxli] D. Bohm, *Wholeness and the Implicate Order*, Routledge & Kegan Paul, London (1980), p. 118.
[cxlii] T. Alerstam, *Bird Migration*, Cambridge University Press, Cambridge (1991).
[cxliii] A. P. Møller, *Sexual selection and the barn swallow*, Oxford University Press, Oxford (1994).
[cxliv] Newton's law has been found to give adequate results in over 300 years of observation. Most physicists now conclude that we are "entitled" to the "rational belief" that this situation can be extended in space and time to the whole universe. But there is in nature absolutely no guarantee for the validity of this assumption. Still, radical skepticism being inherently sterile, this extrapolation is customarily admitted. To the point that, when astronomers found that Newton's law is clearly violated in objects such as galaxies, they chose to postulate some as yet unknown and unobserved "dark matter" to save, not the phenomena, but our *confidence* in Newton's law. The intense effort to find - and define - this elusive exotic matter-form is now on.
[cxlv] For four species of birds living in very different environments it has been shown that reproductive success in one year is predicted by reproductive success the previous year. However, as the interval increases, the predictability of environmental conditions decreases to zero. In other words, the environment is not constant. See E. Danchin, T. Boulinier & M. Massot, *Ecology* **79**, 2415-2428 (1998), S. Schjørring, J. Gregersen & T. Bregnballe, *Anim. Behav*. **57**, 647-654 (1999), E. Danchin, C. R. Brown & M. B. Brown, *J. Anim. Ecol.* **69**, 133-142 (2000), B. Doliguez, L. Gustafsson & E. Danchin, *J. Anim. Ecol*. (in press).
[cxlvi] T. Boulinier, E. Danchin, J. Y. Monnat, C. Doutrelant & B. Cadiou, *J. Avian Biol*. **27**, 252-256 (1996), E. Danchin & R. Wagner, *Trends Ecol. Evol*. **12**, 342-347 (1997), S. Schjørring, J. Gregersen & T. Bregnballe, *Anim. Behav*. **57**, 647-654 (1999).
[cxlvii] E. Danchin, T. Boulinier & M. Massot, *Ecology* **79**, 2415-2428 (1998), S. Schjørring, J. Gregersen & T. Bregnballe, *Anim. Behav*. **57**, 647-654 (1999), E. Danchin, C. R. Brown & M. B. Brown, *J. Anim. Ecol.* **69**, 133-142 (2000), B. Doliguez, L. Gustafsson & E. Danchin, *J. Anim. Ecol*. (in press).
[cxlviii] See note 12.

[cxlix] C. Rae, R. B. Scott, C. H. Thompson, G. K. Kemp, I. Dumughn, P. Styles, I. Tracey & G. K. Radda, *Proc. R. Soc. Lond. B* **263**, 1061-1064 (1996).
[cl] F. B. Furlow, T. Armijo-Prewitt, S. Gangestad & R. Thornhill, *Proc. R. Soc. Lond. B* **264**, 823-829 (1997).
[cli] S. Blinkhorn, *Nature* **387**, 849-850 (1997).
[clii] The number of descendants recruiting to the population in the subsequent generation.
[cliii] A general description of this species and the influence of its reproductive biology on its entire life history can be found in A. P. Møller, *Sexual selection and the barn swallow*, Oxford University Press, Oxford (1994). A popular account of the biology of this species can be found in A. K. Turner, *The swallow*, Hamlyn, London (1993).
[cliv] P. Berthold & U. Querner, *Science* **212**, 77-79 (1981).
[clv] M. C. Linn & A. C. Petersen, *Child Dev*. **56**, 1479-1498 (1985).
[clvi] M. Wilson & M. Daly in J. H. Barkow, L. Cosmides & J. Tooby (ed.), *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, Oxford University Press, Oxford (1992), pp. 289-326.
[clvii] C. Darwin, *The descent of man, and selection in relation to sex*, J. Murray, London (1881). A modern synthesis of sexual selection can be found in M. Andersson, *Sexual selection*, Princeton University Press, Princeton (1994).
