

The Systems View of Life

Chapter 8 of the Turning Point - Fritjof Capra

The first obvious difference between machines and organisms is the fact that machines are constructed, whereas organisms grow. This fundamental difference means that the understanding organisms must be process-oriented. For example, it is impossible to convey an accurate picture of a cell by means of static drawings or by describing the rate picture of a cell by means of static drawings or by describing the cell in static forms. Cells, like all living systems, have to be understood in terms of processes reflecting the system's dynamic organization. Whereas the activities of a machine are determined by its structure, the relation is reversed in organisms - organic structure is determined by processes.

Machines are constructed by assembling a well-defined number of parts in a precise and pre-established way. Organisms, on the other hand, show a high degree of internal flexibility and plasticity. The shape of their components may vary within certain limits and no two organisms will have identical parts. Although the organism as a whole exhibits well-defined regularities and behaviour patterns, the relationships between its parts are not rigidly determined. As Weiss has shown with many impressive examples, the behaviour of the individual parts can, in fact, be so unique and irregular that it bears no sign of relevance to the order or the whole system. This order is achieved by co-ordinating activities that do not rigidly constrain the parts but leave room for variation and flexibility, and it is this flexibility that enables living organisms to adapt to new circumstances.

Machines function according to linear chains of cause and effect, and when they break down a single cause for the breakdown can usually identified. In contrast, the functioning of organisms is guided by cyclical patterns of information flow known as feedback loops. For example, component A may affect component B; B may affect C; and C may "feed back" the influence to A and thus close the loop. When such a system breaks down, the breakdown is usually caused by multiple factors that may amplify each other through interdependent feedback loops. Which of these factors that may amplify each other through interdependent feedback loops. Which of these factors was the initial cause of the breakdown is often irrelevant.

This nonlinear interconnectedness of living organisms indicates that the conventional attempts of biomedical science to associate diseases with single causes are highly problematic. Moreover, it shows the fallacy of "genetic determinism," the belief that various physical or mental features of an individual organism are "controlled" or "dictated" by its genetic

makeup. The systems view makes it clear that genes do not uniquely determine the functioning of an organism as cogs and wheels determine the working of a clock. Rather, genes are integral parts of an ordered whole and thus conform to its systemic organisation.

The internal plasticity and flexibility of living systems, whose functioning is controlled by dynamic relations rather than rigid mechanical structures, gives rise to a number of characteristic properties that can be seen as different aspects of the same dynamic principle—the principle of self-organisation. A living organism is a self-organising system, which means that its order in structure and function is not imposed by the environment but is established by the system itself. Self-organising systems exhibit a certain degree of autonomy; for example, they tend to establish their size according to internal principles of organisation, independent of environmental influences. This does not mean that living systems are isolated from their environment; on the contrary, they interact with it continually, but this interaction does not determine their organisation. The two principal dynamic phenomena of self-organisation are self-renewal—the ability of living systems continuously to renew and recycle their components while maintaining the integrity of their overall structure—and self-transcendence—the ability to reach out creatively beyond physical and mental boundaries in the processes of learning, development, and evolution.

The relative autonomy of self-organising systems sheds new light on the age-old philosophical question of free will. From the systems point of view, both determinism and freedom are relative concepts. To the extent that it depends on it through continuous interaction its activity will be shaped by environmental influences. The relative autonomy of organisms usually increases with their complexity, and it reaches its culmination in human beings.

This relative concept of free will seems to be consistent with the views of mystical traditions that exhort their followers to transcend the notion of an isolated self and become aware that we are inseparable parts of the cosmos in which we are embedded. The goal of these traditions is to shed all ego sensations completely and, in mystical experience, merge with the totality of the cosmos. Once such a state is reached, the question of free will seems to lose its meaning. If I am the universe, there can be no "outside" influences and all my actions will be spontaneous and free. From the point of view of mystics, therefore, the notion of free will is relative, limited and - as they would say - illusory, like all other concepts we use in our rational descriptions of reality.

To maintain their self-organization living organisms have to remain in a special state that is not easy to describe in conventional terms. The comparison with machines will again be helpful. A clockwork, for example, is

a relatively isolated system that needs energy to run but does not necessarily need to interact with its environment to keep functioning. Like all isolated systems it will proceed according to the second law of thermodynamics, from order to disorder, until it has reached a state of equilibrium in which all processes - motion, heat exchanged, and so on - have come to a standstill. Living organisms function quite differently. They are open systems, which means that they have to maintain a continuous exchange of energy and matter with their environment to stay alive. This exchange involves taking in ordered structures, such as food, breaking them down and using some of their components to maintain or even increase the order of the organism. This process is known as metabolism. It allows the system to remain in a state of nonequilibrium, in which it is always "at work." A high degree of nonequilibrium is absolutely necessary for self-organisation; living organisms are open systems that continually operate far from equilibrium.

At the same time these self-organising systems have a high degree of stability, and this is where we run into difficulties with conventional language. The dictionary meanings of the word "stable" include "fixed", "not fluctuating", "unvarying," and "steady," all of which are inaccurate to describe organisms. The stability of self-organising systems is utterly dynamic and must not be confused with equilibrium. It consists in maintaining the overall structure in spite of ongoing changes and replacements of its components. A cell, for example, according to Weiss, "retains its identity far more conservatively and remains far more similar to itself from moment to moment, as well as to any other cell of the same strain, than one could ever predict from knowing only about its inventory of molecules, macromolecules, and organelles which is subject to incessant change, reshuffling, and smiling of its population." The same is true for human organisms. We replace all our cells, except for those in the brain, within a few years, yet we have no trouble recognising our friends even after long periods of separation. Such is the dynamic stability of self-organising systems.

The phenomenon of self-organisation is not limited to living matter but occurs also in certain chemical systems, which have been studied extensively by the physical chemist and Nobel laureate Ilya Prigogine, who developed a detailed dynamic theory to describe their behaviour. Prigogine has called these systems "dissipative structures" to express the fact that they maintain and develop structure by breaking down other structures in the process of metabolism, thus creating entropy - disorder - which is subsequently dissipated in the form of degraded waste products. Dissipative chemical structures display the dynamics of self-organisation in its simplest form, exhibiting most of the phenomena characteristic of life - self-renewal, adaptation, evolution, and even primitive forms of "mental" processes. The only reason why they are not considered alive is that they do

not reproduce or form cells. These intriguing systems thus represent a link between animate and inanimate matter. Whether they are called living organisms or not is, ultimately, a matter of convention.

Self-renewal is an essential aspect of self-organising systems. Whereas a machine is constructed to produce a specific product or to carry out a specific task intended by its designer, an organism is primarily engaged in renewing itself; cells are breaking down and building up structures, tissues and organs are replacing their cells in continual cycles. Thus the pancreas replaces most of its cells every twenty-four hours, the stomach lining every three days; our white blood cells are renewed in ten days and 98 percent of the protein in the brain is turned over in less than one month. All these processes are regulated in such a way that the overall pattern of the organism is preserved, and this remarkable ability of self-maintenance persists under a variety of circumstances, including changing environmental conditions and many kinds of interference. A machine will fail if its parts do not work in the rigorously predetermined manner, but an organism will maintain its functioning in a changing environment, keeping itself in running condition and repairing itself through healing and regeneration. The power of regenerating organic structures diminishes with increasing complexity of the organism. Flatworms, polyps, and starfish can regenerate almost their entire body from a small fraction; lizards, salamanders, crabs, lobsters, and many insects are able to renew a lost organ or limb; and higher animals, including humans, can renew tissues and thus heal their injuries.

Even though they are capable of maintaining and repairing themselves, no complex organisms can function indefinitely. They gradually deteriorate in the process of ageing and, eventually, succumb to exhaustion even when relatively undamaged. To survive, these species have developed a form of "super-repair." Instead of replacing the damaged or worn-out parts they replace the whole organism. This, of course, is the phenomenon of reproduction, which is characteristic of all life.

