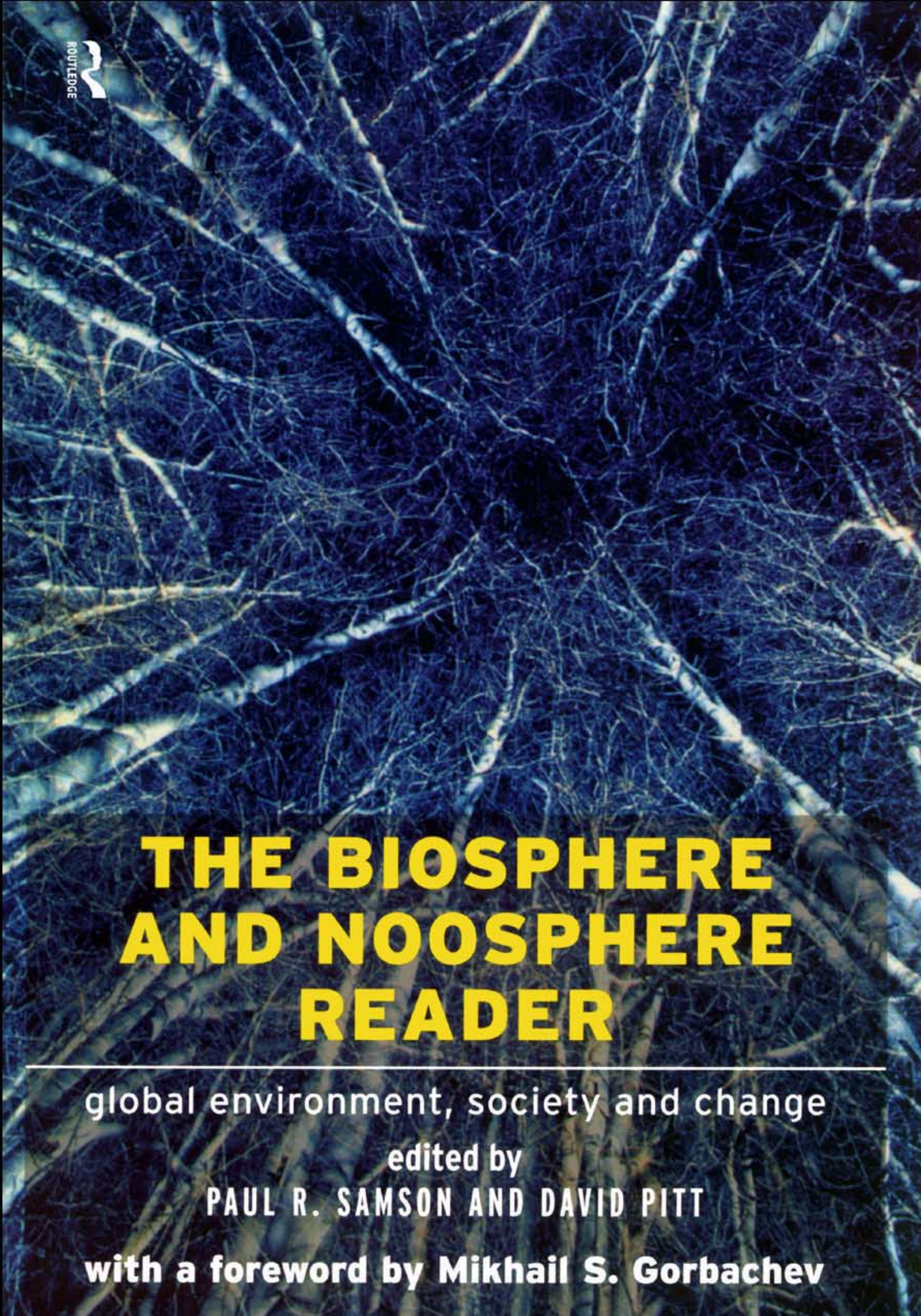

ROUTLEDGE

THE BIOSPHERE AND NOOSPHERE READER

global environment, society and change

edited by
PAUL R. SAMSON AND DAVID PITT

with a foreword by Mikhail S. Gorbachev

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THE BIOSPHERE AND NOOSPHERE READER

Literally the 'sphere of mind or intellect', the noosphere is part of the realm of the possible in human affairs, where there is a conscious effort to tackle global issues. The history of this rich but poorly explored idea has significant contemporary resonance in understanding the evolution of human society and our position in the biosphere (the sphere of life). The noosphere concept captures a number of key contemporary issues—social evolution, global ecology, Gaia, deep ecology and global environmental change—contributing to ongoing debates concerning the implications of emerging technologies such as human-created biospheres and the Internet.

This Reader is the first comprehensive history of the noosphere and biosphere. Drawing on classical influences, modern parallels and insights into the future, the Reader traces the emergence of the concepts of noosphere and biosphere within the context of environmental change. Reproducing material from seminal works, both past and present, the central ideas and key writings of many prominent thinkers are presented, including Bergson, Vernadsky, Lovelock, Margulis, Russell, Needham, Huxley, Medawar, Toynbee and Boulding. Extensive introductory pieces by the editors draw attention to common themes and competing ideas.

The structure of the book focuses on issues of origins, theories, parallels and potential, relating to the noosphere and biosphere concepts. Discussion of origins places issues in a broad context, moving from the emergence of humans as a planetary agent of change to the articulation of specific theories about social evolution. Discussion on parallels compares and contrasts central concepts with those of the Gaia hypothesis, sustainability and global change. Discussion on the potential application of noospheric ideas to current debates about culture, education and technology explores such realms as the Internet, space colonisation, and the emergence of super-consciousness.

The Biosphere and Noosphere Reader is an original contribution to an essential and highly topical debate which is likely to become even more relevant as we enter the twenty-first century. With significant portions of the material appearing here for the first time in English or gathered from inaccessible sources, this Reader offers a unique reference for a variety of scholars, teachers and others with an interest in current global dilemmas.

Paul R.Samson is a Global Environmental Assessment Fellow at the Belfer Center for Science and International Affairs, the Kennedy School of Government, Harvard University.
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FOREWORD

Each successive generation has a tendency to believe itself living through a decisive turning point—a revolutionary moment—in human history. The current one is certainly no exception. Yet, as we enter the twentyfirst century, we are witnessing the emergence of the first truly *global* civilisation. It is a unique era in the history of humankind, not only due to the wondrous material achievements that span our world but equally for the profound risks inherent in such success. Paradoxically, like the period during the French Revolution described in Dickens' *A Tale of Two Cities,* we live, simultaneously, in the best *and* worst of times. It is an era where our technological grasp extends into the farthest reaches of our world—from the quantum level to outer space—yet we do not fully master or comprehend the consequences of our touch. As a society, we tend not to look before we leap, and we employ technology to very different, often contradictory, ends. For example, we rely on miracle drugs created from the diversity of the rain forests, yet we annihilate plant and animal species almost daily. We generate incredible wealth, yet countless numbers of our kind remain destitute. In an era of globalisation, the fantastic and the perilous flow side by side towards an uncertain future.

The dilemmas of globalisation can be captured in contemplating the state of the living world—the biosphere. Since the monumental effort at the United Nations' 'Earth Summit' in 1992, now more than five years past, it appears that little has changed in practical terms. There has been no dramatic step forward, and some would say we have gone backwards. In fact, it has become widely accepted that if we continue to develop along our current trajectory, the consequences may be irreversible changes in the biosphere within a few decades, possibly including the extermination of human beings. Indeed, *Homo sapiens* has likely already overdrawn nature's credit line. There can be no challenge to the objective and immutable laws of our biosphere. The choice for society is clear, and we have not much time to act: we either simply float in rudderless existence and face the grim prospect of scarcity, degradation or worse, or, having drawn our conclusions, undertake the necessary first steps to change our course.

When we speak about living within the limits set by the biosphere, I do not believe that this means that the evolution of humankind must stop at this point. On the contrary, the evolution of society through the development of spirit and culture is not fettered by the physical constraints of the biosphere. However, in the euphoria of our modern success, society has emphasised the material too much, at the expense of the spiritual and cultural. This trend has become even more pronounced since the collapse of communism and the subsequent 'victory' that has been proclaimed in the name of the Western way of life. It is time to recognise that the world has outlived the phase of ideological dichotomy. What is really needed is a new synthesis comprising the valuable elements of many existing perspectives, including liberal and socialist values and individualist and community ideals. On this basis, society will have the capacity to ensure innovation and diversity, but at the same time will not exclude broad social justice and the systematic protection of the biosphere.

Modern civilisation has proved our insatiable need for continuous progress yet is itself in danger of fatal stagnation. How can we ensure progress for the generations to come? One way to build the future is to shape it in the present. Nearly a decade after the end of the Cold War, it is time to get beyond rejoicing the notion that freedom has won over history, and to understand the responsibilities of freedom. We have reached the phase in cultural evolution where we must assume full responsibility for our power. In thinking of the future, we need to remember what the ancients knew: that self-restraint is the most fundamental and wisest aim of a person who is truly free. This is the key to future progress. Knowing and reaching our fullest potential within the constraints of the biosphere must be the ultimate goal, the driving vision of the twenty-first century. And the noosphere concept suggests a philosophy for such a necessary balance.

Mikhail S.Gorbachev

PREFACE

The material in this Reader on the noosphere (the realm of mind or intellect) lies at an intersection where science and philosophy meet, and where the former provides a base for understanding but falls short of definitive answers. It is an interdisciplinary domain of wide interest and high relevance that remains outside the purview of most specialists, but it is of major significance for the future of humankind and the biosphere (the realm of life).

Precisely because a broad definition of the noosphere can imply very different meanings, ranging from a type of human-controlled 'technotopia' to a form of convergence of mind across the universe, it captures the wide debate concerning humanity's place in the biosphere. This issue—the fate of humanity in the biosphere—will surely dominate the background of our existence in the next millennium. We may all be forced to evaluate, or re-evaluate, this relationship. In the set of readings that follow—many of them classics long forgotten, unappreciated or previously unknown in English—we have been careful to choose those that unite cross-cutting elements and which reveal that the noosphere is neither pseudo-science nor new age nirvana, but rather a 'vision of the possible' based on the combination of physical parameters and human potential.

One of the most surprising and interesting findings in this work is the way in which it has grown from a modest origin. As research on this book moved forward it became increasingly obvious that the term 'noosphere' not only had a richer history than we first assumed but also that it is used much more frequently than one might imagine—although rarely as a central theme. In addition, the noosphere appears to be of increasing interest and relevance to many contemporary discussions and issues. For example, a simple search with *Alta Vista* on the Internet in April 1998 revealed 1,955 documents and references for the term noosphere. Comparatively, Harvard University's multi-library database (*Hollis*) revealed only six documents using a similar keyword search. This finding is interesting for at least two reasons. First, it highlights an enormous interest in the noosphere among those who are active on the Internet, many of whom claim it as a useful concept to describe the ultimate evolution of the World-Wide Web into an unprecedented form of super-consciousness. Second, it shows that much of the use of the term 'noosphere' is in secondary literature or at least not in the main titles and keywords of more traditional databases.