[clviii] A. P. Møller, *Nature* **322**, 640-642 (1988).
[clix] F. de Lope & A. P. Møller, *Evolution* **47**, 1152-1160 (1993).
[clx] W. D. Hamilton & M. Zuk, *Science* **218**, 384-387 (1982).
[clxi] N. Saino & A. P. Møller, *Behav. Ecol*. **7**, 227-232 (1996).
[clxii] D. M. Buss, *The evolution of desire*, BasicBooks, New York (1994).
[clxiii] S. W. Gangestad & D. M. Buss, *Ethol. Sociobiol*. **14**, 89-96 (1994).
[clxiv] A. P. Møller & J. T. Nielsen, *Anim. Behav*. **54**, 1545-1551 (1997).
[clxv] A. P. Møller & F. de Lope, *Evolution* **48**, 1676-1683, (1994).
[clxvi] N. Saino, A. M. Bolzern & A. P. Møller, *Proc. Natl. Acad. Sci. USA* **94**, 549-552 (1997). A component of the immune system of male barn swallows was challenged with a novel antigen (a small, standardized injection with sheep red blood cells), and the amount of antibody produced in response to this challenge was subsequently estimated based on a second blood sample.
[clxvii] C. Wedekind, T. Seebeck, F. Bettens & A. J. Paepke, *Proc. R. Soc. Lond B* **260**, 245-249 (1995).
[clxviii] T. R. Birkhead & A. P. Møller (eds.), *Sperm Competition and Sexual Selection*, Academic Press, London (1998).
[clxix] N. Saino, C. Primmer, H. Ellegren & A. P. Møller, *Evolution* **51**, 562-570 (1997).
[clxx] R. R. Baker & M. J. Bellis, *Human sperm competition*, Chapman and Hall, London (1994).
[clxxi] R. Thornhill & S. W. Gangestad, *Psychol. Science* **5**, 297-302 (1994).
[clxxii] D. F. Sherry, M. R. L. Forbes, M. Khurgel & G. O. Ivy, *Proc. Natl. Acad. Sci. USA* **90**, 7839-7843 (1993).
[clxxiii] T. Székely, C. K. Catchpole, A. DeVoogd, Z. Marchl & T. J. DeVoogd, *Proc. R. Soc. Lond. B* **263**, 607-610 (1996).
[clxxiv] B. Pakkenberg & H. J. Gundersen, *J. Comp. Neurol*. 384, 312-320 (1997).
[clxxv] G. Turner, *The Lancet* **347**, 1814-1815 (1995).
[clxxvi] G. Turner, *The Lancet* **347**, 1814-1815 (1995).
[clxxvii] R. L. Trivers, *Am. Zool*. **14**, 249-264 (1974).
[clxxviii] D. Haig, *Q. Rev. Biol*. **68**:495-532 (1993).
[clxxix] D. W. Bianchi, G. K. Zickwolf, G. J. Weil, S. Sylvester & M. A. DeMaria, *Proc. Natl. Acad. Sci. USA* 93, 705-708 (1996).
[clxxx] A. P. Møller, *J. theor. Biol*. **185**, 415-422 (1997).
[clxxxi] D. A. Roff, *Life-history evolution*, Chapman & Hall, New York (1992), S. Stearns, *Life-history evolution*, Oxford University Press, Oxford (1992).
[clxxxii] G. Hausfater & S. B. Hrdy (eds.), *Infanticide: Comparative and evolutionary perspectives*, Aldine, New York (1984).
[clxxxiii] D. Mahsberg in P. H. Brownell & G. A. Polis (eds.), *Scorpions and research*, Oxford Univ. Press (1996).
[clxxxiv] A. P. Møller, *Behav. Ecol. Sociobiol*. **22**, 365-371 (1988).
[clxxxv] M. Daly & M. Wilson in G. Hausfater & S. B. Hrdy (eds.), *Infanticide: Comparative and evolutionary perspectives*, Aldine, New York (1984).
[clxxxvi] M. Daly & M. Wilson, *Homicide*, Aldine de Gruyter, Hawthorne (1988).