Fluctuations play a central role in the dynamics of self-maintenance. Any living system can be described in terms of interdependent variables, each of which can vary over a wide range between an upper and a lower limit. All variables oscillate between these limits, so that the system is in a state of continual fluctuation, even when there is no disturbance. Such a state is known as homeostasis. It is a state of dynamic, transactional balance in which there is great flexibility; in other words, the system has a large number of options for interacting with its environment. When there is some disturbance, the organism tends to return to its original state, and it does so by adapting in various ways to environmental changes. Feedback mechanisms come into play and tend to reduce any deviation from the balanced state. Because of these regulatory mechanisms, also known as negative feedback, the

body temperature, blood pressure, and many other important conditions of higher organisms remain relatively constant even when the environment changes considerably. However, negative feedback is only one aspect of self-organisation through fluctuations. The other aspect is positive feedback, which consists in amplifying certain deviations rather than damping them. We shall see that this phenomenon plays a crucial role in the processes of development, learning, and evolution.

The ability to adapt to a changing environment is an essential characteristic of living organisms and of social systems. Higher organisms are usually capable of three kinds of adaptation, which come into play successively during prolonged environmental changes. A person who goes from sea level to a high altitude may begin to pant and her heart may race. These changes are swiftly reversible; descending the same day will make them disappear immediately. Adaptive changes of this kind are part of the phenomenon of stress, which consists of pushing one or several variables of the organism to their extreme values. As a consequence the system as a whole will be rigid with respect to these variables and thus unable to adapt to further stress, which consists of pushing one or several variables of the organism to their extreme values. As a consequence the system as a whole will be rigid with respect to these variables and thus unable to adapt to further stress. For example, the person at high altitude will not be able to run up a staircase. Furthermore, since all variables in the system are interlinked, a rigidity in one will also affect the others, and the loss of flexibility will spread through the system.

If the environmental change persists, the organism will go through a further process of adaptation. Complex physiological changes take place among the more stable components of the system to absorb the environmental impact and restore flexibility. Thus the person at high altitude will be able to breathe normally again after a certain period of time and to use her panting mechanism for adjusting to other emergencies that might otherwise be lethal. This form of adaptation is known as somatic change. Acclimzation, habit-forming, and addiction are special cases of this process.

Through somatic change the organism recaptures some of its flexibility by substituting a deeper and more enduring change for a more superficial and reversible one. Such an adaptation will be achieved comparatively slowly and will be slower to reverse. Yet somatic changes are still reversible. This means that various circuits of the biological system must be available for such a reversal for the entire time during which the change is maintained. Such a prolonged loading of circuits will limit the organism's freedom to control other functions and thus seduce its flexibility. Although the system is more flexible after the somatic change than it was before, when it was under stress, it is still less flexible than it was before the original stress occurred. Somatic change, then, internalises stress, and the

accumulation of such internalised stress may, eventually, lead to illness.

The third kind of adaptation available to living organisms is the adaptation of the species in the process of evolution. The changes brought about by mutation, also known as genotypic changes, are totally different from somatic changes. Through genotypic change a species adapts to the environment by shifting the range of some of its variables, and notably of those which result in the most economical changes. For example, when the climate gets colder an animal will grow thicker fur rather than just running around more to keep warm. Genotypic change provides more flexibility than somatic change. Since every cell contains a copy of the new genetic information, it will behave in the changed manner without needing any messages from surrounding tissues and organs. Thus more circuits of the system will remain open and the overall flexibility is increased. On the other hand, genotypic change is irreversible within the lifetime of an individual.

The three modes of adaptation are characterised by increasing flexibility and decreasing reversibility. The quickly reversible stress reaction will be replaced by somatic change in order to increase flexibility under continuing stress, and evolutionary adaptation will be induced to further increase flexibility when the organism has accumulated so many somatic changes that it becomes too rigid for survival. Thus successive modes of adaptation restore as much as possible the flexibility that the organism has lost under environmental stress. The flexibility of an individual organism will depend on how many of its variables are kept fluctuating within their tolerance limits; the more fluctuations, the greater the stability of the organism. For populations of organisms the criterion corresponding to flexibility is variability. Maximum genetic variation within a population provides the maximum number of possibilities for evolutionary adaptation.

The ability of species to adapt to environmental changes through genetic mutations has been studied extensively and very successfully in our century, together with the mechanisms of reproduction and heredity. However, these aspects represent only one side of the phenomenon of evolution. The other side is the creative development of new structures and functions without any environmental pressure, which is inherent in all living organisms. The Darwinian concepts, therefore, express only one of two complementary views that are both necessary in understanding evolution. Discussion of the view of evolution as an essential manifestation of self-organising systems will be easier if we first take a closer look at the relation between organisms and their environment.

As the notion of an independent physical entity has become problematic in subatomic physics, so has the notion of an independent organism in biology. Living organisms, being open systems, keep themselves alive and functioning

through intense transactions with their environment, which itself consists partially of organisms. Thus the whole biosphere - our planetary ecosystem - is a dynamic and highly integrated web of living and nonliving forms. Although this web is multilevel, transactions and interdependencies exist among all its levels.

Most organisms are not only embedded in ecosystems but are complex ecosystems themselves, containing a host of smaller organisms that have considerable autonomy and yet integrate themselves harmoniously into the functioning of the whole. The smallest of these living components show an astonishing uniformity, resembling one another quite closely throughout the living world, as vividly described by Lewis Thomas.

There they are, moving about in my cytoplasm.....They are much less closely related to me than to each other and to the free-living bacteria out under the hill. They feel like strangers, but the thought comes that the same creatures, precisely the same, are out there in the cells of seagulls, and whales, and dune grass, and seaweed, and hermit crabs, and further inland in the leaves of the beech in my backyard, and in the family of skunks beneath the back fence, and even in that fly on the window. Through them, I am connected: I have close relatives, once removed, all over the place.

Although all living organisms exhibit conspicuous individuality and are relatively autonomous in their functioning, the boundaries between organism and environment are often difficult to ascertain. Some organisms can be considered alive only when they are in a certain environment; others belong to larger systems that behave more like an autonomous organism than its individual members; still other collaborate to build large structures which become ecosystems supporting hundreds of species.

In the world of microorganisms, viruses are among the most intriguing creatures, existing on the borderline between living and nonliving matter. They are only partly self-sufficient, alive only in a limited sense. Viruses are unable to function and multiply outside of living cells. They are vastly simpler than any microorganism, the simplest among them consisting of just a nucleic acid, DNA or RNA. In fact, outside of cells viruses show no apparent signs of life. They are simply chemicals, exhibiting highly complex but completely regular molecular structures. In some cases it has even been possible to take viruses apart, purify their components, and then put them back together again without destroying their capacity to function.

Although isolated virus particles are just assemblages of chemicals, they consist of chemical substances of a very special kind - the proteins and nucleic acids that are the essential constituents of living matter. In viruses these substances can be studied in isolation, and it was such studies that led molecular biologists to some of their greatest discoveries

in the 1950s and 1960s. Nucleic acids are chainlike macro-molecules that carry information for self-replication and protein synthesis. When a virus enters a living cell it is able to use the cell's biochemical machinery to build new virus particles according to the instructions encoded in its DNA or RNA. A virus, therefore, is not an ordinary parasite which takes nourishment from its host to live and reproduce itself. Being essentially a chemical message, it does not provide its own metabolism, nor can it perform many other functions characteristic of living organisms. Its only function is to take over the cell's replication machinery and use it to replicate new virus particles. This activity takes place at a frantic rate. Within an hour an infected cell can produce thousands of new viruses and in many cases the cell will be destroyed in the process. Since so many virus particles are produced by a single cell, a virus infection of a multicelled organism can rapidly destroy a great number of cells and thus lead to disease. Although the structure and functioning of viruses is now well known, their basic nature still remains intriguing. Outside living cells a virus particle cannot be called a living organism; inside a cell it forms a living system together with the cell, but one of a very special kind. It is self-organising, but the purpose of its organization is not the stability and survival of the entire virus-cell system. Its only aim is the production of new viruses that will then go on to form living systems of this peculiar kind in the environments provided by other cells.