Apart from the Internet itself and greater computing power in general, a number of factors might help to explain the exploding interest in noospheric ideas. First, there is a broadening interest in green and holistic ideas implying many links with nature. Second, scientists are demonstrating the enormous complexity of the brain and mind and the possibility of unique quantum processes and as yet unexplained communicative forces, all of which imply a decline of faith in

Cartesian distinctions. Third, as mind assumes more prominence over matter there may be a reviving interest in human capabilities to encourage sustainability through international organisations such as the United Nations, non-governmental organisations and individual self-reliance. These ideas may be seen to be part of a movement that queries the deterministic ideas inherent in Darwinism and neoclassical economics, both of which encourage a basically *laissez-faire* approach to the world. Finally, the awesome efforts of misguided human endeavours continue. This is still evident in the nuclear field —particularly armaments— despite the end of the Cold War.

This book is intended to draw attention to the use of noospheric ideas as promising tools for understanding and action in a complex world, presenting for the first time a systematic exposition of different strands of related ideas. We do not assert that this is a universal panacea for solving emerging world problems but rather that this is a potential first step to creating new approaches that combine a variety of elements, including human reflexivity, spirituality and science.

Finally, it is necessary to add a note on materials. No one can completely escape the bias inherent in selecting materials, and this book is no exception. Work on the noosphere and biosphere is, at least to the present, virtually exclusively male and European (including the former Soviet sphere) in origin. A number of interesting themes such as eco-feminism (e.g. Merchant 1982) and non-Western spirituality (e.g. Aurobindo 1963) certainly have potential linkages to the topics addressed here but are beyond the scope of this book. With such a broad topic at hand, further extension would not have resulted in more clarity. In choosing a narrow focus, we hope that the results fit into the broader landscape of ideas, of which those just mentioned are two important examples.

Paul R.Samson
and
David Pitt
4 May 1998

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1

INTRODUCTION: SKETCHING THE NOOSPHERE

This anthology is intended as a contribution to the history of ideas, or more specifically a single idea—the noosphere. In an era of accelerating change across the globe, we assert that the concept of the noosphere (literally, the sphere of mind or intellect) is an increasingly important part of the debate on the evolution of human society and its position in the biosphere. One current and pressing example concerns what humans are capable of doing in the face of global environmental change (climate change, biodiversity loss, stratospheric ozone depletion, etc.) on a scale and volatility unprecedented at least since the beginning of human civilisation. Finally, as we begin a new millennium, there is a yearning for a new vision of the future. We suggest that the noosphere represents a crucial reference point for such a discussion.

Although the idea of noosphere is not new (the term itself has been in use for more than seventy years), contemporary changes are likely to make it increasingly pertinent. We are witnessing a reassessment of old ideas. Reflecting on the need for a new vision, Harvard biologist E.O.Wilson (1998a: 8) suggests that many thinkers of the Enlightenment were mostly right in their assumptions 'about a lawful material world, the intrinsic unity of knowledge, and the potential for indefinite human progress.' *Time* magazine, in a special issue (1997) entitled 'The New Age of Discovery', drew attention to the relevance of old schools of thought for present and future problems (Boorstin 1997). Old scientific questions continue to be hotly debated. One of the most central questions—the place and role of humans in the Earth's evolution—remains a fundamental issue of discussion. Is *Homo sapiens* merely *primus inter pares*—no more than first among equals in the animal world—or does consciousness and reflexivity set humanity apart from all other species in an unprecedented and fundamental way? Are we guardians or tenants on Earth? Are we masters of our future? These are, of course, perennial philosophical questions, but the complexity of today's computing and information technology has reached a point where we can ask such questions and get answers not considered before. Kevin Kelly, editor of *Wired,* argues a similar point in suggesting that today's new tools, made possible through high technology, enable us to formulate fresh theories for old questions (1998). From this perspective, we find both historical bearing and contemporary resonance in the idea of the noosphere.

The noosphere is variously used but rarely defined. It is employed with some regularity in metaphysical discussions on human evolution and global ecology, and has recently become a favourite term for a nascent form of 'global consciousness' that is said to be emerging through worldwide information networks. The noosphere is described concisely by the British scientist Sir Peter Medawar 'as signifying the realm or domain in which mind is exercised' (1988:588). However, such a strict definition tells us little about the origins or implications. For our purposes, the noosphere may be broadly seen as a process of an increasingly complex intermeshing of cognitive realms within the biosphere—an unfolding of individual and collective ideas, mentalities, aspirations and experience.

At the outset, it is essential to underline that the noosphere concept is intrinsically linked to the notion of a continuously evolving planet Earth. As such, evolution may be conceptualised as consisting of three principal phases, each with a corresponding 'layer': the physical formation of the planet itself (the geosphere), the birth of life (the biosphere) and the emergence of human consciousness and self-reflexivity (the noosphere). Although this last phase—originally conceptualised in French (Le Roy 1928:37–57) as the 'hominisation' of life—is our main focus here, the three phases are part of an inseparable process of planetary evolution that continues to the present. The broad context is therefore one of dynamic flow and interdependence between each of these phases and layers. The crucial issue becomes one of debating different interpretations of these relationships and their implications for society.

The noosphere idea is grounded on a firm physical, scientific foundation. Following the pioneering work of the Russian Vladimir Vernadsky (1924; 1929) on the evolution of global natural systems, the biosphere has become a firmly established concept—albeit with varying degrees of precision—in the natural sciences. In contrast to some of the deterministic ideas often attached to the biosphere, the notion of noosphere places the major importance on cognitive and humanistic processes. The concepts of noosphere and biosphere are nonetheless complementary—necessarily so. They may be seen as different halves of the larger whole, conflicting elements providing a form of balance between the creative world of our imagination and the physical domain of our material existence. In contrast to postmodernist thinking (e.g. Foucault 1982), the idea of the noosphere suggests that mental constructs, although enjoying great latitude, are themselves a product of the biosphere and are therefore inseparable from it.

Although the noosphere idea is a product of the scientific revolution, it implies different approaches to the concept of evolution. In contrast to classical Darwinism, the aim is co-operation rather than competition. Unlike a deep ecologist perspective on life, it is firmly based on anthropocentric principles. The context is emergent and convergent, and there is a sense of continuity that sets it apart from material-based notions. The force behind the notion of 'mind'—a form of dissipative self-organisation—is seen to consist of more than mechanical animation and has been viewed as a possible bridge between science and spirituality. The noosphere idea, however, has not been only theoretical or mystical. There has been a practical side, especially in the senses of global education, environmental management and most recently, global information systems such as the Internet. The United Nations is one form of application of such ideas, especially within that body's Educational, Scientific and Cultural Organisation (UNESCO), whose development was partly inspired by the ideas of the noosphere.

In order to provide a common thread through the readings that follow, we outline four basic senses in which the concept of the noosphere has been, and is being, used. Although these concepts are interrelated and potentially overlapping, each has important distinctions.

1 *The noosphere is a product of the biosphere as transformed by human knowledge and action*. This view asserts that the Earth, over time, is reconstituted through deliberate, large-scale human impacts on the natural environment. The product is a world in which the environment is altered (perhaps detrimentally) but in which human knowledge offers the potential for longer-term sustainable management or even improvement. In this view,

humans have the potential to more or less control their environment, for better or worse. The origins of this perspective may be traced to geology in the latter half of the nineteenth century and the recognition of 'man as a planetary geological agent' — a view that was forcefully elaborated by Vladimir Vernadsky in the 1920s and 1930s. More recently, this view has provided a cornerstone for work on global environmental change and sustainable development (e.g. Clark and Munn 1986). Importantly, this perspective raises the notion of some form of planetary management—the idea of a 'mission to planet Earth' (Malone 1986).

2 *The noosphere represents an ultimate and inevitable sphere of evolution.* In this view, the emergence of *Homo sapiens* as a conscious, self-reflexive being on the planet is as fundamental as the appearance of life itself, and represents a higher plane of evolution, moving beyond Darwinism. From this moment onwards, the Earth is seen to be part of a universal process where intelligent life takes on a new form of existence in which the spiritual takes precedence over the material. The result places humans in a superior position *vis-à-vis* the natural environment. Marxism, particularly as influenced by Frederich Engels, proposed cosmological notions of inevitability and the triumph of the conscious being. The most direct influence, however, has been the strand of thought developed by the Frenchmen Pierre Teilhard de Chardin and Edouard Le Roy in the 1920s as a scientific approach with a bridge to religion. Extending these ideas, some contemporary religious thinkers continue to pursue similar arguments, although they do not claim a scientific base (Marie 1984; Cunningham 1997).

3 *The noosphere is a manifestation of global mind.* This view holds that the noosphere is essentially the sum of all intellectual processes, not necessarily implying rational direction, but subsuming rapidly expanding technological globalisation, notably global computer networks, and possibly foreshadowing a superior form of computer-based artificial intelligence. Emphasis here is on the importance of the sheer volume of interactions and connections—particularly of *information*—between individuals and communities. Marshall McLuhan pointed to the existence of such trends in the early 1960s, largely due to the apparent power of technology to compress the world into a 'global village'. More recent thinkers, many 'new age', have modified and extended this view to different ends, namely the emergence of a 'global brain' (Russell 1982) and super-consciousness through the Internet and global information networks (Mizrach 1997).

4 *The noosphere is the mental sphere in which change and creativity are inherent although essentially unpredictable.* In this view, the world may be altered through conscious human intervention, but such action takes place neither on a predirected path nor with a predetermined outcome. This contrasts with some of the deterministic elements embedded in theories such as Marxist evolution. However, unpredictability does not imply a total lack of human influence. Henri Bergson, who influenced these ideas at the beginning of the century, was a 'prophet of the unpredictable human spirit' (Boorstin 1997:27). Bergson felt this spirit was the life force, or *élan vital*: a 'stream of consciousness' that led to an open and pluralist society, although not limited to the capitalist-based one of subsequent thinkers such as Popper (1991). More recently, the notion of life force—an idea always at the margin of science—has been replaced with the idea of complex, adaptive and emergent systems that are self-organising and perpetuate from their internal dynamics. This view is often described as the 'science of complexity' (Kaufmann 1996).

GENESIS AND FIRST USE OF NOOSPHERE

The etymological roots of the word 'noosphere' can be traced to the Greek *noos* (mind) and Latin *sphœra* (sphere). According to the *Oxford Companion for Classical Literature* (1997:34, 434), Anaxagoras (*c.* 500–428 BC) was the first to point out that mind and intelligence (*nous*) was a major force distinct from matter. The *Oxford English Dictionary* (1978: VII, 178), states that the term 'noetic' has been employed since the seventeenth century to describe 'that which applies to mind'. As early as 1834, the French scientist André-Marie Ampère employed the term *sciences noologiques* in reference to 'the sciences which have as their object the world of the mind' (*Petit Robert* 1982:1,280). This usage was in contrast to the cosmological sciences, which, from the sixteenth century, had been primarily used to describe physical laws of nature. The biosphere stems from the Greek *bios* (life) and was coined by Eduard Suess in 1875. The early roots, although not the explicit use of the term, may be traced to earlier thinkers such as the Frenchman Jean Baptiste Lamarck in his *Hydrologie* (1802). A supplemental discussion and analysis of definitions and origins is presented in Chapter 2.