[clxxxvii] R. Kilner, *Proc. R. Soc. Lond. B* **264**, 963-968 (1997), F. Götmark & M. Ahlström, *Proc. R. Soc. Lond. B* **264**, 959-962 (1997).
[clxxxviii] N. Saino, P. Ninni, S. Calza, R. Martinelli, F. De Bernardi & A. P. Møller, *Proc. R. Soc. Lond. B* **267**, 57-61 (2000).
[clxxxix] A. P. Møller, C. Biard, J. D. Blount, D. C. Houston, P. Ninni, N. Saino & P. F. Surai, *Poultry Avian Biol. Rev.* **11**, 137-159 (2000).
[cxc] N. Saino, P. Ninni, S. Calza, R. Martinelli, F. De Bernardi & A. P. Møller, *Proc. R. Soc. Lond. B* **267**, 57-61 (2000).
[cxci] This subject is reviewed extensively in F. B. Furlow, *Evol. Human Behav.* **18**, 175-193 (1997), and R. Thornhill & F. B. Furlow, *Adv. Study Behav.* **27**, 319-369 (1998).
[cxcii] Readers interested in the relationship between stress, ecology and evolution may consult the following recent books: A. A. Hoffmann & P. A. Parsons, *Evolutionary Genetics and Environmental Stress*, Oxford University Press, Oxford (1989); R. Bijlsma & V. Loeschcke (eds.) *Stress, Adaptation, and Evolution*, Birkhäuser, Basle (1997); A. P. Møller & J. P. Swaddle, *Asymmetry, Developmental Stability, and Evolution*, Oxford University Press, Oxford (1997); A. P. Møller, M. Milinski & P. J. B. Slater (eds.) *Stress and behavior*, Academic Press, New York (1998).
[cxciii] A. P. Møller & M. Pagel, *J. theor. Biol.* **193**, 497-506 (1998).
[cxciv] The balance of this chapter has been written by A. Tobeña.
[cxcv] H. Selye, *Nature* **138**, 32 (1936).
[cxcvi] G. P. Chrousos, R. McCarty, K. Pacak, G. Cizza, E. Sternberg, P. W. Gold & R. Kvetnansky (eds.) *Ann. NY Acad. Sci.* **771** (1995); P. Csermely (ed.) *Ann. NY Acad. Sci.* **851** (1998).
[cxcvii] J. Axelrod & T. Reisine, *Science* **224**, 452-457 (1984).
[cxcviii] G. P. Chrousos, *Ann. NY Acad. Sci.* **851**, 311-335 (1998).
[cxcix] J. Le Doux, *The emotional brain*, Weidenfeld and Nicholson, London (1997).
[cc] J. A. Gray, *The neuropsychology of anxiety: An inquiry into the functions of the septohippocampal system*, Oxford University Press, New York (1982); J. A. Gray, *The psychology of fear and stress*, Cambridge University Press, New York (1987).
[cci] R. M. Sapolsky, *Ann. NY Acad. Sci.* **771**, 628-639 (1995).
[ccii] R. M. Sapolsky, *Why zebras don't get ulcers?* Freeman, San Francisco (1993); R. M. Sapolsky, *Ann. NY Acad. Sci.* **771**, 628-639 (1995).
[cciii] D. C. Blanchard, R. R. Sakai, B. McEwen, S. M. Weiss & R. J. Blanchard, *Behav. Brain Res.* **58**, 113-121 (1993).
[cciv] S. Kollack-Walker, S. Watson & H. Akil, *J. Neurosci.* **17,** 8842-8855 (1997).
[ccv] R. M. Sapolsky & J. Ray, *Am. J. Primatol.* **18,** 1-13 (1989).
[ccvi] A. M. Magarinos, B. S. McEwen, G. Flugge & E. Fuchs, *J. Neurosci.* **16,** 3534-3540 (1996).
[ccvii] R. M. Sapolsky, *Stress, the aging brain and the mechanisms of neuron death*, MIT Press, Cambridge, Mass. (1992).
[ccviii] R. M. Sapolsky, S. Alberts & J. Altmann, *Arch. Gen. Psychiatr.* **54**, 1137-1143 (1997).