The special way in which viruses exploit their environment is an exception in the living world. Most organisms integrate themselves harmoniously into their surroundings, and some of them reshape their environment in such a way that it becomes an ecosystem capable supporting large numbers of animals and plants. The outstanding example of such ecosystem-building organisms are corals, which for a long time were thought to be plants but are more appropriately classified as animals. Coral polyps are tiny multicellular organisms that join to form large colonies and, as such, can grow massive skeletons of limestone. Over long periods of geological time many of these colonies have grown into huge coral reefs, which represent by far the largest structures created by living organisms on earth. These massive structures support innumerable bacteria, plants, and animals; encrusting organisms living on top of the coral framework, fishes and invertebrates hiding in its nooks and crannies, and various other creatures that cover virtually all the available space on the reef. To build these densely populated ecosystems the coral polyps function in a highly coordinated way, sharing nervous networks and reproductive capabilities to such an extent that it is often difficult to consider them individual organisms.

Similar patterns of coordination exist in tightly knit animal societies of higher complexity. Extreme examples are the social insects - bees, wasps, ants, termites, and others - that form colonies whose members are interdependent and in such close contact that the whole system resembles a

large, multicreasured organism. Bees and ants are unable to survive in isolation, but in great numbers they act almost like the cells of a complex organism with a collective intelligence and capabilities for adaptation far superior to those of its individual members. This phenomenon of animals joining up to form larger organismic systems is not limited to insects but can also be observed in several other species, including, of course, the human species. Close coordination of activities exists not only among individuals of the same species but also among different species, and again the resulting living systems have the characteristics of single organisms. Many types of organisms that were thought to represent well-defined biological species have turned out, upon close examination, to consist of two or more different species in intimate biological association. This phenomenon, known as symbiosis, is so widespread throughout the living world that it has to be considered a central aspect of life. Symbiotic relationships are mutually advantageous to the associated partners, and they involve animals, plants, and microorganisms in almost every imaginable combination. Many of these may have formed their union in the distant past and evolved toward ever more interdependence and exquisite adaptation to one another.

Bacteria frequently live in symbiosis with other organisms in way that makes both their own lives and the lives of their hosts dependent on the symbiotic relationship. Soil bacteria, for example, alter the configurations of organic molecules so that they become usable for the energy needs of plants. To do so the bacteria incorporate themselves so intimately into the roots of the plants that the two are almost indistinguishable. Other bacteria live in symbiotic relationships in the tissues of higher organisms, especially in the intestinal tracts of animals and humans. Some of these intestinal microorganisms are highly beneficial to their hosts, contributing to their nutrition and increasing their resistance to disease.

At an even smaller scale, symbiosis takes place within the cells of higher organisms and is crucial to the organization of cellular activities. Most cells contain a number of organelles, which perform specific functions and until recently were thought to be molecular structures built by the cell. But it now appears that some organelles are organisms in their own right. The mitochondria, for example, which are often called the powerhouses of the cell because they fuel almost all cellular energy systems, contain their own genetic material and can replicate independently of the replication of the cell. They are permanent residents in all higher organisms, passed on from generation to generation and living in inmate symbiosis within each cell. Similarly, the chloroplasts of green plants which contain the chlorophyll and the apparatus for photosynthesis are independent, self-replicating inhabitants in the plant's cells.

The more one studies the living world the more one comes to realise that the

tendency to associate, establish links, live inside one another and cooperate is an essential characteristic of living organisms. As Lewis Thomas has observed, "We do not have solitary beings. Every creature is, in some sense, connected to and dependent on the rest. Larger networks of organisms from ecosystems, together with various inanimate components linked to the animals, plants, and microorganisms through an intricate web of relations involving the exchange of matter and energy in continual cycles. Like individual organisms, ecosystems are self-organizing and self-regulating systems in which particular populations of organisms undergo periodic fluctuations. Because of the nonlinear nature of the pathways and interconnections within an ecosystem, any serious disturbance will not be limited to a single effect but is likely to spread through the system and may even be amplified by its internal feedback mechanisms.

In a balanced ecosystem animals and plants live together in a combination of competition and mutual dependency. Every species has the potential of undergoing an exponential population growth but these tendencies are kept in check by various controls and interactions. When the system is disturbed, exponential "runaways" will start to appear. Some plants will turn into "weeds" and some animals into "pests," and other species will be exterminated. The balance, or health, of the whole system will be threatened. Explosive growth of this kind is not limited to ecosystems but occurs also in single organisms. Cancers and other tumours are dramatic examples of pathological growth.

Detailed study of ecosystems over the past decades has shown quite clearly that most relationships between living organisms are essentially co-operative ones, characterised by coexistence and interdependence, and symbiotic in various degrees. Although there is competition, it usually takes place within a wider context of cooperation, so that the larger system is kept in balance. Even predator-prey relationships that are destructive for the immediate prey are generally beneficial for both species. This insight is in sharp contrast to the views of the Social Darwinists, who saw life exclusively in terms of competition, struggle, and destruction. Their view of nature has helped create a philosophy that legitimates exploitation and the disastrous impact of our technology on the natural environment. But such a view has no scientific justification, because it fails to perceive the integrative and cooperative principles that are essential aspects of the ways in which living systems organise themselves at all levels.

As Thomas has emphasised, even in cases where there have to be winners and losers the transaction is not necessarily a combat. For example, when two individuals of a certain species of corals find themselves in place where there is room for only one, the smaller of the two will always disintegrate, and it will do so by means of its own autonomous mechanisms: "he is not thrown out, not outgamed, not outgunned; he simply chooses to bow out."

Excessive aggression, competition, and destructive behaviour are predominant only in the human species and have to be dealt with in terms of cultural values rather than being "explained" pseudoscientifically as inherently natural phenomena.

Many aspects of the relationships between organisms and their environment can be described very coherently with the help of the systems concept of stratified order, which has been touched upon earlier. The tendency of living systems to form multileveled structures whose levels differ in their complexity is all-pervasive throughout nature and has to be seen as a basic principle of self-organization. At each level of complexity we encounter systems that are integrated, self-organising wholes consisting of smaller parts and, at the same time, acting as parts of larger wholes. For example, the human organism contains organ systems composed of several organs, each organ being made up of tissues and each tissue made up of cells. The relations between these systems levels can be represented by a "systems tree".

As in a real tree, there are interconnections and interdependencies between all systems levels; each level interacts and communicates with its total environment. The trunk of the systems tree indicates that the individual organism is connected to larger social and ecological systems, which in turn have the same tree structure.

At each level the system under consideration may constitute an individual organism. A cell may be part of a tissue by may also be a microorganism which is part of an ecosystem, and very often it is impossible to draw a clear-cut distinction between these descriptions. Every sub-system is a relatively autonomous organism while also being a component of a larger organism; it is a "holon," in Arthur Koestler's term, manifesting both the independent properties of wholes and the dependent properties of parts. Thus the pervasiveness or order in the universe takes on a new meaning; order at one systems level is the consequence of self-organization at a larger level.

From an evolutionary point of view it is easy to understand why stratified, or multileveled, systems are so widespread in nature. They evolve much more rapidly and have much better chances of survival than nonstratified systems, because in cases of severe disturbances they can decompose into their various subsystems without being completely destroyed. Nonstratified systems, on the other hand, would totally disintegrate and would have to start evolving again from scratch. Since living systems encounter many disturbances during their long history of evolution, nature has sensibly favoured those which exhibit stratified order. As a matter of fact, there seem to be no records of survival of any others. The multileveled structure of living organisms, like any other biological structure, is a visible manifestation of the underlying processes of self-organization. At each

level there is a dynamic balance between self-assertive and integrative tendencies, and all holons act as interfaces and relay stations between systems levels. Systems theorists sometimes call this pattern of organization hierarchical, but that word may be rather misleading for the stratified order observed in nature. The word "hierarchy" referred originally to the government of the Church. Like all human hierarchies, this ruling body was organized into a number of ranks according to levels of power, each rank being subordinate to one at the level above it. In the past the stratified order of nature has often been misinterpreted to justify authoritarian social and political structures.

To avoid confusion we may reserve the term "hierarchy" for those fairly rigid systems of domination and control in which orders are transmitted from the top down. The traditional symbol for these structures has been the pyramid. By contrast, most living systems exhibit multileveled patterns of organization characterized by many intricate and nonlinear pathways along which signals of information and transaction propagate between all levels, ascending as well as descending. That is why I have turned the pyramid around and transformed it into a tree, a more appropriate symbol for the ecological nature of stratification in living systems. As a real tree takes its nourishment through both its roots and its leaves, so the power in a systems tree flows in both directions, with neither end dominating the other and all levels interacting in interdependent harmony to support the functioning of the whole.