The actual word 'noosphere' (in French, *noosphere*) was coined in Paris in the 1920s by the French scientist and Jesuit priest Pierre Teilhard de Chardin, his compatriot and philosopher Edouard Le Roy and the Russian geochemist Vladimir I. Vernadsky (the latter of whom appears not to have adopted the term until many years later). Although there has been some confusion over who actually used the term first, Teilhard de Chardin (1956) clearly states that the concept was jointly developed by all three, while confiding to his biographer that 'I believe, so far as one can ever tell, that the word "noosphere" was my invention; but it was he [Le Roy] who launched it' (Cuénot 1965:59). The idea of the noosphere seems to have come to Teilhard de Chardin when he was a non-combatant stretcher bearer amid the horrors of the trenches during the First World War. The discussion of the noosphere in Paris in the early 1920s, a loose circle that included Teilhard de Chardin, Le Roy, Bergson and Vernadsky, reflected deep emotion and revulsion against the horrors of war and strong faith in human potential and in science.

For a number of years in the Soviet literature, Vernadsky was given exclusive credit for inventing the term 'noosphere'. Only after the mid-1980s was the role of non-Soviet influences clearly asserted (Yanshin 1988). Perhaps this can help to explain why much confusion continues over its origins. For example, *Webster's Third New International Dictionary* (1997) incorrectly asserts that the noosphere was 'probably originally formed as the Russian noosfera'. The absence of any comprehensive study of the subject has added to the inconsistencies. In addition, the noosphere concept was frequently and widely used in the Soviet Union as both a scientific and a political idea—not always with clear distinction in its usage. Moreover, the term was often used for conference themes and even the name of research institutes. A number of these institutes remain in operation, such as the Center for Ecological Noosphere Studies at the National Academy of Sciences of the Republic of Armenia (founded in 1989) and the Vernadsky Foundation, which has worked closely with the USSR (and Russian) Academy of Sciences. The principal reason why the concept has not been widely discussed in non-Soviet literature is presumably simple ignorance as well as, during the Cold War, a Western allergy to everything remotely linked to the Soviet Union. This has changed in the late 1990s as a significant, though still small, group of English-speaking thinkers has embraced Vernadsky and the concepts of biosphere and noosphere (e.g. Margulis *et al.* 1998; Margulis and Sagan 1995). Another recent use of'noosphere' —particularly in the United States—has been widely promulgated within 'new age' and 'cyberspace' groups, often with little notion of the original use of the concept. These interesting recent developments are taken up in Chapters 2 and 5.

If Teilhard de Chardin, Le Roy and Vernadsky were similarly inspired to use the concept of the noosphere, they developed it in different ways. Whereas Teilhard de Chardin saw it as a thinking layer above the biosphere, Vernadsky described it in essentially scientific terms as a transformed state of the biosphere. Similarly to Teilhard de Chardin, Le Roy believed that the noosphere represented a higher level of the biosphere, but he placed more emphasis on their intimate and evolving relationship. Both Frenchmen were deeply religious and sought a bridge between science and religion. Details of each of these personalities are taken up in Chapter 3, although their basic ideas on the noosphere are briefly outlined here.

In the first published reference to the noosphere, Le Roy emphasised the inherent link with the living biosphere. He describes a complementary relationship in the following terms:

> I recall our previous discussions on the intrinsic substantiality of change and of the reality of life above that of the mere living. Vitalism, as I describe it, is nothing more than another way to make the same assertion. It is incarnated in the notion of biosphere and its final legitimacy comes from the biosphere's dual link: on the one hand with the sphere of brute matter and on the other with that which must be later called the 'noosphere'; of a type which a thorough study assumes two combined but opposite phases: one physico-chemical and the other psychological.
>
> (Le Roy 1927:246)

In a second book, Le Roy entitled the last chapter 'The Contemporary Crisis', in which he draws attention to the notion of the noosphere as an evolving process, ultimately separating itself from the biosphere and carrying with it both positive and negative potential:

> We are, in truth, confronting a phenomenon of planetary, perhaps cosmic, importance. This new force is human intelligence; the reflexive will of humankind. Through human action, the noosphere disengages itself, little by little, from the biosphere and becomes more and more independent, and all this with rapid acceleration and an amplification of effects which continue to grow. Correlatively however, by a sort of return shock, hominisation has introduced, in the course of life, some formidable risks.
>
> (Le Roy 1928:332)

Teilhard de Chardin's description of the noosphere would seem to be more spiritual than that of Le Roy, underlining a 'psycho-biological' dimension linking mind and spirituality to the physical nature of living systems. In his most famous and widely discussed work, *The Phenomenon of Man,* Teilhard de Chardin (1959:202) defined the noosphere as 'a new layer, the "thinking layer", which since its germination at the end of the Tertiary era, has spread over and above the world of plants and animals. In other words, outside and above the biosphere there is the noosphere.' He draws attention to the idea of an emerging globally reflexive consciousness—creating a 'plurality of individual reflections grouping themselves together and reinforcing one another in the act of a single unanimous reflection' (*ibid.*: 277). The human phenomenon is seen as a manifestation of the universe unfolding on itself and becoming aware of its own existence—akin to a baby seeing itself in the mirror for the first time. He continues as follows:

> Unless we give up all attempts to restore man to his place in the general history of Earth as a whole without damaging him or disorganising it, we must place him above it, without, however, uprooting him from it. And this amounts to imagining, in one way or another, above the animal biosphere a human sphere, the sphere of reflexivity, of conscious invention, of the conscious unity of souls (the noosphere if you will) and to conceiving, at the origin of this new entity, a phenomenon of special transformation affecting pre-existent life: hominisation…. Nothing can be compared with the coming of reflective consciousness except the appearance of consciousness itself.
>
> (Teilhard de Chardin 1966:63)

For Vernadsky, the concept of the noosphere always remained inseparably tied to the biosphere, from which there was no ultimate escape. In spite of his optimistic view of human potential, Vernadsky was therefore cautious in declaring a definitive triumph over nature and knew that humankind could very well destroy itself. In his book *Scientific Thought as a Planetary Phenomenon,* written in the 1930s, he commented:

> Now we are witnessing an extraordinary display of the living matter in the biosphere genetically related to the appearance of *Homo sapiens* hundreds of thousands of years ago, with the creation, owing to that, of a new geological force, scientific thought, which has greatly increased the influence of the living matter, the biosphere's evolution. Being embraced by the living matter, the biosphere seems to increase its geological force to an infinite degree; it seems to also become transformed by the scientific thought of *Homo sapiens* and to pass to its new state—*noosphere*.
>
> (Vernadsky 1997:36)

In the last year of his life, witnessing the destruction of the Second World War, in which at least 20 million Soviet citizens perished, Vernadsky wrote in a final paper, published posthumously in January 1945, that:

> The historical process is being radically changed under our very eyes. For the first time in the history of mankind the interests of the masses on the one hand, and the free thought of individuals on the other, determine the course of life of mankind and provide standards for men's ideas of justice. Mankind taken as a whole is becoming a mighty geological force. There arises the problem of the *reconstruction of the biosphere in the interests of freely thinking humanity as a single totality*. This new state of the biosphere, which we approach without our noticing it, is the *noosphere*.
>
> (Vernadsky 1945:1)

Julian Huxley, one of the founders of the 'modern synthesis' of evolution (Huxley 1944) and a grandson of T.H.Huxley, although not mentioning Vernadsky's work, was well aware of Teilhard de Chardin's. Nevertheless, Huxley developed a view of the noosphere not unlike that of Vernadsky:

> Thus since the advent of man, a new habitat has been opened up to evolving life, a habitat of thought: for this I shall use Teilhard de Chardin's term, the noosphere, until someone invents something better. This covering of the earth's sphericity with a thinking envelope, whose components are interacting with a steadily rising intensity, is now generating a powerful psycho-social pressure favouring a solution of least effort, by way of integration in a unitary organisation of ideas and beliefs. But this will not happen automatically: it can only be achieved by a large-scale co-operative exercise of human reason and imagination.
>
> (Huxley 1963:7)

Le Roy, Teilhard de Chardin and Vernadsky provide a starting point by which to explore the concept of the noosphere in the broader historical and evolutionary context.

BROADER ORIGINS OF THE NOOSPHERE

Important elements behind the noosphere concept are strongly linked to two revolutionary conceptual developments during the nineteenth and early twentieth centuries. First, the influence of Marxism was crucial in describing (and promoting) the force of a progressive and universal social evolution across the globe based on stages and internal dialectical processes—a notion that seemed to be supported by Charles Darwin's monumentally important *Origin of the Species* (1859). Second, the study of planetary biogeochemical cycles (as a forerunner to global ecology) and the recognition of human activity as an integral and growing force in the biosphere emerged during the early part of this century. With the rise of modern science, a growing anthropogenic influence was noted in these natural systems.

The anthropocentric idea that the human species—in one form or another—is ultimately destined to reach a higher plane of existence is a common theme across history and many cultures. In modern times, it may be traced to the nineteenth century ideas of progress and social evolution. Karl Marx (1818–1883) and Friedrich Engels (1820–1895) asserted that human history had at last discovered its own eminent and necessary place in the cosmos as well as an assurance of irreversible progress. *The Communist Manifesto,* first published in 1848, suggested that capitalism proved that the power of ideas had finally conquered the globe: 'The bourgeoisie, by the rapid improvement of all instruments of production, by the immensely facilitated means of communication, draws all, even the most barbarian, nations into civilisation.… In one word, it creates a world after its own image' (Marx and Engels 1985:84). Following the Hegelian lead, Marx built on the proposition that history unfolds according to a predestined, necessary and positive programme. This anthropocentric view was seeming confirmation that human thought was a necessary end-product of the evolutionary process. As Engels put it in *Dialectics of Nature* (1875), humankind provides the means by which nature finally attains consciousness of itself:

> we have the certainty that matter remains eternally the same in all its transformations, that none of its attributes can ever be lost, and therefore, also, that with the same iron necessity that it will exterminate on the earth its highest creations, the thinking mind, it must somewhere else and at another time again produce it.
>
> (Engels 1940:25)

Similar viewpoints, although not necessarily Marxist-inspired or even mainstream, continue through the present. There are also scientific perspectives, which do not view the ultimate future of humanity as inherently doomed by the entropy law, implosion or cometary collision. The physicist Freeman Dyson notes, that the universe—in a manner similar to Gödel's inexhaustible world of pure mathematic—may be 'growing without limit in richness and complexity', with 'life surviving forever' (1979). In *The Anthropological Cosmological Principle,* Barrow and Tipler assert that, according to the age-old notion that they label the 'final anthropic principle', 'Intelligent information-processing must come into existence in the Universe, and, once it comes into existence, it will never die out' (1986:23). Finally, Paul Davies, in his critical analysis of the quest for a theory of everything, also finds broader meaning:

> I cannot believe that our existence in this universe is a quirk of fate, an accident of history, an incidental blip in the great cosmic drama. Our involvement is too intimate. The physical species *Homo* may count for nothing, but the existence of mind in some organism on some planet in the universe is surely a fact of fundamental significance. Through conscious beings the universe has generated self-awareness. This can be no trivial detail, no minor by-product of mindless, purposeless forces. We are truly meant to be here.
>
> (Davies 1992:232)

Many scientists today discard the concept of the noosphere as the work of Teilhard de Chardin has been dismissed. Of Teilhard de Chardin's work, Jacques Monod suggested that 'For my part I am most of all struck by the intellectual spinelessness of this philosophy. In it I see more than anything else a systematic truckling, a willingness to conciliate at any price, to come to any compromise' (1971:32). Similarly, in reviewing *The Phenomenon of Man,* Peter Medawar (1982:242) wrote that the greater part of this book 'is nonsense, tricked out with a variety of metaphysical conceits, and its author can be excused of dishonesty only on the grounds that before deceiving others he has taken great pains to deceive himself. Medawar later softened the harshness of his remarks, declaring that 'with hindsight I do think that I was coarsely insensitive in not reading Teilhard de Chardin's work—or rather in not interpreting its great popularity—as a symptom of hunger, a hunger for answers to questions of the kind that science does not profess to be able to answer (questions that are loftily dismissed by positivists as non-questions or pseudo-questions)' (1982:22). He also later included the concept of the noosphere (attributing it solely to Teilhard de Chardin) in his contribution to the *Fontana History of Modern Thought* (Stallybrass 1988).