[ccix] J. House, K. Landis & D. Umberson, *Science* **241**, 540-546 (1988).
[ccx] J. A. Gray,*The psychology of fear and stress*, Cambridge University Press, New York (1987); D. L. Ely, *Ann. NY Acad. Sci.* **771**, 594-608 (1995).
[ccxi] K. Uvnäs-Moberg, *Ann. NY Acad. Sci.* **807**, 146-163 (1997).
[ccxii] J. Panksepp, *Ann. NY Acad. Sci.* **652**, 243-252 (1992).
[ccxiii] C. A. Pedersen, J. D. Caldwell, G. F. Jirikowski & T. R. Insel (eds.) *Ann. NY Acad. Sci.* **652** (1992); S. Carter, I. I. Lederhendler & B. Kirkpatrick (eds.) *Ann. NY Acad. Sci.* **807** (1997).
[ccxiv] J. Panksepp, E. Nelson & M. Bekkedal, *Ann. NY Acad. Sci.* **807**, 78-100 (1997).
[ccxv] K. Lorenz, *Das sogennante Böse. Zur Naturgeschichte der Aggression*, Dr. Borotha-Schoeler Verlag (1963).
[ccxvi] J. Weiss, P. Goodman, P. Losito, S. Corrigan, J. Charry & W. Bailey, *Brain Res. Rev.* **3**, 167-205 (1981); H. Anisman & L. S. Sklar, *Psychopharmacol.* **61**, 107-124 (1979).
[ccxvii] M. E. P. Seligman, *Helplessness: On depression, development and death,* Freeman, San Francisco (1975).
[ccxviii] J. Weiss, P. Goodman, P. Losito, S. Corrigan, J. Charry & W. Bailey, *Brain Res. Rev.* **3**, 167-205 (1981).
[ccxix] R. M. Sapolsky, *Stress, the aging brain and the mechanisms of neuron death*, MIT Press, Cambridge, Mass. (1992).
[ccxx] S. J. Lupien, M. De Leon, S. De Santi, A. Convit, C. Tarshish, N. Nair, M. Thakur, B. S. McEwen, R. L. Hauger & M. J. Meaney, *Nature Neurosci.* **1**, 69-73 (1998).

[ccxxi] H. Ursin, E. Baade & S. Levine, *Psychobiology of stress: A study of coping men*, Academic Press, New York (1978).
[ccxxii] M. E. P. Seligman, *Learned optimism*, Knopf, New York (1991).
[ccxxiii] A. Tobeña, I. M. Marks & R. Dar, *Advantages of bias and prejudice: an exploration of their neurocognitive templates. Neurosci. Biobehav. Rev.* **23**, 1047-1058 (1999).
[ccxxiv] J. Le Doux, *The emotional brain*, Weidenfeld and Nicholson, London (1997).
[ccxxv] J. Kagan, *Galen's prophecy: Temperament in human nature*, Basic Books, New York (1994).
[ccxxvi] P. Driscoll, R. M. Escorihuela, A. Fernández-Teruel, O. Giorgi, H. Schwegler, T. Steimer, A. Wiersma, M. Corda, J. Flint, J. M. Koolhas, W. Langhans, P. E. Schulz, J. Siegh & A. Tobeña, *Ann. NY Acad. Sci.* **851**, 501-510 (1998).
[ccxxvii] J. Flint, R. Corley, J. C. DeFries, D. W. Fulker, J. A. Gray, S. Miller & Collins, *Science* **269**, 1432-1435 (1995).
[ccxxviii] R. Cloninger, Adolfsson & N. M. Svrakic, *Nature Genetics* **12**, 3-4 (1996).
[ccxxix] J. F. Nuñez, P. Ferré, R. M. Escorihuela, A. Tobeña & A. Fernández-Teruel, *Physiol. Behav.* **60,** 1355-1359 (1996); A. Fernández-Teruel, R. M. Escorihuela, B. Castellano, B. González & A. Tobeña, *Behavior Genetics* **27**, 513-526 (1997).