The important aspect of the stratified order in nature is not the transfer of control but rather the organization of complexity. The various systems levels are stable levels of differing complexities, and this makes it possible to use different descriptions for each level. However, as Weiss has pointed out, any "level" under consideration is really the level of the observer's attention; The new insight of subatomic physics also seems to hold for the study of living matter; the observed patterns of matter are reflections of patterns of mind.

The concept of stratified order also provides the proper perspective on the phenomenon of death. We have seen that self-renewal - the breaking down and building up of structures in continual cycles - is an essential aspect of living systems. But the structures that are continually being replaced are themselves living organisms. From their point of view the self-renewal of the larger system is their own cycle of birth and death. Birth and death, therefore, now appear as a central aspect of self-organization, the very essence of life. Indeed, all living things around us renew themselves all the time. "If you stand in a meadow," Thomas writes, "at the edge of a hillside and look around carefully, almost everything you can catch sight of is in the process of dying." But for every organism that dies another one is born. Death, then, is not the opposite of life but an essential aspect of

it.

Although death is a central aspect of life, not all organisms die. Simple one-celled organisms, such as bacteria and amoebae, reproduce by cell division and in doing so simply live on in their progeny. The bacteria around today are essentially the same that populated the earth billions of years ago, but they have branched into innumerable organisms. This kind of life without death was the only kind of life for the first two-thirds of evolutionary history. During that immense time span there is no ageing and no death, but there was not much variety either - no higher life forms and no self-awareness. Then, about a billion years ago, the evolution of life went through an extraordinary acceleration and produced a great variety of forms. To do so, "life had to invent sex and death," as Leonard Shlain put it. "Without sex there could be no variety, without death no individuality." From then on higher organisms would age and die and individuals would pair their chromosomes in sexual reproduction, thus generating enormous genetic variety which made evolution proceed several thousand times faster.

Stratified systems evolved along with these higher life forms, systems that renew themselves at all levels and thus maintain ongoing cycles of birth and death for all organisms throughout the tree structure. And beings in the living world. Since we too are born and are bound to die, does this mean that we are parts of larger systems that continually renew themselves? Indeed, this seems to be the case. Like all other living creatures we belong to ecosystems and we also form our own social systems. Finally, at an even larger level, there is the biosphere, the ecosystem of the entire planet, upon which our survival is utterly dependent. We do not usually consider these larger systems as individual organisms like plants, animals, or people, but a new scientific hypothesis does just that at the largest accessible level. Detailed studies of the ways in which the biosphere seems to regulate the chemical composition of the air, the temperature on the surface of the earth, and many other aspects of the planetary environment have led the chemist James Lovelock and the microbiologist Lynn Margulis to suggest that these phenomena can be understood only if the planet as a whole is regarded as a single living organism. Recognising that their hypothesis represents a renaissance of a powerful ancient myth, the two scientists have called it the Gaia hypothesis, after the Greek goddess of the earth.

Awareness of the earth as alive, which played an important role in our cultural past, was dramatically revived when astronauts were able, for the first time in human history, to look at our planet from outer space. Their perception of the planet in all its shining beauty - a blue and white globe floating in the deep darkness of space - moved them deeply and, as many of them have since declared, was a profound spiritual experience that forever changed their relationship to the earth. The magnificent photographs of the "Whole Earth" which these astronauts brought back became a powerful new

symbol for the ecology movement and may well be the most significant result of the whole space program.

What the astronauts, and countless men and women on earth before them, realised intuitively is now being confirmed by scientific investigations, as described in great detail in Lovelock's book. The planet is not only teeming with life but seems to be a living being in its own right. All the living matter on earth, together with the atmosphere, oceans, and soil, forms a complex system that has all the characteristic patterns of self-organization. It persists in a remarkable state of chemical and thermodynamic nonequilibrium and is able, through a huge variety of processes, to regulate the planetary environment so that optimal conditions for the evolution of life are maintained.

For example, the climate on earth has never been totally unfavourable for life since living forms first appeared, about four billion years ago. During that long period of time the radiation from the sun increased by at least percent. If the earth were simply a solid inanimate object, its surface temperature would follow the sun's energy output, which means that the whole earth would have been a frozen sphere for more than a billion years. We know from geological records that such adverse conditions never existed. The planet maintained a fairly constant surface temperature throughout the evolution of life, much as a human organism maintains a constant body temperature in spite of varying environmental conditions.

Similar patterns of self-regulation can be observed for other environmental properties, such as the chemical composition of the atmosphere, the salt content of the oceans, and the distribution of trace elements among plants and animals. All these are regulated by intricate cooperative networks that exhibit the properties of self-organising systems. The earth, then, is a living system; it functions not just like an organism but actually seems to be an organism - Gaia, a living planetary being. Her properties and activities cannot be predicted from the sum of her parts; every one of her tissues is linked to every other tissue and all of them are mutually interdependent; her many pathways of communication are highly complex and nonlinear; her form has evolved over billions of years and continues to evolve. These observations were made within a scientific context, but they go far beyond science. Like many other aspects of the new paradigm, they reflect a profound ecological awareness that is ultimately spiritual.

The systems view of living organisms is difficult to grasp from the perspective of classical science because it requires significant modifications of many classical concepts and ideas. The situation is not unlike the one encountered by physicists during the first three decades of this century, when they were forced to adopt drastic revisions of their basic concepts of reality to understand atomic phenomena. This parallel is

further enforced by the fact that the notion of complementarity, which was so crucial in the development of atomic physics, also seems to play an important role in the new systems biology.

Besides the complementarity of self-assertive and integrative tendencies, which can be observed at all levels of nature's stratified systems, living organisms display another pair of complementary dynamic phenomena that are essential aspects of self-organization. One of them, which may be described loosely as self-maintenance, includes the processes of self-renewal, healing, homeostasis, and adaptation. The other, which seems to represent an opposing but complementary tendency, is that of self-transformation and self-transcendence, a phenomenon that expresses itself in the processes of learning, development, and evolution. Living organisms have an inherent potential for reaching out beyond themselves to create new structures and new patterns of behaviour. This creative reaching out into novelty, which in time leads to an ordered unfolding of complexity, seems to be a fundamental property of life, a basic characteristic of the universe which is not - at least for the time being - amenable to further explanation. We can, however, explore the dynamics and mechanisms of self-transcendence in the evolution of individuals, species, ecosystems, societies, and cultures.

The two complementary tendencies of self-organising systems are in continual dynamic interplay, and both of them contribute to the phenomenon of evolutionary adaptation. To understand this phenomenon, therefore, two complementary descriptions will be needed. One will have to include many aspects of neo-Darwinian theory, such as mutation, the structure of DNA, and the mechanisms of reproduction and heredity. The other description must not deal with the genetic mechanisms but with the underlying dynamics of evolution, whose central characteristic is not adaptation but creativity. If adaptation alone were the core of evolution, it would be hard to explain why living forms ever evolved beyond the blue-green algae, which are perfectly adapted to their environment, unsurpassed in their reproductive capacities, and have proved their fitness for survival over billions of years.

The creative unfolding of life toward forms of ever increasing complexity remained an unsolved mystery for more than a century after Darwin, but recent study has outlined the contours of a theory of evolution that promises to shed light on this striking characteristic of living organisms. This is a systems theory that focuses on the dynamics of self-transcendence and is based on the work of a number of scientists from various disciplines. Among the main contributors are the chemist Ilya Prigogine and Manfred Eigen, the biologists Conrad Waddington and Paul Weiss, the anthropologist Gregory Bateson, and the systems theorists Erich Jantsch and Ervin Laszlo. A comprehensive synthesis of the theory has recently been published by Erich Jantsch, who regards evolution as an essential aspect of the dynamics of self-organisation. This view makes it possible to begin to understand

biological, social, cultural and cosmic evolution in terms of the same pattern of systems dynamics, even though the different kinds of evolution involve very different mechanisms. A basic complementarity of descriptions, which is still far from being understood, is manifest throughout the theory, examples being the interplay between adaptation and creation, the simultaneous action of chance and necessity, and the subtle interaction between macro- and micro-evolution.