Other criticisms of the noosphere have taken a different line, assessing the implications of the concept rather than its scientific base. For example, the ecologist E.P.Odum, in his noted work *Principles of Ecology* (1959:26), enthusiastically embraced Vernadsky's concept of the biosphere but found the 'replacement' of this sphere with the noosphere to be 'a dangerous philosophy because it is based on the assumption that mankind is now wise enough to understand the results of all his actions.' Alternatively, Odum proposed that 'Man's power to change and control seems to be increasing faster than man's realization and understanding of the results of the profound change of which he is now capable.' Along similar lines, brother and fellow ecologist H.T.Odum proposed that the noosphere should be seen as part of an emerging, if tenuous and potentially unmanageable, super-network:

> A noosphere is possible only where and when the power flows of man, or those completely controlled by him, displace those of nature. This kind of dominance over the power of nature is now prevalent in industrialized areas, but these areas survive only because of the purifying stability of the greater areas of the globe not yet so invaded and polluted.
>
> (H.T.Odum 1970:244–5)

Such criticisms raise very relevant questions as to the potential of the noosphere. In *The Arrogance of Humanism* and *Beginning Again,* David Ehrenfeld laments the extent to which society continuously 'forgets' important bits of knowledge despite our impressive technology and pretensions of an ever-expanding knowledge base. He suggests that whether or not the noosphere is desirable or not is beside the point, because we have not, and are not, moving towards the optimistic sense of the term but are instead awash in a sea of unsorted, and therefore often useless, information (Ehrenfeld 1978:239; 1993:187).

Could it be that the nature of the questions raised by the concept of the noosphere (e.g. the limits of reductionist scientific knowledge) more than the work itself causes unease in the minds of some scientists? In addressing this debate, biologist Theodosius Dobzhansky (1974:131) probably came closer to the real issue when he wrote that: 'This makes one wonder: may it be that the attacker feels deep down that his [Monod's] world view fails to provide a purpose for living and an escape from feelings of emptiness and futility,' adding that 'The Teilhardian synthesis is, to many people, more successful in these respects.' Indeed, many of these ideas retain broad interest and support. In *Earth in the Balance* (1992), American Vice President Al Gore cites Teilhard de Chardin's ideas as helpful in understanding the importance of faith in the future. Moreover, associations created specifically to study and promote Teilhard de Chardin's work flourish to this day in several countries, including France, Britain, the USA and the Netherlands.

Teilhard de Chardin's work in particular, and the noosphere in general, is not without its leading scientific supporters, including Julian Huxley, Theodosius Dobzhansky, Joseph Needham, C.H.Waddington and Christian de Duve. Huxley was pleased to write the introduction to *The Phenomenon of Man* for its first translation into English and had Teilhard de Chardin as a confidant during the early period of UNESCO, as well as recommending him to help to design early natural resources work at the United Nations in New York. Christian de Duve (1995a), although not agreeing with all of Teilhard de Chardin's views, ultimately prefers this vision to that of pure and blind chance and necessity. Needham (1959) also embraced Teilhard de Chardin's views and presided over the British Teilhard Society. Barrow and Tipler are clear in their support of the basic ideas underlying the noosphere concept, claiming them to be credible science because if physics (in particular, the second law of thermodynamics) can demolish Teilhard de Chardin's theory, this shows that it is falsifiable and hence scientific (at least in the Popperian sense) just as Teilhard de Chardin had always claimed. Barrow and Tipler go on to explain why they believe that this is so:

> His original theory has been refuted, or perhaps we should say it has become obsolete. However, the basic framework of his theory is really the only framework wherein the evolving Cosmos of modern science can be combined with an ultimate meaningfulness to reality.... if in the end all life becomes extinct, meaning must also disappear.
>
> (1986:202)

Resistance to even considering the noosphere concept is, in our view, due to exaggerated scepticism and, worse, a failure of reflexive thinking. Some scientists hesitate to address such discussions, because of the apparent spiritual or mystical elements involved, much in the same way that serious discussion of the 'Gaia hypothesis' (see Chapter 4) was resisted, and is still resisted. Moreover, the term has been much confused by 'new age' writers, some of whom appear to disregard science altogether. Scientists should be cautious and rigorous in their judgement, just as Thomas Kuhn's ideas on the evolution of scientific paradigms would predict (Kuhn 1962), but they are misguided in being outright dismissive. As Thomas Goudge (1962: 543) notes in direct response to Medawar's powerful critique, the noosphere concept is worth salvaging because it 'might serve as a useful model for anthropologists, sociologists, and psychologists who undertake to theorise about cultural evolution.' Peter Westbroek (1991: 224) offers similar advice, suggesting that 'For the moment, noosphere is only a descriptive term with little scientific meaning…but we lack a comprehensive theory that explains the integration of culture and natural science as a global phenomenon.'

OUTLINE OF THE BOOK

This anthology is divided into four basic sections: origins, theories, parallels and potential. Chapter 2, on origins, presents readings relating to the conceptual revolutions of humankind as an agent of change at the global level, the science of biogeochemistry and the biosphere as a fundamental concept in the development of society. Chapter 3 presents the context in which the original theories of the noosphere were developed and describes some of the key scientists and thinkers involved. Parallels, in Chapter 4, are discussed for Gaia, and global environmental change, revealing a contemporary redevelopment of the concepts of the biosphere and the noosphere. Chapter 5, on potential, focuses on emerging issues and potential manifestations of the noosphere, including the relevance of global information, the development of new 'biospheres' and the institutionalisation of global learning. Finally, the conclusions, Chapter 6, offer reflections on the potential application of noospheric ideas to a number of current issues. Each reading selection is preceded by a brief description of the author and the context in which it was written.

2

ORIGINS: THE BIOSPHERE AND THE NOOSPHERE

According to Le Roy (1928:85), we should seek 'to understand the biosphere by way of the noosphere.' He might well have added 'and *vice versa*'. Indeed, as is stressed throughout this book, the two concepts are inseparable and interdependent. Early promoters of the noosphere concept—Teilhard de Chardin, Le Roy and Vernadsky—all saw the noosphere as a natural extension of the physical nature of the biosphere. All three based their conceptualisation and legitimisation (although in different forms) of the noosphere idea on this physical and scientific base. Since then, scientific evidence that the concept of the biosphere is of paramount importance continues to grow and the idea that living and non-living matter are linked in an intricate, co-evolving web is well-accepted in global ecology and Earth systems science. Particularly important is the remarkable role of micro-organisms as agents of global transformation. No less important is the increasing recognition that how we define and design the role of human society in the biosphere has pressing planetary implications. In some senses, the biosphere concept has emerged as a reality check on human progress: how compatible are our social and cultural ambitions with the physical nature of life on Earth? The readings in this chapter are intended to draw attention to the importance of the physical nature of this concept and to highlight its importance.

A WORLD OF SPHERES

The idea of imagining the world that surrounds us in terms of concentric 'spheres' long dominated cosmology, particularly in Western science (Lerner 1997). At the centre of the innermost sphere has usually been humankind, with knowledge and attention expanding outwards, encompassing one sphere after another. In an example of this thinking, Giovanni Camillo Maffei published the *Scala Naturale* in Venice in 1564, depicting fourteen spheres that contained, layer by layer, the full store of knowledge about the universe. Maffei dedicated his book to the Count of Altavilla, whom he imagined climbing the giant stairway of knowledge as depicted in Figure 2.1 (Ingold 1993:33). The legacy of this thinking remains apparent in the modern Earth and life sciences, although current discussion has often focused on the idea of 'globe' rather than 'sphere'. Tim Ingold suggests an important distinction, noting that 'spheres are defined as layer surfaces that successively *cover over* one another and the world, not as successive horizons disclosed from a centre. And the outer wrapping is none other than the human mind and its products.' It is a transparent view that allows one to discover the world through a kind of 'sensory attunement' or 'education of attention', because

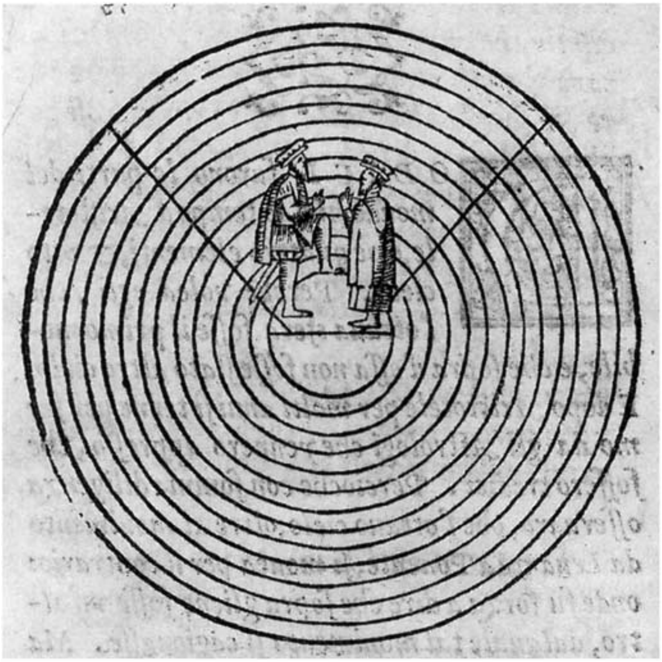

Figure 2.1 The fourteen spheres of knowledge, drawn by Giovanni Camillo Maffei in *Scala Naturale* (1564). Maffei's patron, the Count of Altavilla, is shown taking a first step towards comprehensive knowledge of the universe, attained once all fourteen spheres are mastered

more one explores the more there is to see and learn. In contrast, a globe (representing the Earth) is seen as 'pure substance', as 'an opaque and impenetrable surface of literal reality *upon which* form and meaning are overlaid by the human mind.' A world perceived as a solid globe therefore 'becomes a *tabula rasa* for the inscription of human history' (*ibid*.: 37). Some critics suggest that such a 'global view' leads to a seriously misguided notion of planetary management (e.g. Sachs 1993:18). Indeed, these points are important food for thought throughout this anthology, because these competing conceptions appear frequently.