[ccxxx] T. Steimer, R. M. Escorihuela, A. Fernández-Teruel & P. Driscoll, *Int. J. Dev. Neurosci.* **16,** 165-174 (1998).
[ccxxxi] S. Levine, G. C. Haltmeyer, G. C. Karas & V. Denenberg, *Physiol. Behav.* **2,** 55-59 (1967); R. M. Escorihuela, A. Tobeña & A. Fernández-Teruel, *Learning Memory* **2**, 40-48 (1995).
[ccxxxii] A. Fernández-Teruel, R. M. Escorihuela, B. Castellano, B. González & A. Tobeña, *Behavior Genetics* **27**, 513-526 (1997); P. Driscoll, R. M. Escorihuela, A. Fernández-Teruel, O. Giorgi, H. Schwegler, T. Steimer, A. Wiersma, M. Corda, J. Flint, J. M. Koolhas, W. Langhans, P. E. Schulz, J. Siegh & A. Tobeña, *Ann. NY Acad. Sci.* **851**, 501-510 (1998).
[ccxxxiii] D. Liu, J. Diorio, B. Tannenbaum, C. H. Caldjich, D. Francis, A. Freedman, S. Sharma, D. Pearson, P. Plotsky & M. Meaney, *Science* **277**, 1659-1662 (1997).
[ccxxxiv] W. Burkert, *Tracks of Biology in Early Religions*, Harvard University Press, Cambridge, Mass. (1996), p. 177**.**
[ccxxxv] This is the fundamental property distinguishing *signals*, as commonly found in all organisms, from human language. Not that these signals are unable to convey 'meaning', such as warning signals, advertising health status, alarm calls, and so forth.
[ccxxxvi] In order to 'convince', in order to be assigned a truth-value, signals – see previous note **-** must be associated with a substantial additional cost. In humans, however, since emitting any of the infinite potentially possible messages is basically without cost, their truth-value must be located elsewhere.
[ccxxxvii] See, for instance, G. Frege, *Funktion, Begriff, Bedeutung*, Vandenhoek & Ruprecht, Göttingen (1986), A. J. Ayer, *Language, Truth and Logic*, Penguin, London (1990), J. B. Carroll, ed., *Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf*, MIT Press, Cambridge, Mass. (1956), W. V. O. Quine, *Word and Object*, MIT Press, Cambridge, Mass. (1960), H. Putnam, *Mind, Language and Reality*, Cambridge University Press, Cambridge (1975), and, of course, L. Wittgenstein's *Philosophische Untersuchungen.*
[ccxxxviii] Of course, a shared world-view includes a shared hierarchy of the truth-value of signals.
[ccxxxix] Not to be forgotten is the not-yet Time feature inherent in this trait: The world-order is only trusted to be orderly in future not-yet time-spans.
[ccxl] *Wenn der Gläubige sich endlich genötigt findet, von Gottes "unerforschlichen Ratschluß" zu reden, so gesteht er damit ein, daß ihm als letzte Trostmöglichkeit und Lustquelle im Leiden nur die bedingungslose Unterwerfung übriggeblieben ist. Und wenn er zu dieser bereit ist, hätte er sich wahrscheinlich den Umweg ersparen können.* S. Freud, *Das Unbehagen in der Kultur*, Studienausgabe Band IX, S. Fischer Verlag, Frankfurt am Main (1974), p. 216, our approximate translation.
[ccxli] R. Otto, *Das Heilige*, translated by J. W. Harvey as *The Idea of the Holy*, Oxford University Press, Oxford [1923], (1958), pp. 14-15.
[ccxlii] W. Burkert, *op. cit.*, p.177.
[ccxliii] R. Otto, *op. cit.*, p.114.
[ccxliv] R. Otto, *op. cit.* p 7.
[ccxlv] R. Otto, *op. cit.* p 17.
[ccxlvi] Consequently, deviations from the Algorithmic rule are strenuously avoided.
[ccxlvii] Shakespeare, *Hamlet*, Act III, Sc. I.
[ccxlviii] G. A. Clark, *Science* **282**, 1047 (1998).