The basic dynamics of evolution, according to the new systems view, begins with a system in homeostasis - a state of dynamic balance characterised by multiple, interdependent fluctuations. When the system is being disturbed it has the tendency to maintain its stability by means of negative feedback mechanisms, which tend to reduce the deviation from the balanced state. However, this is not the only possibility. Deviations may also be reinforced internally through positive feedback, either in response to environmental changes or spontaneously without any external influence. The stability of a living system is continually tested by its fluctuations, and at certain moments one or several of them may become so strong that they drive the system over an instability into an entirely new structure, which we again see fluctuating and relatively stable. The stability of living systems is never absolute. It will persist as long as the fluctuations remain below a critical size, but any system is always ready to transform itself, always ready to evolve. This basic model of evolution, worked out for chemical dissipative structures by Prigogine and his collaborators, has since been applied successfully to describe the evolution of various biological, social, and ecological systems.

There are a number of fundamental differences between the new systems theory of evolution and the classical neo-Darwinian theory. The classical theory sees evolution as moving toward an equilibrium state, with organisms adapting themselves ever more perfectly to their environment. According to the systems view, evolution operates far from equilibrium and unfolds through an interplay of adaptation and creation. Moreover, the systems theory takes into account that the environment is, itself, a living system capable of adaptation and evolution. Thus the focus shifts from the evolution of an organism to the coevolution of organism plus environment. The consideration of such mutual adaptation and coevolution was neglected in the classical view, which has tended to concentrate on linear, sequential processes and to ignore transaction phenomena that are mutually conditioning and going on simultaneously.

Jacques Monod saw evolution as a strict sequence of chance and necessity, the chance of random mutations and the necessity of survival. Chance and necessity are also aspects of the new theory, but their roles are quite different. The internal reinforcement of fluctuations and the way the system reaches a critical point may occur at random and are unpredictable, but once

such a critical point has been reached the system is forced to evolve into a new structure. Thus chance and necessity come into play simultaneously and act as complementary principles. Moreover, the unpredictability of the whole process is not limited to the origin of the instability. When a system becomes unstable, there are always at least two new possible structures into which it can evolve. The further the system has moved from equilibrium, the more options will be available. Which of these options is chosen is impossible to predict; there is true freedom of choice. As the system approaches the critical point, it "decides" itself which way to go, and this decision will determine its evolution. The totality of possible evolutionary pathways must be imagined as a multiforked graph with free decisions at each branching point.

The picture shows that the evolution is basically open and indeterminate. There is no goal in it, or purpose, and yet there is a recognisable pattern of development. The details of this pattern are unpredictable because of the autonomy living systems possess in their evolution as in other aspects of their organisation. In the systems view the process of evolution is not dominated by "blind chance" but represents an unfolding of order and complexity that can be seen as a kind of learning process, involving autonomy and freedom of choice.

Since the days of Darwin, scientific and religious views about evolution have often been in opposition, the latter assuming that there was some general blueprint designed by a divine creator, the former reducing evolution to a cosmic game of dice. The new systems theory accepts neither of these views. Although it does not deny spirituality and can even be used to formulate the concept of a deity, as we shall see below, it does not allow for a pre-established evolutionary plan. Evolution is an ongoing and open adventure that continually creates its own purpose in a process whose detailed outcome is inherently unpredictable. Nevertheless, the general pattern of evolution can be recognised and is quite comprehensible. Its characteristics include the progressive increase of complexity, coordination, and interdependence; the integration of individuals into multileveled systems; and the continual refinement of certain functions and patterns of behaviour. As Ervin Laszlo sums it up, "There is a progression from multiplicity and chaos to oneness and order."

In classical science nature was seen as a mechanical system composed of basic building blocks. In accordance with this view, Darwin proposed a theory of evolution in which the unit of survival was the species, the subspecies, or some other building block of the biological world. But a century later it has become quite clear that the unit of survival is not any of these entities. What survives is the organism-in-its-environment. An organism that thinks only in terms of its own survival will invariably destroy its environment and, as we are learning from bitter experience, will

thus destroy itself. From the systems point of view the unit of survival is not at entity at all, but rather a pattern of organisation adopted by an organism in its interactions with its environment; or, as neurologist Robert Livingston has expressed it, the evolutionary selection process acts on the basis of behaviour.

In the history of life on earth, the coevolution of , microcosm and macrocosm is of particular importance. Conventional accounts of the origin of life usually describe the build-up of higher life forms in microevolution and neglect the macroevolutionary aspects. But these two are complementary aspects of the same evolutionary process, as Jantsch has emphasised. From one perspective microscopic life creates the macroscopic conditions for its further evolution; from the other perspective the macroscopic biosphere creates its own microscopic life. The unfolding of complexity arises not from adaptation of organisms to a given environment but rather from the coevolution of organism and environment at all systems levels.

When the earliest life forms appeared on earth around four billion years ago-half a billion years after the formation of the planet-they were single-celled organisms without a cell nucleus that looked rather like some of today's bacteria. These so-called prokaryotes lived without oxygen, since there was little or no free oxygen in the atmosphere. But almost as soon as the microorganisms originated they began to modify their environment and create the macroscopic conditions for the further evolution of life. For the next two billion years some prokaryotes produced oxygen through photosynthesis, until it reached its present levels of concentration in the earth's atmosphere. Thus the stage was set for the emergence of more complex, oxygen-breathing cells that would be capable of forming cell tissues and multicellular organisms.

The next important evolutionary step was the emergence of eukaryotes, single-celled organisms with a nucleus contained the organism's genetic material in its chromosomes. It was these cells that later on formed multicellular organisms. According to Lynn Margulis, co-author of the Gaia hypothesis, eukaryotic cells originated in a symbiosis between several prokaryotes that continued to live on as organelles within the new type of cell. We have mentioned the two kinds of organelles - mitochondria and chloroplasts-that regulate the complementary respiration requirements of animals and plants. These are nothing but the former prokaryotes, which still continue to manage the energy household of the planetary Gaia system, as they have done for the past four billion years.

In the further evolution of life, two steps enormously accelerated the evolutionary process and produced an abundance of new forms. The first was the development of sexual reproduction, which introduced extraordinary genetic variety. The second step was the emergence of consciousness, which

made it possible to replace the genetic mechanisms of evolution with more efficient social mechanisms, based upon conceptual thought and symbolic language.

To extend our systems view of life to a description of social and cultural evolution, we will deal first with the phenomena of mind and consciousness. Gregory Bateson proposed to define mind as a systems phenomenon characteristic of living organisms, societies, and ecosystems, and he listed a set of criteria which systems have to satisfy for mind to occur. Any system that satisfies those criteria will be able to process information and develop the phenomena we associate with mind thinking, learning, memory, for example. In Bateson's view, mind is a necessary and inevitable consequence of a certain complexity which begins long before organisms develop a brain and a higher nervous system.

Bateson's criteria for mind turn out to be closely related to those characteristics of self-organizing systems which I have listed above as the critical differences between machines and living organisms. Indeed, mind is an essential property of living systems. As Bateson said, "Mind is the essence of being alive." From the systems point of view, life is not a substance or a force, and mind is not an entity interacting with matter. Both life and mind are manifestations of the same set of systemic properties, a set of processes that represent the dynamics of self-organization. This new concept will be of tremendous value in our attempts to overcome the Cartesian division. The description of mind as a pattern of organization, or a set of dynamic relationships, is related to the description of matter in modern physics. Mind and matter no longer appear to belong to two fundamentally separate categories, as Descartes believed, but can be seen to represent merely different aspects of the same universal process.

Bateson's concept of mind will be useful throughout our discussion, but to remain closer to conventional language I shall reserve the term "mind" for organisms of high complexity and will use "mentation," a term meaning mental activity, to describe the dynamics of self-organization at lower levels. This terminology was suggested some years ago by the biologist George Coghill, who developed a beautiful systemic view of living organisms and of mind well before the advent of systems theory. Coghill distinguished three essential and closely interrelated patterns of organization in living organisms: structure, function, and mentation. He saw structure as organization in space, function as organization in time, and mentation as a kind of organization which is intimately interwoven with structure and function at low levels of complexity but goes beyond space and time at higher levels. From the modern systems perspective, we can say that mentation, being the dynamics of self-organization, represents the organization of all functions and is thus a meta-function. At lower levels

it will often look like behavior, which can be defined as the totality of all functions, and thus the behaviorist approach is often successful at these levels. But at higher levels of complexity mentation can no longer be limited to behaviour, as it takes on the distinctive nonspatial and nontemporal quality that we associate with mind.