Following the pioneering use of 'atmosphere' as early as the seventeenth century, a whole slew of 'spheres' were eventually coined to describe the various areas of the terrestrial elements as well as their interactions. The concept of the noosphere is clearly built on the classical geological representation of the Earth as a sequence of concentric, spherical shells or envelopes —the barysphere, lithosphere and biosphere as first described by the Austrian Edward Suess (1875; 1909). In a detailed analysis of the subject, Richard Huggett (1995) identifies no less than a dozen sphere terms that are commonly in use; some with multiple definitions. In addition to the key concepts of biosphere and noosphere, which are our principal subjects, common usage of several of the most relevant spheres is summarised in Box 2.1.

Viewing the world as a set of concentric spheres allows us an attempt to describe graphically what we imagine. The first level is that of imagining the biosphere as a layer that stems imperceptibly from, and remains integrally tied to, the geosphere. One way to see this is to perceive the noosphere as a higher sphere that subsumes the others (Figure 2.2). Alternatively, Figure 2.3 represents a very different notion, that of 'co-evolution': the joint development of the noosphere and the other layers.

> ***Box 2.1* The Earth's spheres**
>
> Atmosphere: the gaseous sphere.
> Hydrosphere: the watery sphere.
> Lithosphere: the solid sphere.
> Geosphere: the combination of the three above.

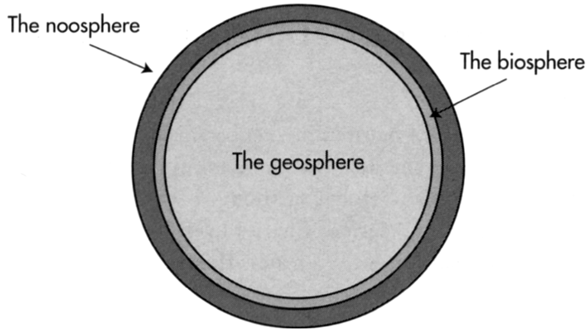

Figure 2.2 The geosphere, biosphere and noosphere. The noosphere appears *over* the other layers

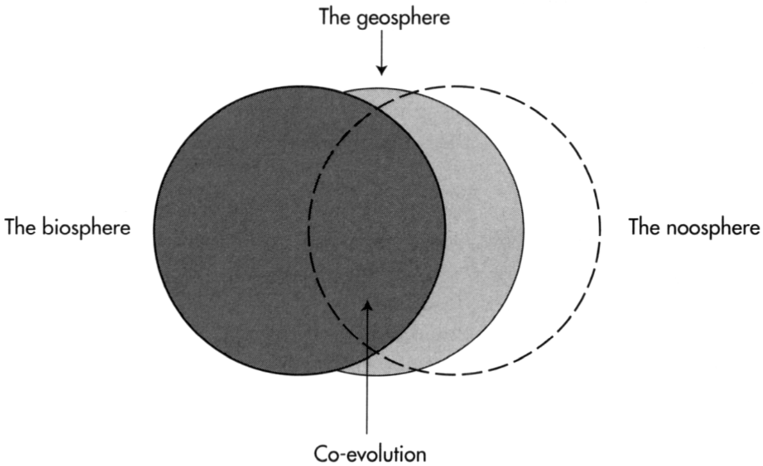

Figure 2.3 The co-evolution of the noosphere and the biosphere. The noosphere develops in conjunction with other spheres

The notion of the 'sphere'—imperceptibly overlapping without sharp boundaries—may offer a more flexible image than that of 'hierarchy', but the latter is one of the most common ways in which we conceptually arrange ideas or objects, and it is useful to illustrate the idea of layers further. Some of the best-known examples of hierarchies include physiological, military and geographical classifications. For our purposes, here it is important to be able to situate—at least generally—the concepts of biosphere and noosphere in relation to other, more familiar, concepts. The ecologist E.P.Odum ascribes the most basic level of an ecological hierarchy (that of the organism) up to the level of the biosphere, which he defines as 'all of the Earth's ecosystems functioning on a global scale.' Each unit in the chain is inextricably linked with the next. A similar technique is used to describe geopolitical hierarchies, which range from the individual to the world level (Odum 1993:26). In a modified version of Odum's description, Box 2.2 lists several hierarchy examples, adding the noosphere and Gaia. The latter term, as we shall see, is used in a similar way to that of biosphere—although perhaps with even greater emphasis on the interdependencies between living and non-living matter. We have placed it here because it is important in the readings and discussions that follow, notably in Chapter 4.

HUMANKIND AS AN AGENT OF PLANETARY ENVIRONMENTAL CHANGE

Although Plato and other observers of nature noted substantial environmental impacts due to human activity throughout history, the idea that humankind's role was nominal in environmental change remained the dominant school of thought well into the nineteenth century. According to a leading authority of the period, Charles Lyell in his *Principles of Geology* (1830– 33), human impacts were not significantly greater than the cumulative effect

Box 2.2 Examples of organised hierarchies

Large-scale hierarchies

Socio-geographical	*Ecological*
Noosphere?	Gaia?
World	Biosphere
Continent	Biogeographical region (major continents and oceans)
Nation	Biome (e.g. a sea or grassland region)
Region	Landscape (ecosystems together with human artefacts)
Province	Ecosystem (populations plus non-living environment)
County	Biotic community (all the populations in an area)
Township	Population (species)
Human group (ethnicity, etc.)	Organismic colony
Individual	Organism

Smaller-scale hierarchies

Taxonomic	*Military*
Kingdom	General
Phylum	Colonel
Class	Major
Order	Captain
Family	Lieutenant
Genus	Sergeant
Species	Private

(Adapted from E.P.Odum 1993:26)

of 'brute' animals. Lyell later modified this view in light of new observations by George Perkins Marsh and others, who openly attacked the notion of humankind as a weak geological agent (Glacken 1956). By the last quarter of the nineteenth century, new thinking about humankind's relationship with the natural environment began to emerge, significantly influenced by the earlier collective work of Jean Baptiste Lamarck (1744–1829), Alexander von Humbolt (1769–1859) and others.

It was only during the first decade of the twentieth century that geologists began explicitly to acknowledge humankind's role as the dominant geological force on the planet. Following the pioneering work of thinkers such as George Perkins Marsh, Eduard Suess and others, humankind was increasingly viewed as having the potential to alter the face of the Earth at the *global* level. Marsh, through his world travels as a diplomat, scientist and businessman, observed what he perceived to be significant human-induced changes. He was particularly struck by human impacts on the Nile and Colorado Rivers and the Aral Sea, the unintended cumulative effects of agricultural and industrial activity, and the problems of urban waste. Around the same time, the Austrian scientist Eduard Suess introduced the term 'biosphere' (as well as lithosphere and hydrosphere) for the first time in a book on the origin of mountain formation entitled *The Origin of the Alps* (*Die Entstehung der Alpen,* 1875). Suess never expanded much on the biosphere term, but he used it again in his internationally influential work *The Face of the Earth* (*Das Antlitz der Erde,* 1909). By the beginning of the twentieth century, the notion that human impacts on the environment constituted a significant (if not yet predominant) geological force was firmly established. This was a considerable revolution in thought. More broadly, as geographer/historian Clarence Glacken summarises:

> In looking back on the past, it seems that the thinkers of ancient and early modern times saw only the changes that appeared in localities known to them, that those of the eighteenth century realized these changes were world wide, and that the thinkers of the nineteenth recognized both their extent and their cumulative effect, while contemporary thinkers are impressed with the acceleration of change as a consequence of population growth and technological advance.
>
> (1956:88)

According to Glacken (*ibid*.: 86) 'Terms like the 'psychozoic era', 'anthropozoic era', and the 'mental era' were used [by scientists] to characterize this new geological period, anticipating Vernadsky's thesis, a generation later, that the world was no longer a biosphere but a noosphere.' In one example of such use, an Italian abbot, Antonio Stoppani (1824–1891), writing at the same time as Marsh (who was US ambassador in Rome during much of his writing of *Man and Nature* in 1865), argued that man constituted a new geological force, and designated the period as the 'anthropozoic era'. He wrote that 'the creation of man…was the introduction of a new element into nature, of a force wholly unknown to earlier periods…. It is a new telluric force which in power and universality may be compared to the greater forces of earth' (cited in Clark and Munn 1986:10). By the early twentieth century, T.Chamberlin and R.Salisbury (1906:619) declared that the 'mental era has but just begun, and that its effects are increasing with a rapidity quite phenomenal when measured by the slow pace of most geological change.'

In 1921, Teilhard de Chardin (1966:45) became an early promoter of the biosphere concept, reviewing Suess' *The Face of the Earth* in the French journal *Études* and remarking that: 'Where at first glance we saw only an incoherent distribution of altitudes, lands and waters, we have succeeded in putting together a solid network of true relationships.' From the same article, it is evident that Teilhard de Chardin already had an outline of the noosphere idea: 'The great educative [*sic*] value of geology is that by revealing to us a truly *unified* earth, an earth that, having one face, has only one body, it reminds us of the organisational possibilities even more deeply concealed in the zone of thought that envelops the world' (*ibid.*: 46). Throughout his life, Teilhard de Chardin continued to develop the concept of the biosphere as a 'layer of animated matter', using it as an anchor for the noosphere and other non-materialist ideas.

The geochemical works of Vernadsky and Alfred J.Lotka, which were instrumental in the development of biogeochemistry, were another landmark at the beginning of the 1920s. Working in Paris from 1922 to 1925, Vernadsky began to publish his work in scientific journals (e.g. 1925; 1926), and produced his pioneering book *La Géochemie,* which was published in French in 1924 and was based on his 1922–23 lectures at the Sorbonne. Vernadsky opened this remarkable book with the following statement: 'The foundations of our conceptions of the universe, on this nature—the unique entity—of this all, of which one heard so much in the eighteenth and first half of the nineteenth centuries, is transforming before our very eyes with an extraordinary speed rare in the history of thought.' He explicitly acknowledged humankind as 'a new geological force' that has 'disturbed the established order' (1924:306). At almost the same time, Lotka published his *Elements of Physical Biology,* starting from the assumption that 'the several organisms that make up the earth's living population, together with their environment, constitute one system' (1925:16). As Herbert Simon (1959: 493) remarked in a review of this book, it presents 'an essentially cybernetic view of organismic behavior.' Such works identified the importance of planetary geochemical cycles and highlighted the interrelationships between living and non-living matter. It was also at this time that Vernadsky began to conceptualise this idea more fully and prepare his most important contribution, *The Biosphere.* This important work was first published in Russian (1926) and French (1929) and only translated, in its entirety, into English in 1998. Vernadsky became the first to provide a detailed explanation of the concept and functioning of the biosphere, emphasising the meshing of living and non-living matter as an essential part of the structure of the Earth. Finally, around the same time, the South African Jan Christiaan Smuts published a seminal book entitled *Holism and Evolution* (1926), which influenced the thinking of other scientists such as Vernadsky and later became standard reference and inspirational material for the environmental movement.