[ccxlix] Of course, not only by 'primitive' humans!
[ccl] And, last but not least, death is also always in the future.

[ccli] R. Otto, *op. cit.* p. 27.
[cclii] *Ibid.* p. 27.
[ccliii] *Ibid,* p. 28.
[ccliv] Otto cites Luther's *Great Catechism:* "To have a God is nothing else than to trust Him from the heart".
[cclv] R. Otto, *op. cit.* p.46.
[cclvi] *Ibid.* p. 46-47.
[cclvii] *Ibid.* p. 59.
[cclviii] W. Burkert, *op. cit.*, p. 82.
[cclix] *Ibid*, p. 92.
[cclx] *Ibid*, p. 91.
[cclxi] *Ibid*, p. 95.
[cclxii] E. O. Wilson, *Sociobiology*, Belknap, Harvard, Mass. (1975).
[cclxiii] W. Burkert, *op. cit.* p. 169.
[cclxiv] *Ibid*, p. 170.
[cclxv] Written at a time when the US Congress has considered the impeachment of a US president for perjury!
[cclxvi] References:
Hesiod, *Theogony*, edited with prolegomena and commentary by M. L. West, Clarendon Press, Oxford (1966).
Hesiod, *Works and Days*, edited with prolegomena and commentary by M. L. West, Clarendon Press, Oxford (1978).
[cclxvii] For instance, the important manuscript *Bodleianus Clarkianus,* one of the most ancient source for Plato, is dated to the end of the 9th century AD, almost 1,300 years after its original composition!
[cclxviii] The meaning of this term is described in chapter 11.
[cclxix] A beautiful alabaster vase, now in the State Antiquities Org., Baghdad, approx. one meter in height.
[cclxx] T. Jacobsen, *The Treasures of Darkness, A History of Mesopotamian Religion,* Yale University Press, New Haven and London (1976), page 73. Hereafter, quotations from this book will be indicated as TD, followed by the page number.
[cclxxi] TD 96.
[cclxxii] TD 97.
[cclxxiii] TD 107.
[cclxxiv] TD 121.
[cclxxv] TD 168.
[cclxxvi] TD *ibid*.
[cclxxvii] TD 191.
[cclxxviii] Written in Akkadian, almost perfectly preserved, the stele originally comprised 44 columns running around the stone comprising over 3,000 lines.
[cclxxix] Quoted in M. Jastrow, *Aspects of Religious Belief and Practice in Babylonia and Assyria,* G. P. Putnam's Sons, New York and London (1911), p. 387.
[cclxxx] Short bibliography:
J. Bottéro, *Mésopotamie, L'écriture, la raison et les dieux,* Gallimard, Paris (1987).
J. Bottéro, *La plus vielle religion, En Mésopotamie*, Gallimard, Paris (1998).
M. Eliade, *Le mythe de l'éternel retour,* Gallimard, Paris (1969).
H. Frankfort, *Kingship and the Gods, A study of Ancient Near Eastern Religion as the Integration of Society and Nature,* University of Chicago Press, Chicago and London (1948, 1978).
T. Jacobsen, *The Treasures of Darkness, A History of Mesopotamian Religion,* Yale University Press, New Haven and London (1976).
T. Jacobsen, *The Harps that once... Sumerian poetry in translation,* Yale University Press, New Haven and London (1987).
M. Jastrow, *Aspects of Religious Belief and Practice in Babylonia and Assyria,* Putnam, New York and London (1911).
H.-P. Müller, ed., *Babylonien und Israel*, Wissenschaftliche Buchgesellschaft, Darmstadt (1991).
H. J. Nissen, *Grundzüge einer Geschichte der Frühzeit des Vorderen Orients*, Wissenschaftliche Buchgesellschaft, Darmstadt (1983).
G. Roux, *La Mésopotamie,* Seuil, Paris (1995).
W. von Soden, *Einführung in die Altorientalistik,* Wissenschaftliche Buchgesellschaft, Darmstadt (1985).

[cclxxxi] P. W. Price, *Evolutionary biology of parasites,* Princeton University Press, Princeton (1980).