In the systems concept of kind, mentation is characteristic not only of individual organisms but also of social and ecological systems. As Bateson has emphasized, mind is immanent not only in the body but also in the pathways and messages outside the body. There are larger manifestations of mind of which our individual minds are only subsystems. This recognition has very radical implications for our interactions with the natural environment. If we separate mental phenomena from the larger systems in which they are immanent and confine them to human individuals, we will see the environment as mindless and will tend to exploit it. Our attitudes will be very different when we realize that the environment is not only alive but also mindful, like ourselves.

The fact that the living world is organized in multileveled structure means that there are also levels of mind. In the organism, for example there are various levels of "metabolic" mentation involving cells, tissues, and organs, and then there is the "neural" mentation of the brain, which itself consists of multiple levels corresponding to different stages of human evolution. The totality of these mentations constitutes what we would call the human mind. Such a notion of mind as a multileveled phenomenon, of which we are only partly aware in ordinary states of consciousness, is widespread in many non-Western cultures and has recently been studied extensively by some Western psychologists.

In the stratified order of nature, individual human minds are embedded in the larger minds of social and ecological systems, and these are integrated into the planetary mental system - the mind of Gaia-which in turn must participate in some kind of universal or cosmic mind. The conceptual framework of the new systems approach is in no way restricted by associating this cosmic mind with the traditional idea of God. In the words of Jantsch, "God is not the creator, but the mind of the universe." In this view the deity is, of course, neither male or female, nor manifest in any personal form, but represents nothing less than the self-organizing dynamics of the entire cosmos.

The organ of neural mentation - the brain and its nervous system - is a highly complex, multileveled, and multidimensional living system that has remained deeply mysterious in many of its aspects in spite of several decades of intensive research in neuroscience. The human brain is a living system par excellence. After the first year of growth no new neurons are produced, yet plastic changes will go on for the rest of its life. As the environment

changes, the brain models itself in response to these changes, and any time it is injured the system makes very rapid adjustments. You can never wear it out; on the contrary, the more you use it the more powerful it becomes.

The major function of neurons is to communicate with one another by receiving and transmitting electrical and chemical impulses. To do so, each neuron has developed numerous fine filaments that branch out to make connection with other cells, thus establishing a vast and intricate network of communication which interweaves tightly with the muscular and skeletal systems. Most neurons are engaged in continual spontaneous activity, sending out a few pulses per second and modulating the patterns of their activity in various ways to transmit information. The entire brain is always active and alive, with billions of nervous impulses flashing through its pathways every second.

The nervous systems of higher animals and humans are so complex and display such a rich variety of phenomena that any attempt to understand their functioning in purely reductionistic terms seems quite hopeless. Indeed, neuroscientists have been able to map out the structure of the brain in some detail and have clarified many of its electrochemical processes, but they have remained almost completely ignorant about its integrative activities. As in the case of evolution, it would seem that two complementary approaches are needed: a reductionist approach to understand the detailed neural mechanisms, and a holistic approach to understand the integration of these mechanisms into the functioning of the entire system. So far there have been very few attempts to apply the dynamics of self-organizing systems to neural phenomena, but those currently undertaken have brought some encouraging results. In particular, the significance of regular fluctuations in the process of perception, in the form of frequency patterns, has received considerable attention.

Another interesting development is the discovery that the two complementary modes of description which seem to be required to understand the nature of living systems are reflected in the very structure and functioning of our brains. Research over the last twenty years [to the mid '80's] has shown consistently that the two hemispheres of the brain tend to be involved in opposite but complementary functions. The left hemisphere, which controls the right side of the body, seems to be more specialised in analytic, linear thinking, which involves processing information sequentially; the right side hemisphere, controlling the left side of the body, seems to function predominantly in a holistic mode that is appropriate for synthesis and tends to process information more diffusely and simultaneously.

The complementary modes of functioning have been demonstrated dramatically in a number of "split-brain" experiments involving epileptic patients whose corpus callosum, the band of fibres that normally connects the two

hemispheres, had been cut. These patients showed some striking anomalies. For example, with closed eyes they could describe an object they were holding in their right hand but could only make a guess if the object was held in the left hand. Similarly, the right hand could still write but could no longer draw pictures, whereas the opposite was the case for the left. Other experiments indicated that the different specialisations of the two sides of the brain represented preferences rather than absolute distinctions, but the general picture was confirmed.

In the past, brain researchers often referred to the left hemisphere as the major, and to the right as the minor hemisphere, thus expressing our culture's Cartesian bias in favour of rational thought, quantification, and analysis. Actually the preference for the "left-brain" or "right-hand" values is much older than the Cartesian worldview. In most European languages the right side is associated with the good, the just, and the virtuous, the left side with evil, danger, and suspicion. The very word "right" also means "correct", "appropriate", "just", whereas "sinister", which is the Latin word for "left", conveys the idea of something evil and threatening. The German for "law" is Recht, and the French droit, both of which also mean "right". Examples of this kind can be found in virtually all Western languages and probably in others as well. The deep-rooted preference for the right side - the one controlled by the left brain - in so many cultures makes one wonder whether it may not be related to the patriarchal value system. Whatever its origins may be, there have recently been attempts to promote more balanced views of brain functioning and to develop methods for increasing one's mental faculties by stimulating and integrating the functioning of both sides of the brain.

The mental activities of living organisms from bacteria to primates can be discussed fairly consistently in terms of patterns of self-organisation, without the need to modify one's language very much as one moves up the evolutionary ladder in the direction of increasing complexity. But with the human organisms things become quite different. The human mind is able to create an inner world that mirrors the outer reality but has an existence of its own and can move an individual or a society to act upon the outer world. In human beings this inner world - the psychological realm - unfolds as an entirely new level and involves a number of phenomena that are characteristic of human nature. They include self-awareness, conscious experience, conceptual thought, symbolic language, dreams, art, the creation of culture, a sense of values, interest in the remote past, and concern for the distant future. Most of these characteristics exist in rudimentary form in various animal species. In fact, there seems to be no single criterion that would allow us to distinguish humans from other animals. What is unique about human nature is a combination of characteristics foreshadowed in lower forms of evolution but integrated and developed to a high level of sophistication only in the human species.

In our interactions with our environment there is a continual interplay and mutual influence between the outer world and our inner world. The patterns we perceive around us are based in a very fundamental way on the patterns within. Patterns of matter mirrored patterns of mind, coloured by subjective feelings and values. In the traditional Cartesian view it was assumed that every individual had basically the same biological apparatus and that each of us, therefore, had access to the same "screen" of sensory perception. The differences were assumed to arise from the subjective interpretation of the sensory data; they were due, in the well-known Cartesian metaphor, to the "little man looking at the screen". Recent neurophysiological studies have shown that this is not so. The modification of sensory perception by past experiences, expectations, and purposes occurs not only in the interpretation but begins at the very outset, at the "gates of perception". Numerous experiments have indicated that the registration of data by the sense organs will be different for different individuals before perception is experienced. These studies show that the psychological aspects of perception cannot be separated from the psychological aspects of interpretation. Moreover the new view of perception also blurs the conventional distinction between sensory and extrasensory perception - another vestige of Cartesian thinking - by showing that all perception is, to some extent, extrasensory.

Our responses to the environment, then, are determined not so much by the direct effect of external stimuli on our biological system but rather by our past experience, our expectations, our purposes, and the individual symbolic interpretation of our perceptual experience. The faint smell of a perfume may evoke joy or sorrow, pleasure or pain, through its association with past experience, and our response will vary accordingly. Thus the inner and outer worlds are always interlinked in the functioning of a human organism; they act upon each other and evolve together.

As human beings, we shape our environment very effectively because we are able to represent the outer world symbolically, to think conceptually, and to communicate our symbols, concepts, and ideas. We do so with the help of abstract language, but also nonverbally through painting, music and other forms of art. In our thinking and communication we not only deal with the present but can also refer to the past and anticipate the future, which gives us a degree of autonomy far beyond anything found in any other species. The development of abstract thinking, symbolic language, and the various other human capabilities all depend crucially on a phenomenon that is characteristic of the human mind. Human beings possess consciousness; we are aware not only of our sensations but also of ourselves as thinking and experiencing individuals.