THE SCIENCE OF THE BIOSPHERE

In contrast to the noosphere, the biosphere can be defined in basic, relatively clear, scientific terms. Based on Vernadsky's original conceptualisation, the biosphere is defined by a leading ecologist, G.Evelyn Hutchinson (1970), as that 'part of the earth in which life exists', with several qualifications allowing for a parabolic shape that captures life drifting in the atmosphere or beneath the Earth's surface. Building further on this, Polunin and Grinevald (1988:118) offer a more precise definition as the 'integrated living and life-supporting system comprising the peripheral envelope of Planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally.' The actual boundary remains uncertain as scientists continue to discover new microbes living miles inside the Earth's mantle, new life forms in the deepest sea trenches and transient spores in the lower atmosphere (and not including possible life forms on Mars or other bodies). Most of the Earth's species (estimated to be between two and 100 million) remain undiscovered, and only about 1.4 million of them have names (World Resources Institute 1992).

An important distinction is made here between the sense of 'envelope of life' and a strictly limited sense of biosphere, which would be the total sum of living organisms. To give an idea

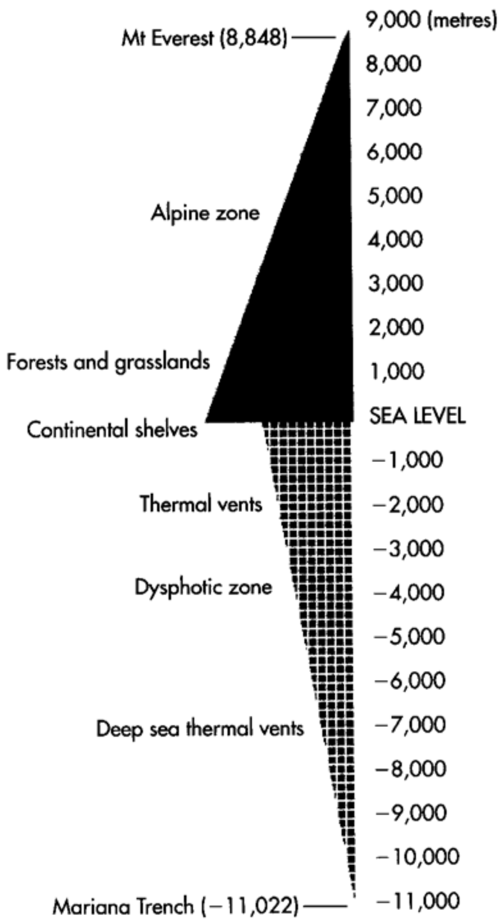

Figure 2.4 Schematic extent of the biosphere. The biosphere extends across a band that stretches approximately 20,000 m from the highest mountain ranges and lower atmosphere to the deepest oceanic trenches and caverns. Most active areas are found in relatively concentrated locations. Terrestrial zones contain much more life than do the aquatic ones. Data sources: Hutchinson 1970 and Southwick 1996

of the total extent of this envelope we are reminded that the biosphere stretches from approximately +10,000 m to −10,000 m from the surface of the Earth, but that this represents a band that is only approximately 20 km thick (see Figure 2.4). Taken as a whole, the biosphere represents less than two-tenths of 1 percent of the diameter of the Earth (12,800 km). As Charles Southwick (1996:23) points out, if the diameter of the Earth were represented by an eight-storey building (approximately 30 m), the total thickness of the biosphere would be equal to that of a wooden board 4 cm thick on the top, and the most active parts (rain forests, coral reefs, etc.) by a sheet of paper.

Three basic definitions can be assigned to the concept of biosphere, and these are set out in Box 2.3. It is important to note the key differences between the conceptualisations of Teilhard de Chardin, Le Roy and Vernadsky. For Teilhard de Chardin and Le Roy, the noosphere is seen as an irreversible phase of development of the biosphere—a predestined process driven by the human phenomenon—with the noosphere as a sort of evolutionary stage beyond the biosphere. In essence, they saw the biosphere as an intermediate step leading to the higher plane of the noosphere, and these ideas were present in their work from

Box 2.3 Three definitions of the biosphere

Vital skin of the Earth (P.Teilhard de Chardin)
The actual layer of vitalised substance enveloping the Earth; the totality of living beings.

Integrated life and support entity (V.I.Vernadsky)
The unit, partly created and controlled by life, resulting from the co-evolution of living things and their planetary environment.

Space in which life resides (G.E.Hutchinson)
That part of the Earth in which life exists.

earliest stage. Teilhard de Chardin imagined a partial separation of living and non-living matter in a way that allowed him to conceptualise the noosphere as 'above and beyond the biosphere'. For Vernadsky, the biosphere was the fundamental principal of life's existence, and the noosphere was not predestined but rather part of human potential and a possible (and desirable) phase in the development of the former. He did not really begin to use the concept of the noosphere until towards the end of his life, though it is implicit in his earlier writings. For Vernadsky, the two concepts are intricately bound together in a co-evolutionary process. Hutchinson's view, based on that of Vernadsky, was developed in a slightly more narrow, but not incongruous, form. In trying to make sense of these competing definitions, Huggett (1995:11) concludes that the biosphere is a product of the human mind, and it is therefore not surprising to find that it has been conceived in different ways. In any event, without the biosphere there could be no noosphere, irrespective of how one defines the latter.

Despite the important aspects described here, the concept of the biosphere appears to remain underdeveloped in much scientific thinking. While the term is commonly employed, the concept behind it remains confused, and the use of neologisms such as 'ecosphere' (Cole 1958) has not helped. Most surprisingly, perhaps, is the fact that, until recently, there has been little recognition or awareness of the deeper underlying issues raised by the notion of intricate interactions between living and non-living systems at the planetary level. This is surprising given the high profile of such events as the 1968 UNESCO 'Biosphere Conference' (UNESCO 1970), the 'The Biosphere' special issue of *Scientific American* (Hutchinson 1970) and the 1972 United Nations conference on the environment in Stockholm. Much of the evidence in the readings here suggests that the biosphere should be viewed as a fundamental concept for life on Earth, highlighting the way in which humans relate to the environment and the cosmos. The development of biogeochemistry acknowledges its roots in the work of Vernadsky on the biosphere (e.g. Degens 1989; Dobrovolsky 1994); and today, the study of 'biogeochemical cycles' has become an active branch of science, promoted by research by groups such as the Scientific Committee on Problems of the Environment (Bolin and Cook 1983). The approach is aptly described as follows:

> In general, biogeochemical cycles describe the pathways along which organic and inorganic substances move and interact in the various compartments of our Earth. Globally combined, they can be looked upon

Box 2.4 Co-evolution

Co-evolution is a well-established concept in ecology. Species are said to co-evolve when their respective levels of fitness depend, not only on their own genetic base and adaptations, but also on the development of another species. Co-evolution leads to selection pressures through interactions that establish structure between species, whether symbiotic, parasitic, predatory or competitive. Together, co-evolution and symbiosis (where neither member suffers from their structural relationship) can create distinct communities and resistance to distrubances in species. Humans are very much part of co-evolutionary relationships, and by analogy this may be extended to the relationship between society and the global environment. This raises an important question: is the co-evolution of humankind and the rest of the biosphere a symbiotic one?

> as a complex and dynamic network of flows or matter and forces in the air-water-earth-life system. To assess their operation principle requires a constant crossing of disciplinary boundaries between physics, chemistry, and the environmental sciences. A holistic approach seems to be mandatory.
>
> (Degens 1989)

Why did this concept, and links to the idea of the noosphere, receive so little attention or even acknowledgement until the mid-1980s? Greater recognition may be coming. Referring to the biosphere, Ghilarov (1995:193) notes that: 'Perhaps it is no accident that as we approach the end of this century, some ideas that had emerged at its beginning are reexamined by the scientific community.' The work of scholars such as Polunin (1982), Clark and Munn (1986), Grinevald (1987; 1988) and Huggett (1995) have been particularly helpful in promoting the idea. Such books as *What is Life?* (Margulis and Sagan 1995) and *Cycles and Life: Civilization and the Biosphere* (Smil 1997) have paid significant attention to these same issues. Moreover, it is perhaps indicative of the changing times that Vernadsky's fundamental contribution on this subject—*The Biosphere*—was published in its unabridged form for the first time in 1998 with a foreword by a distinguished group of scholars led by the microbiologist Lynn Margulis. According to Lynn Margulis and Dorion Sagan:

> Indeed, Vernadsky did for space what Darwin had done for time: as Darwin showed all life descended from a remote ancestor, so Vernadsky showed all life inhabited a materially unified place, the biosphere. Life was a single entity, transforming to earthly matter the cosmic energies of the sun. Vernadsky portrayed life as a global phenomenon in which the sun's energy was transformed.
>
> (1995:47)

Finally, we must not forget that the emergence of weapons of mass destruction is central to the development of a global perspective. The space age was inaugurated in 1957, and by the time the first images of the Earth from outer space arrived in 1965, if not before, nuclear weapons had the power potentially to destroy the entire biosphere. The invention of this new global threat led to the development of theories such as 'nuclear winter' (e.g. Erlich *et al.* 1983), which, in turn, was an important precursor for work on climate change, even if the prediction was for an ice age rather than global warming.

The notion of *biosphere* can be seen as a fundamental organising principle on Planet Earth, but many scientists continue to ignore (or are unaware) of the origins. Could this be partly due to ideological influence—a lingering scepticism of Soviet, now Russian, science? Much Soviet academic work was highly suspect by American and other Western academics during the Cold War, and Vernadsky's work was occasionally distorted in Soviet propaganda. Suspicion, however, was certainly tempered with jealousy and competition, because the Soviets often outclassed the Americans in space. The French natural philosopher Jacques Grinevald (1998) has compared the slow recognition of Vernadsky to Thomas Kuhn's notion of the 'invisible' scientific revolution. This analogy would seem to be particularly appropriate, although it may be moving out of its invisibility phase. The biosphere concept is increasingly recognised as a crucial idea in the more recent thinking about global environmental change, Gaia, sustainable development and deep ecology, as discussed in the chapters which follow. Indeed, the biosphere concept may finally be arriving at a point where it is viewed as politically central. As David Orr notes, from a world politics perspective, the central importance of the biosphere is not limited to ecological factors but deeply affects all types of social and political organisation:

> Ecological interdependence was largely unknown to the statesmen of 1648 [the Treaty of Westphalia]. It is now the predominant global fact. At some future time, the death of the modern Westphalian system and the beginning of a post-modern consciousness may be given as 1926, the year in which the Russian ecologist Vladimir Vernadsky published *The Biosphere*. Although few noticed, the implications of a planetary system of life, which Vernadsky called the biosphere, foreshadowed the end of the nation-state system predicated upon absolute sovereignty and the threat of violence.
>
> (1992:41–2)

GEORGE PERKINS MARSH

George Perkins Marsh (1801–1882) was a US diplomat, scholar and conservationist whose greatest work, *Man and Nature* (1864), is considered to be one of the most significant advances in geography, ecology and resource management of the nineteenth century. Marsh was fluent in numerous languages and travelled extensively. He was one of the first thinkers to suggest that anthropogenic changes were beginning to have significant impact across the globe, an important precursor for the concepts of both noosphere and biosphere.

MAN AND NATURE, OR THE EARTH AS MODIFIED BY HUMAN ACTION

MAN AND NATURE

The object of the present volume is to indicate the character and, approximately, the extent of the changes produced by human action in the physical conditions of the globe we inhabit; to point out the dangers of imprudence and the necessity of caution in all operations which, on a large scale, interfere with the spontaneous arrangements of the organic or the inorganic world; to suggest the possibility and the importance of the restoration of disturbed harmonies and the material improvement of waste and exhausted regions; and, incidentally, to illustrate the doctrine that man is, in both kind and degree, a power of a higher order than any of the other forms of animated life, which, like him, are nourished at the table of bounteous nature.