[cclxxxii] G. A. Lozano, *Adv. Study Behav*. **27**, 291-317 (1998).
[cclxxxiii] J. Klein, *Immunology*, Oxford University Press, Oxford (1990), I. Roitt, J. Brostoff & D. Male, *Immunology*, 4th edn, Mosby, London (1996), D. Wakelin, *Immunology to parasites*, 2nd edn., Cambridge University Press, Cambridge (1996).
[cclxxxiv] A. A. Freitas & B. Rocha, *Science* **277**, 1950 (1997).
[cclxxxv] A. R. McLean, M. M. Rosado, F. Agenes, R. Vasconcellos & A. A. Freitas, *Proc. Natl. Acad. Sci. USA* **94**, 5792-5797 (1997).
[cclxxxvi] R. K. Chandra & P. M. Newberne, *Nutrition, immunity, and infection*, Plenum Press, New York (1977), M. E. Gershwin, R. S. Beach & L. S. Hurley, *Nutrition and immunity*, Academic Press, Orlando (1985).
[cclxxxvii] J. E. Blalock, *Immunologist* **2**(1), 8-15 (1994).
[cclxxxviii] V. Apanius, *Adv. Study Behav*. **27**, 133-153 (1998)
[cclxxxix] The find of six complete flutes carved from bones and dated in the range 7000-5700 BC has recently been reported by J. Zhang *et al*., *Nature* **401**, 366-368 (1999)
[ccxc] F. H. Rauscher, G. L. Shaw & K. N. Ky, *Nature* **365**, 611 (1993). However, see C. Stough, B. Kerkin, T. Bates & G. Mangan, *Pers. Ind. Diff*. **17**, 695 (1994).
[ccxci] W. E. Kershaw, G. W. H. Leytham & G. Dickerson, *Ann. trop. Med. Parasitol*. **53**, 504-506 (1959), J. D. Kvalsvik, *Parasitol. Today* **4**, 206-208 (1988), J. D. Kvalsvik, R. M. Cooppan & K. J. Connolly, *Ann. trop. Med. Parasitol*. **85**, 551-568 (1991), C. Nokes, S. M. Grantham-McGregor, A. W. Sawyer, E. S. Cooper, B. A. Robinson & D. A. Bundy, *Parasitol*. **104**, 47-60 (1992). See also Z. S. Dolinsky et al., *Science* **213**, 1142-1144 (1981) for one of many similar studies on rodents.
[ccxcii] C. J. Charnetski, Jr. & F. X. Brennan, *Percept. Motor Skills* **87**, 1163-1170 (1998). See also C. J. Charnetski, G. C. Strand, M. L. Olexa, L. J. Turoczi & J. M. Rinehart, *J. Pennsylvania Acad. Sci*. **5**, 86-90 (1989).
[ccxciii] A. Harrington (ed.), *The placebo effect*, Harvard University Press, Cambridge, Mass. (1997); M. Enserink, *Science* **284**, 238-240 (1999).
[ccxciv] G. A. Lozano, *Adv. Study Behav*. **27**, 291-317 (1998).
[ccxcv] J. B. Moseley, Jr., N. P. Wray, D. Kuykendall, K. Willis & G. Landon, *Am. J. Sports Med*. **24**, 28-34 (1996).
[ccxcvi] I. Kirsch & G. Sapirstein, *Prevention & Treatment* **1**, article 0002a (1998) at http://journals.apa.ord/prevention/. See also the subsequent discussion in D. F. Klein, *Prevention & Treatment* **1**, article 0006c (1998) and I. Kirsch, *Prevention & Treatment* **1**, article 0007r (1998) at http://journals.apa.ord/prevention/.
[ccxcvii] E. M. Palace, *J. Consult. Clin Psychol*. **63**, 604-615 (1995).
[ccxcviii] K. A. Hixson, H. W. Gruchow and D. W. Morgan, *Prev. Med*. **27**, 545-552 (1998). See also Levin & Vanderpool, (1998) and A. Walsh, *Behav. Med*. **24**, 122-130 (1998).