The nature of consciousness is a fundamental existential question that has

fascinated men and women throughout the ages and has re-emerged as a topic of intensive discussions among experts from various disciplines, including psychologists, physicists, neuroscientists, artists and representatives of mystical traditions. These discussions have often been very stimulating but have also created considerable confusion, because the term "consciousness" is being used in different senses by different people. It can mean subjective awareness, for example when conscious and unconscious activities are compared, but also self-awareness, which is the awareness of being aware. The term is also used by many in the sense of the totality of mind, with its many conscious and unconscious levels. And the discussion is further complicated by the recent strong interest in Eastern "psychologies" that have developed elaborate maps of the inner realm and use a dozen or more terms to describe its various aspects, all of them usually translated as "mind" or "consciousness".

In view of this situation, we need to specify carefully the sense in which the term "consciousness" is being used. The human mind is a multileveled and integrated pattern of processes that represent the dynamics of human self-organisation. Mind is a pattern of organisation, and awareness is a property of mentation at any level, from single cells to human beings, although of course, differing very widely in scope. Self-awareness, on the other hand, seems to manifest itself only in higher animals, unfolding fully in the human mind, and it is this property of mind that I mean by consciousness. The totality of the human mind, with its conscious and unconscious realms, I shall call, with Jung, the psyche.

Because the systems view of mind is not limited to individual organisms but can extend to social and ecological systems, we may say that groups of people, societies, and cultures have a collective mind, and therefore possess a collective consciousness. We may also follow Jung in the assumption that the collective mind, or collective psyche, also includes a collective unconscious. As individuals we participate in these collective mental patterns, are influenced by them, and shape them in turn. In addition the concepts of a planetary mind and a cosmic mind may be associated with the planetary and cosmic levels of consciousness.

Most theories about the nature of consciousness seem to be variations on either of two opposing views that may nevertheless be complementary and reconcilable in the systems approach. One of these views may be called the Western scientific view. It considers matter as primary and consciousness as a property of complex material patterns that emerges at a certain stage of biological evolution. Most neuroscientists today (88) subscribe to this view. The other view of consciousness may be called the mystical view, since it is generally held in mystical traditions. It regards consciousness as the primary reality and the ground of all being. In its purest form, consciousness, according to this view, is non-material, formless, and void

of all content; it is often described as "pure consciousness", "ultimate reality", "suchness" and the like. This manifestation of pure consciousness is associated with the Divine in many spiritual traditions. It is said to be the essence of the universe and to manifest itself in all things; all forms of matter and all living beings are seen as forms of divine consciousness.

The mystical view of consciousness is based upon the experience of reality in non-ordinary modes of awareness, which are traditionally achieved through meditation but may also occur spontaneously in the process of artistic creation and in various other contexts. Modern psychologists have come to call non-ordinary experiences of this kind "transpersonal" because they seem to allow the individual mind to make contact with collective and even cosmic mental patterns. According to numerous testimonies, transpersonal experiences involve a strong, personal, and conscious relation to reality which goes far beyond the present scientific framework. We should therefore not expect science, at its present stage, to confirm or contradict the mystical view of consciousness. Nevertheless, the systems view of mind seems perfectly consistent with both the scientific and mystical views of consciousness, and thus to provide the ideal framework for unifying the two.

The systems view agrees with the conventional scientific view that consciousness is a manifestation of complex material patterns. To be more precise, it is a manifestation of living systems of a certain complexity. On the other hand, the biological structures of these systems are expressions of underlying processes that represent the system's self-organisation, and hence its mind. In this sense material structures are no longer considered as primary reality. Extending this way of thinking to the universe as a whole, it is not too far-fetched to assume that all its structures - from the subatomic particles to galaxies and from bacteria to human beings - are manifestations of the universe's self-organising dynamics, which we have identified with the cosmic mind. But this is almost the mystical view, the only difference being that mystics emphasise the direct experience of cosmic consciousness that goes beyond the scientific approach. Still, the two approaches seem to be quite compatible. The systems view of nature at last seems to provide a meaningful scientific framework for approaching the age-old questions of the nature of life, mind, consciousness and matter.

To understand human nature we study not only its physical and psychological dimensions but also its social and cultural manifestations. Human beings evolved as social animals and cannot keep well, physically or mentally, unless they remain in contact with other human beings. More than any other social species we engage in collective thinking, and in doing so we create a world of culture and values that becomes an integral part of our natural environment. Thus biological and cultural characteristics of human nature cannot be separated. Humankind emerged through the very process of creating culture and needs this culture for survival and further evolution.

Human evolution, then, progresses through an interplay of inner and outer worlds, individuals and societies, nature and culture. All these realms are living systems in mutual interaction that display similar patterns of self-organisation. Social institutions evolve toward increasing complexity and differentiation, not unlike organic structures, and mental patterns exhibit the creativity and urge for self-transcendence that is characteristic of all life. It is the nature of the mind to be creative", observes the painter Gordon Onslow-Ford. "The more the depths of the mind are plumbed, the more abundantly they produce."

According to generally accepted anthropological findings, the anatomical evolution of human nature was virtually completed some fifty thousand years ago. Since then the human body and brain have remained essentially the same in structure and size. On the other hand, the conditions of life have changed profoundly during this period and continue to change at a rapid pace. To adapt to these changes the human species used its faculties of consciousness, conceptual thought, and symbolic language to shift from genetic evolution to social evolution, which takes place much faster and provides far more variety. However, this new kind of adaptation was by no means perfect. We still carry around biological equipment from the very early stages of our evolution that often makes it difficult for us to meet the challenges of today's environment. The human brain, according to Paul Maclean's theory, consists of three structurally different parts, each endowed with its own intelligence and subjectivity, which stem from different periods of our evolutionary past. Although the three parts are intimately linked, their activities are often contradictory and difficult to integrate, as Maclean shows in a picturesque metaphor: "Speaking allegorically of these three brains within a brain, we might imagine that when the psychiatrist bids the patient to lie on the couch, he is asking him to stretch out beside a horse and a crocodile."

The innermost parts of the brain, known as the brain stem, is concerned with the instinctive behaviour patterns already exhibited by reptiles. It is responsible for biological drives and many kinds of compulsive behaviour. Surrounding this part is the limbic system (from the Latin *limbus* ... border) which is well developed in all mammals and, in the human brain, is evolved with emotional experience and expression. The two inner parts of the brain, also known as the subcortex, are strongly interconnected and express themselves nonverbally through a rich spectrum of body language. The outermost part, finally, is the neocortex which facilitates higher-order abstract functions, such as thought and language. The neocortex originated in the earliest evolutionary phase of mammals and expanded in the human species at an explosive rate, unprecedented in the history of evolution, until it became stabilised about fifty thousand years ago.

By developing our capacity for abstract thinking at such a rapid pace, we seem to have lost the important ability to ritualise social conflicts. Throughout the animal world aggression rarely develops to the point where one of the two adversaries is killed. Instead, the fight is ritualised and usually ends with the loser conceding defeat but remaining relatively unharmed. This wisdom disappeared, or at least was deeply submerged, in the emergent human species. In the process of creating an abstract inner world we seem to have lost touch with the realities of life and have become the only creatures who often fail to co-operate with and even kill their own kind. The evolution of consciousness has given us not only the Cheops Pyramid, the Brandenburg Concertos and the Theory of Relativity, but also the burning of witches, the Holocaust, and the bombing of Hiroshima. But that same evolution of consciousness gives us the potential to live peacefully and in harmony with the natural world in the future. Our evolution continues to offer us freedom of choice. We can consciously alter our behaviour by changing our values and attributes to regain the spirituality and ecological awareness we have lost.

In the future elaboration of the new holistic world view, the notion of rhythm is likely to play a very fundamental role. The systems approach has shown that living organisms are intrinsically dynamic, their visible forms being stable manifestations of underlying processes. Process and stability, however, are compatible only if the processes form rhythmic patterns - fluctuations, oscillations, vibrations, waves. The new systems biology shows that fluctuations are crucial in the dynamics of self-organisation. They are the basis of order in the living world: ordered structures arise from rhythmic patterns.