HUMAN AND BRUTE ACTION COMPARED

It is maintained by authorities as high as any known to modern science that the action of man upon nature, though greater in *degree,* does not differ in *kind* from that of wild animals. It is perhaps impossible to establish a radical distinction in *genre* between the two classes of effects, but there is an essential difference between the motive of action which calls out the energies of civilised man and the mere appetite which controls the life of the beast. The action of man, indeed, is frequently followed by unforeseen and undesired results, yet it is nevertheless guided by a self-conscious will aiming as often at secondary and remote as at immediate objects. The wild animal, on the other hand, acts instinctively, and, so far as we are able to perceive, always, with a view to single and direct purposes. The backwoodsman and the beaver alike fell trees; the man that he may convert the forest into an olive grove that will mature its fruit only for a succeeding generation, the beaver that he may feed upon the bark of the trees or use them in the construction of his habitation. The action of brutes upon the material world is slow and gradual, and usually limited, in any given case, to a narrow extent of territory. Nature is allowed time and opportunity to set her restorative powers at work, and the destructive animal has hardly retired from the field of his ravages before nature has repaired the damages occasioned by his operations. In fact, he is expelled from the scene by the very efforts which she makes for the restoration of her dominion. Man, on the contrary, extends his action over vast spaces, his revolutions are swift and radical, and his devastations are, for an almost incalculable time after he has withdrawn the arm that gave the blow, irreparable.

NOTHING SMALL IN NATURE

It is a legal maxim that 'the law concerneth not itself with trifles,' *de minimis non curat lex;* but in the vocabulary of nature, little and great are terms of comparison only; she knows no trifles, and her laws are as inflexible in dealing with an atom as with a continent or planet. No atom can be disturbed in place, or undergo any change of temperature, of electrical state, or other material condition, without affecting, by attraction or repulsion or other communication, the surrounding atoms. These, again, by the same law, transmit the influence to other atoms, and the impulse thus given extends through the whole material universe. Every human movement, every organic act, every volition, passion or emotion, every intellectual process, is accompanied with atomic disturbance, and hence every such movement, every such act or process, affects all the atoms of universal matter. Though action and reaction are equal, yet reaction does not restore disturbed atoms to their former place and condition, and consequently the effects of the least material change are never cancelled, but in some way perpetuated, so that no action can take place in physical, moral or intellectual nature without leaving all matter in a different state from what it would have been if such action had not occurred. Hence, to use language which I have employed on another occasion: there exists, not alone in the human conscience or in the omniscience of the Creator, but in external nature, an ineffaceable, imperishable record, possibly legible even to created intelligence, of every act done, every word uttered, nay, of every wish and purpose and thought conceived by mortal man, from the birth of our first parent to the final extinction of our race; so that the physical traces of our most secret sins shall last until time shall be merged in that eternity of which not science but religion alone assumes to take cognisance.

The human operations mentioned in the last few paragraphs, therefore; do act in the ways ascribed to them, though our limited faculties are at present, perhaps for ever, incapable of weighing their immediate, still more their ultimate, consequences. But our inability to assign definite values to these causes of the disturbance of natural arrangements is not a reason for ignoring the existence of such causes in any general view of the relations between man and nature, and we are never justified in assuming a force to be insignificant because its measure is unknown, or even because no physical effect can now be traced to it as its origin. The collection of phenomena must precede the analysis of them, and every new fact, illustrative of the action and reaction between humanity and the material world around it, is another step towards the determination of the great question, whether man is of material nature or above her.

EDUARD SUESS

Eduard Suess (1831–1914) was an Austrian geologist who assisted in building the foundations for palaeogeography and tectonics as they were developed towards the end of the nineteenth century. He also coined the term 'biosphere' in a book on the origin of mountains entitled *The Origin of the Alps,* published in German (1875). He later developed the concept more fully in his internationally renowned book, *The Face of the Earth,* which was published in several languages following the original German (*Das Antlitz der Erde,* 1883–1909). While Suess launched the term 'biosphere', it was diversely developed by his successors.

THE FACE OF THE EARTH

THE ORIGIN OF THE ALPS

One thing seems strange on this celestial body consisting of spheres, namely organic life. But the latter is limited to a determined zone, at the surface of the lithosphere. The plant, whose roots plunge deeply into the soil to feed and rises at the same time in the air to breathe, is a good illustration of the situation of organic life in the region of interaction between the upper sphere and the lithosphere, and on the surface of the cont-i-nents we can distinguish a self-maintained biosphere [*eine selbständige Biosphäre*].

THE FACE OF THE EARTH

In the city of Vienna many thousands of human bodies must have passed, in the course of years, under the hands of Carl Rokitansky, one of the great founders of pathological anatomy. He watched the passing generations; he saw, outside the limits of the human race, repeating itself under the most diverse modifications, the same succession of birth, growth, propagation and death. All life appeared to him as a single manifestation, and in summing up his observations he spoke not of unity, or of common origin, but of the *solidarity* of all life.

Lamarck and Darwin led the way to this conception, but now that it is reached it appears to us not as the final result of a comprehensive synthesis, but as the elementary physiological starting-point, to which these great investigators have led us back. It brings with it the idea of a biosphere which assigns to life a place above the lithosphere, is concerned only with life on this planet and all the conditions in regard to temperature, chemical composition and so forth necessary for its existence, and leaves on one side all speculative hypotheses as to the possible presence of living beings on other heavenly bodies. Determined by these conditions, the biosphere is a phenomenon limited not only in space, but also in time.

THOMAS C.CHAMBERLIN AND ROLLIN D.SALISBURY

Thomas C.Chamberlin (1843–1928), was a US geologist and educator who became assistant state geologist with the newly formed Wisconsin Geological Survey in 1873 and three years later was appointed chief geologist. Together with Chamberlin, Rollin D.Salisbury was a founding member of the Geography Department at the University of Chicago and was President of the American Association of Geographers. Their four-volume survey report *Geology* was published during 1904–06 and provides a good example of the increasing attention paid to the global scale as well as the emerging importance of the 'mental element' involved in human interactions with the environment.

GEOLOGY

THE MENTAL ELEMENT

Current opinion does not recognise a mental element as residing in the plant world, and it is divided as to the degree of its development in the lower animal kingdom, but its influential presence in the higher animal orders and in man is beyond legitimate question. Two phases are to be recognised: (1) the material work done under the stimulus and direction of mental impulses, as, for example, excavations, transportations, changes of drainage, removal of forests, cultivation of soil, etc.; and (2) the intellectual work of the faculties themselves irrespective of material changes. In one view, geology is a purely material science concerned solely with the formation of the Earth and with the physical development and relations of its inhabitants. In another, geology is a comprehensive historical science concerned with every phase of the world's history, and certainly not least with the higher forms of life development, with their psychological, sociological and other phases of mental attainments, since these are the highest output of the Earth's evolution. The latter seems to us the more comprehensive view.

THE MATERIAL EFFECTS OF THE MENTAL ELEMENT

Lyell long since urged that the direct work of man in changing the face of the Earth was slight compared with that of the contemporaneous inorganic agencies. He called attention to the relative insignificance of the quarries, pits, cellars and other excavations of man, compared with the work of streams, waves and other inorganic agencies. There is justness in this view, but it needs qualification. It is to be observed that the mental era has but just begun and that its effects are increasing with a rapidity quite phenomenal when measured by the slow pace of most geological events. The excavations and transportations of material today show an enormous advance on those of Lyell's day, which was, geologically speaking, but a moment ago. The mile-tons of industrial freightage in the Mississippi basin are today not wholly incomparable with the drainage transportation of the same area a century ago. A century ago is named because the surface was then covered with natural vegetation, and the normal effect of surface erosion, independent of man, was then experienced. At present the indirect effects of man's action are mingled with those of natural processes, and these indirect effects are probably more important than the direct ones. The removal of the native vegetation and the cultivation of the soil expose the surface to wash to a degree far beyond that prevalent when the surface was prairie sod or leaf-carpeted forest, and denudation and transportation have been greatly multiplied in consequence. Not only has this cultivation increased the exposure to erosion, but, by increasing the rate of run-off, it has added to the erosive power of the streams. The ditching of swamp and other tracts of retarded drainage has contributed to this acceleration. The naked, soil-less uplands of some of the once populous kingdoms of the Orient, notably portions of Syria and Greece, are sad witness of the accelerated erosion that attends cultivation. The erosion of certain southern fields of the United States in the last forty years is another striking illustration. It is doubtful whether some parts of this region suffered as much erosion in the preceding five centuries as they have during the last one. On the other hand, some compensation is found in the reservoirs established for waterpower, and in artificial devices for retarding and steadying stream flow.

In the light of considerations such as these, man may well be regarded not only as a potent geological agent, but as dangerously so to himself. The hope is that the intelligence that has wrought a change of surface conditions serviceable for the present, but dangerous to the future, will be so enlarged as to inspire a still more intelligent control of surface conditions which shall compass the future welfare as well as transient benefit.

HUMAN MODIFICATION OF THE ANIMAL AND VEGETABLE KINGDOMS

Man's agency is also coming to be felt powerfully in the modification of the plant and animal life of the land and even to some extent of the sea. The larger animals that are not propagated by man are fast approaching extinction. At the present rate of extension of man's dominion, a century or so will see the disappearance of nearly every large mammal and reptile that he does not choose to protect or propagate. By way of compensation, certain selected animals are increasing and will doubtless continue to increase. The result is, therefore, likely to be a peculiar assemblage of animal life dependent strictly on the choice of a dominant type, a state of things that has apparently never occurred in an equal degree in the past history of the Earth. How far the minor forms of life, especially the insect life, and the denizens of the sea, may be brought under this monopolistic control may not be predicted so easily.

A similar profound transition in vegetation is being forced by man. The native vegetation is rapidly being replaced by selected varieties, and by varieties that take advantage of conditions furnished by man. As the agricultural control of the Earth becomes more complete and effective, a result towards which very rapid progress is being made, a new flora of man's selection will very generally prevail over the whole land surface of the globe. It is doubtful whether at any time in the history of the Earth changes of flora and of fauna, and of surface, have been more rapid than those that are now taking place under the accelerating influence of man's action, and this accelerating influence springs not mainly from automatic or instinctive reaction, but from conscious impulse and intelligent direction.