[ccxcix] For depression and religious beliefs, see K. A. Alvarado, D. I. Templer, C. Bresler & S. Dobson-Thomas, *J. Clin. Psychol*. **51**, 202-204 (1995), G. J. Kennedy, H. R. Kelman, C. Thomas & J. Chen, *J. Gerontol. B. Psychol. Sci. Soc. Sci*. **51**, P301-308 (1996), H. G. Koenig, L. K. George & B. L. Peterson, *Am. J. Psychiatry* **155**, 536-542 (1998), M. A. Musick, H. G. Koenig, J. C. Hays & H. J. Cohen, *J. Gerontol. B. Psychol. Sci. Soc. Sci*. **53**, S218-227 (1998) and W. J. Strawbridge, S. J. Shema, R. D. Cohen, R. E. Roberts & G. A. Kaplan, *J. Gerontol. B. Psychol. Sci. Soc. Sci*. **53**, S118-126 (1998). For immune response and religious beliefs, see for example L. Kamen-Siegel, J. Rodin, M. E. Seligman & J. Dwyer, *Health Psychol*. **10**, 229-235 (1991) and H. G. Koenig, H. J. Cohen, L. K. George, J. C. Hays, D. B. Larson & D. G. Blazer, *Int. J. Psychiatry Med*. **27**, 233-250 (1997). See also K. S. Markidis, *J. Gerontol*. **38**, 621-625 (1983), W. J. Strawbridge, R. D. Cohen, S. J. Shema & G. A. Kaplan, *Am. J. Public Health* **87**, 957-961 (1997) and H. G. Koenig & D. B. Larson, *South Med. J.* **91**, 925-932 (1998) as examples of studies demonstrating an association between religion, life satisfaction and life expectancy. Two meta-analyses showing an effect of religion on well-being are D. A. Matthews, M. E. McCullough, D. B. Larson, H. G. Koenig, J. P. Swyers & M. G. Milano, *Arch. Fam. Med.* **7**, 118-124 (1998) and M. E. McCullough, W. T. Hoyt, D. B. Larson, H. G. Koenig & C. Thoresen, *Health Psychol*. **19**, 211-222 (2000).
[ccc] The classic study by W. J. Freeland, *Science* **213**, 416-462 (1982) and many subsequent studies.
[ccci] V. Apanius, *Adv. Study Behav*. **27**, 133-153 (1998).
[cccii] R. Trivers, *Social evolution*, Benjamin/Cummings, Menlo Park (1985).
[ccciii] R. Wiseman & P. Lamont, *Nature* **383**, 212-213 (1996).
[ccciv] C. R. Gur & H. A. Sackeim, *J. Pers. Soc. Psychol*. **37**, 147-169 (1979).
[cccv] P. Ekman, *Telling lies: Clues to deceit in the marketplace, politics, and marriage*, Norton, New York (1985).

[cccvi] Matthew 7: And why beholdest thou the mote that is in thy brother's eye, but considerest not the beam that is in thine own eye?
[cccvii] See note 5.
[cccviii] I. Tessman, *Oikos* **74**, 157-158 (1995).
[cccix] J. Austen, *Pride and Prejudice*, London (1813).
[cccx] C. Wedekind & M. Milinski, *Science* **288**, 850-852 (2000).
[cccxi] R. Trivers & H. P. Newton, *Science Digest*, November 1982, 66-67 and 111 (1983).
[cccxii] G. Roberts & T. N. Sherratt, *Nature* **394**, 175-179 (1998).
[cccxiii] L. D. Jamner & G. E. Schwartz, *Psychosom. Med.* **48**, 211-223 (1986).
[cccxiv] R. M. Nesse & G. C. Williams, *Evolution and healing*, Weidenfeld & Nicolson, London (1995).
[cccxv] D. L. Roth & R. E. Ingram, *J. Pers. Soc. Psychol.* **48**, 243-251 (1985); M. Siegrist, *Psychol. Rep.* **76**, 259-265 (1995).
[cccxvi] M. Siegrist, *Psychol. Rep.* **76**, 259-265 (1995).