The conceptual shift from structure to rhythm may be extremely useful in our attempts to find a unifying description of nature. Rhythmic patterns seem to be manifest at all levels. Atoms are patterns of probability waves, molecules are vibrating structures, and organisms are multidimensional, interdependent patterns of fluctuations. Plants, animals, and human beings undergo cycles of activity and rest, and all their physiological functions oscillate in rhythms of various periodicities. The components of ecosystems are interlinked through the cyclical exchanges of matter and energy; civilisations rise and fall in evolutionary cycles, and the planet as a whole has its rhythms and recurrences as it spins on its axis and moves around the sun.

Rhythmic patterns, then, are a universal phenomenon, but at the same time they allow individuals to express their distinctive personalities. The manifestation of a unique personal identity is an important characteristic of human beings, and it appears that this identity may be, essentially, an identity of rhythm. Human individuals can be recognised by their characteristic speech patterns, body movements, gestures, breathing, all of

which represent different kinds of rhythmic patterns. In addition, there are many "frozen" rhythms, like one's fingerprints or handwriting, that are uniquely associated with individuals. These observations indicate that the rhythmic patterns that characterise an individual human being are different manifestations of the same personal rhythm, an "inner pulse" which is the essence of personal identity.

The crucial role of rhythm is not limited to self-organisation and self-expression but extends to sensory perception and communication. When we see, our brain transforms the vibrations of light into rhythmic pulsations of its neurons. Similar transformations of rhythmic patterns occur in the process of hearing, and even the perception of odor seems to be based on "osmic frequencies". The Cartesian notion of separate objects and our experience with cameras have led us to assume that our senses create some kind of internal picture that is a faithful reproduction of reality. But this is not how sensory perception works. Pictures of separate objects exist only in our world of symbols, concepts, and ideas. The reality around us is an ongoing rhythmic dance, and our senses translate some of its vibrations into frequency patterns that can be processed by the brain.

The importance of frequencies in perceptions has been emphasised especially by the neuropsychologist Karl Pibram, who has developed a holographic model of the brain in which visual perception is carried out through an analysis of frequency patterns and visual memory is organised like a hologram. Pibram believes this explains why visual memory cannot be precisely localised within the brain. As in a hologram, the whole is encoded in each part. At present the validity of the hologram for a model of visual perception is not firmly established, but it is useful at least as a metaphor. Its main importance may be its emphasis on the fact that the brain does not store its information locally but distributes it very widely, and, from a broader perspective, on the conceptual shift from structures to frequencies.

Another intriguing aspect of the holographic metaphor is a possible relation to two ideas in modern physics. One of them is Geoffrey Chew's idea of subatomic particles being dynamically composed of one another in such a way that each of them involves all the others; the other idea is David Bohm's notion of implicate order, according to which all of reality is enfolded in each of its parts. What all these approaches have in common is the idea that holonomy - the whole being somehow contained in each of its parts - may be a universal property of nature. This idea has also been expressed in many mystical traditions and seems to play an important role in mystical visions of reality. The metaphor of the hologram has recently inspired a number of researchers and has been applied to various physical and psychological phenomena. Unfortunately, this is not always done with the necessary caution, and the differences between a metaphor, a model, and the real world are sometimes overlooked in the general enthusiasm. The universe

is definitely not a hologram, but it displays a multitude of vibrations of different frequencies, and thus the hologram may often be useful as an analogy to describe the phenomena associated with these vibratory patterns.

As in the process of perception, rhythm also plays an important role in the many ways living organisms interact and communicate with one other. Human communication, for example, takes place to a significant extent through the synchronisation and interlocking of individual rhythms. Recent film analyses have shown that every conversation involves a subtle and largely unseen dance in which the detailed sequence of speech patterns is precisely synchronised not only with minute movements of the speaker's body but also with corresponding movements of the listener. Both partners are locked into an intricate and precisely synchronised sequence of rhythmic movements that lasts as long as they remain attentive and involved in their conversation. A similar interlocking of rhythms seems to be responsible for the strong bonding between infants and their mothers and, most likely, between lovers. On the one hand, opposition, antipathy, and disharmony will arise when the rhythms of two individuals are out of synchrony.

At rare moments in our lives we may feel that we are in synchrony with the whole universe. These moments may occur under many circumstances - hitting a perfect shot at tennis or finding the perfect run down a ski slope, in the midst of a fulfilling sexual experience, in contemplation of a great work of art, or in deep meditation. These moments of perfect rhythm, when everything feels exactly right and things are done with great ease, are high spiritual experiences in which every form of separateness or fragmentation is transcended.

In this discussion of the nature of living organisms we have seen that the systems view of life is spiritual in its deepest essence and thus consistent with many ideas held in mystical traditions. The parallels between science and mysticism are not confined to modern physics but can now extend with equal justification to the new systems biology. Two basic themes emerge again and again from the study of living and non-living matter and are also repeatedly emphasised in the teachings of mystics - the universal interconnectedness and interdependence of all phenomena, and the intrinsically dynamic nature of reality. We also find a number of ideas in mystical traditions that are less relevant, or not yet significant to, modern physics but are crucial to the systems view of living things.

The concept of a stratified order plays a prominent role in many traditions. As in modern science, it involves the notion of multiple levels of reality which differ in their complexities and are mutually interacting and interdependent. These levels include, in particular, levels of mind, which are seen as different manifestations of cosmic consciousness. Although mystical views of consciousness go far beyond the framework of contemporary

science, they are by no means inconsistent with the modern systems concepts of mind and matter. Similar considerations apply to the concept of free will, which is quite compatible with mystical views when associated with the relative autonomy of self-organising systems.

The concepts of process, change and fluctuation, which play such a crucial role in the systems view of living organisms, are emphasised in the Eastern mystical traditions, especially in Taoism. The idea of fluctuations as the basis of order, which Prigogine introduced into modern science, is one of the major themes in all Taoist texts. Because the Taoist sages recognised the importance of fluctuations in their observations of the living world, they also emphasised the opposite but complementary tendencies that seem to be an essential part of life. Among the Eastern traditions Taoism is the one with the most explicit ecological perspective, but the mutual interdependence of all aspects of reality and the nonlinear nature of interconnections are emphasised throughout Eastern mysticism. For example, these are the ideas underlying the Indian concept of karma.

As in the systems view, birth and death are seen by many traditions as stages of endless cycles which represent the continual self-renewal that is characteristic of the dance of life. Other traditions emphasise vibratory patterns, often associated with "subtle energies", and many of them have described the holonomic nature of reality - the existence of "all in each and each in all" - in parables, metaphors, and poetic imagery.

Among Western mystics the one whose thought comes closest to that of the new systems biology is probably Pierre Teilhard de Chardin. Teilhard was not only a Jesuit priest but an eminent scientist who made major contributions to geology and paleontology. He tried to integrate his scientific insights, mystical experiences, and theological doctrines into a coherent world view, which was dominated by process thinking and centered on the phenomenon of evolution. Teilhard's theory of evolution is in sharp contrast to the neo-Darwinian theory but shows remarkable similarities with the new systems theory. Its key concept is what he called the "Law of Complexity-Consciousness" which states that evolution proceeds in the direction of increasing complexity, and that this increase in complexity is accompanied by a corresponding rise of consciousness, culminating in human spirituality. Teilhard uses the term "consciousness" in the sense of awareness and defines it as "the specific effect of organised complexity", which is perfectly compatible with the systems view of mind.

Teilhard also proposed the manifestation of mind in larger systems and wrote that in human evolution the planet is covered with a web of ideas, for which he coined the term "mind layer", or "noosphere" - (from the Greek noos - mind). Finally, he saw God as the source of all being, and in particular as the source of the evolutionary force. In view of the systems concept of God

as the universal dynamics of self-organisation, we can say that among the many images mystics have used to describe the Divine, Teilhard's concept of God, if liberated from its patriarchal connotations, may well be the one that comes closest to the views of modern science.

Teilhard de Chardin has often been ignored, disdained, or attacked by scientists unable to look beyond the reductionist Cartesian framework of their disciplines. However, with the new systems approach to the study of living organisms, his ideas will appear in a new light and are likely to contribute significantly to general recognition of the harmony between the views of science and mystics.