THE PSYCHOLOGICAL FACTORS AS SUCH

Are the introduction and the evolution of the psychological factors themselves to be regarded as subjects of geological study? We shall find that, at the outset, the geological record is a complete blank so far as clear evidence of terrestrial organisms actuated by their own intelligence is concerned; that later, organisms with some apparent consciousness and intelligence appeared, and that the mental element increased apace unto its present attainment. We know that relationships of a sociological nature arose in apparent feebleness, and gradually evolved into more definite, higher and more complex forms. By sociological factors we mean merely those conscious relations which one organism bears to another, of which the parental and the gregarious impulses are two fundamental expressions. For manifest reasons, the introduction and evolution of the psychological and sociological factors themselves have received little direct recognition as a portion of geological studies. The record of such factors in the fossils of past ages is necessarily obscure and imperfect, and the interpretation of what there is lacks certainty and precision. Nonetheless, this psychological record, with all its imperfections, is beyond valuation, and must, we think, come to be an indispensable factor in the study of psychological and sociological evolution, for it shows, what nothing else can show equally well, the extremely prolonged history of that evolution, and it gives hints of modes and means which no study of existing stages can equally reveal. The organisation of the Cambrian trilobites, for example, implies no small development of the senses and of the co-ordinating faculties even at that early stage, and a study of the relations of these to their fellow creatures opens up the first known chapter in the sociological record of the Earth's inhabitants. From this stage onwards the progress in the development of the higher faculties, and of the sociological relations of the leading forms, is one of the most instructive phases of the great history. Such a study reveals the fact that many questions, narrowly supposed to be purely human, have had their prototypes in the earlier experiences of the animal kingdom. Some of these questions have found solutions, temporary or permanent, which passed under the test of ages to whose length human experience affords no parallel, and have received the sanction or disapproval of such tests according as they were well- or ill-adapted to the actual conditions involved. If one seeks the lessons of history in the largest sense, one cannot wisely neglect the prolonged record of the great biological family.

VLADIMIR I.VERNADSKY

Vladimir I.Vernadsky (1863–1945) was a Russian (and later Soviet) mineralogist, geochemist and natural philosopher who pioneered work on geochemistry. Vernadsky was the first to develop fully the concept of biosphere, and he is considered to be one of the founders of biogeochemistry. His work remains poorly known outside the former Soviet Union, although it has recently been recognised as an important precursor for work on such contemporary issues as global change and Gaia. Within the former Soviet Union, Vernadsky's influential school of thought is widely recognised to this day. In his writings in the 1920s, Vernadsky developed a view of life on Earth that ultimately led him to consider the increasingly important role of the intellectual realm—or noosphere. Although, he did not actually use this term until the 1930s, the ideas that led to its development are evident earlier. Many of his most interesting works, such as *Geochemistry* (*La Géochimie,* 1924) have not previously been translated into English.

GEOCHEMISTRY

GEOCHEMISTRY, A NEW SCIENCE FOR THE TWENTIETH CENTURY

We live in a critical epoch of the history of humanity. I am not speaking of the political and social upheaval which takes place before our eyes and appears to be just the beginning. Much more serious and profound events are unfolding in the domain of human thought.

The foundations of our conceptions on the universe, on nature—the unique entity—on everything, of which one heard so much in the eighteenth and first half of the nineteenth centuries, is transforming before our very eyes with an extraordinary speed rare in the history of thought.

We are studying a very small space—but inseparably linked to an immensity of the cosmos—in establishing laws and regularities in the history of the chemical elements of our planet. Profound analogies—and even more than analogies—exist within.

THE GEOCHEMICAL ACTIVITY OF HUMANITY

The geochemical cycle of carbon—and with it the geochemical history of other chemical elements—does not remain invariable in the course of time. It is certain that during the evolution of plant and animal species the chemical molecules which form them are not the same. But this change of chemical composition is apparent in the course of geological time only in living matter. Outside of the latter, in inert matter, from the Archean to the Pleistocene they have always carried the same mineral associations and have been formed of the same natural composites.

But in our geological epoch—the psychozoic era, the era of reason—a new geochemical fact of capital importance is manifest. In the course of the last few thousand years, the geochemical action of humanity has, by means of agriculture seizing the living green matter, become intensive and excessively multiplied. We observe a surprising rapidity of growth of this action. This is the action of the conscious and the collective spirit of humanity on the geochemical processes. Man has introduced a new form of action of living matter on the exchange of atoms of living matter with inert matter. These are no longer the only necessary elements of production and the formation of living matter which enter into play here and change their molecular structure. These are necessary elements to the techniques and creation of civilised forms of life. Here, man acts not as *Homo sapiens,* but as *Homo faber* (Bergson 1911).

He spreads his action across all the chemical elements. He changes the geochemical history of all metals, he makes new composites, reproducing them in enormous quantities of the same order that the masses of minerals produce natural reactions. In the history of all chemical elements, this is a fact of unique importance. For the first time in the history of our planet we see in the formation of new composites an extraordinary change of the face of the planet. From a geochemical point of view, all of these products: the mass of free metal such as iron, copper, tin or zinc; the mass of carbonic acid; products of the calcification of limestone or the combustion of coal; the enormous quantities of sulphur dioxide or sulphuric hydrogen formed during chemical and metallurgical processes lead to larger and larger quantities of other technical products which are not distinguishable from minerals. They change the eternal course of geochemical cycles.

It is clear that this is not an accidental fact; that it has been pre-formed by the whole of palaeontological evolution. It is natural fact like the others and we see in it a new phenomenon where living matter acts in apparent contradiction with Carnot's principle. Where will this process, this completely new geological fact, stop itself? Will it stop? Poets and philosophers give us responses, which often do not appear improbable or impossible to the scientist. The study of geochemistry demonstrates the importance of this process and its intricate link to the whole chemical mechanism of the Earth's core. It is the final effects on the state of evolution which have yet to be revealed.

But how ever it is now and how ever it will surely become in the coming centuries, it remains a fact that changes the reversible geochemical cycles of all elements. It adds new composites to them and these composites are less stable in the thermodynamic conditions of the core than the ancient ones, representing a more intense source of energy and raising the active energy of the core which has been constant since time immemorial.

Man augments everywhere the quantity of atoms which come from the ancient or 'eternal' geochemical cycles. He reinforces the perturbation of these processes, and in adding new ones, disrupts the ancient ones. With the arrival of man, a new geological force has certainly appeared on the planet's surface.

ALFRED J.LOTKA

Alfred J.Lotka (1880–1949) was an American citizen born in Lemberg (then part of the Austro-Hungarian Empire and now western Ukraine) who was educated in Germany, France and England before moving to the United States. In 1924, he joined the statistical bureau of the Metropolitan Life Insurance Company, where he remained until retirement, although he kept active in various scientific associations throughout his life. Lotka mastered many different fields of science but was perhaps most influential as a population theorist or biophysicist, and best known for his book, *Elements of Physical Biology* (1925), which remains somewhat of a classic (and was reprinted posthumously in 1965 under a different title). This book influenced Vernadsky and others, and took a similar view of living and non-living matter as part of a single, integrated system—an important building block for the emergent idea of global ecology.

ELEMENTS OF PHYSICAL BIOLOGY

The several organisms that make up the Earth's living population, together with their environment, constitute one system, which receives a daily supply of available energy from the Sun. This fact deserves emphasis. It is customary to discuss the 'evolution of a species of organisms'. As we proceed we shall see many reasons why we should constantly take in view the evolution, as a whole, of the system (organism plus environment). It may appear at first sight as if this should prove a more complicated problem than the consideration of the evolution of a part only of the system. But it will become apparent, as we proceed, that the physical laws governing evolution in all probability take on a simpler form when referred to the system as a whole than to any portion thereof. It is not so much the organism or the species that evolves, but the entire system, species and environment. The two are inseparable. 'The organism', as Uexküll teaches us, 'must be studied, not as a heaping together of anatomical and physiological abstraction, but as a piece of machinery, at work among external conditions.'

Each individual is composed of various chemical substances assembled into a definite structure and capable of growth, i.e. of accretion out of the environment by chemical reaction—provided a suitable medium or environment is offered. Moreover, each mobile organism carries with it a travelling environment, suitable for the growth of its substance. It maintains this environment by virtue of the peculiar mechanical properties associated with its structure, whereby it is enabled to turn to this use, directly or indirectly, the available energy of the Sun's light. And while the travelling environment may not be absolutely constant, it is more nearly so than the more remote portions of the system, and keeps within such limits of variation as are compatible with the survival of the organism or its species. A concrete illustration may help to make this point clear. Many aquatic forms of life are constantly bathed in a saline solution—sea water. Their body fluids are accordingly in equilibrium with this environment. Variations in the salinity of their environment, if they exceed certain comparatively narrow bounds, are apt to be fatal to such organisms.

The higher organisms have made themselves (largely) independent of their immediate environment. Their tissues are bathed from within by a fluid (the blood) which they carry around with them, a sort of 'internal environment'. 'Given that sea water has such an intimate contact with sea organisms —

and that not only does the former surround them with its flotsam and jetsam but it covers gills and impregnates, in part, the bodies of invertebrates—it seems quite justified to place sea water in the same category as the physiological liquids.'

Compare also the following: 'Not only do the body fluids of the lower forms of marine life correspond exactly with sea water in their composition, but there are at least strong indications that the fluids of the highest animals are really descended from sea water …the same substances are present in both cases and in both cases sodium chloride largely predominates' (Henderson 1913: 187–8; and others).

The degree of perfection with which this constancy of the internal or travelling environment, independently of the external environment, is developed increases as we ascend the biological scale. This is lucidly set forth, for example, by Claude Bernard: 'In all living beings the inside is a product of the organism, conserving the necessary interactions of exchange with the outside; but it bounds the extent to which the organism becomes more perfect—the organic milieu, in certain ways, specifying and fitting itself more and more in terms of the surrounding milieu.'

It is the peculiar structure and the mechanical properties of the organism that enable it to secure and maintain the required environment (including the internal milieu). The higher animals, in particular, are provided with an intricate apparatus, comprising many members, for securing food (internal environment) as well as for warding off hostile influences.

The increasing independence, as we ascend the biological scale, which the organism displays towards its more remote environment is thus accompanied by a parallel increase in the perfection of the apparatus by which this independence is earned. Here again we may quote Claude Bernard: 'As we move up the ladder of beings, these apparati become more perfected and complicated. They tend to completely set free the organism from influences and changes coming from the external milieu. It is the contrary with animal invertebrates, where such independence *vis-à-vis* the external milieu is only relative.'

Whatever may be our ultimate conclusions, we may do well to adopt at least as a temporary expedient the policy of resignation; with Sir Edward Schafer we may abandon the attempt to define life. Perhaps, in doing this, we are following historical precedents: geometers have had to resign themselves to the fact that Euclid's parallel axiom cannot be proved. But as the reward of this resignation came the new geometrics of Bolyai, Lobatchewski and Riemann. Enlightened inventors have abandoned the attempt to build a perpetual motion machine; but again, resignation is rewarded with the recognition of a fundamental law, the law of conservation of energy. Physicists, following Einstein, have abandoned, for the time being at any rate, the attempt to determine experimentally the Earth's absolute motion through space. The reward has been the theory of relativity, one of the greatest events in the history of science.

The whole development of science, especially in recent years, is a record of tearing down barriers between separate fields of knowledge and investigation. Little harm, and perhaps much gain, can come from a frank avowal that we are unable to state clearly the difference between living and non-living matter. This does not in any way commit us to the view that no such difference exists.

For the present, then, we shall adopt the position that the problem is essentially one of definition. The question is not so much 'What is life?' but rather, 'What shall we agree to call life?' And the answer, for the present at any rate, seems to be that it is immaterial how we define life; that the progress of science and our understanding of natural phenomena is quite independent of such a definition.

We shall, wherever convenient, continue to employ the terms life, living organism, merely as a matter of convenience. This use of the terms does not imply or presuppose any precise distinction between living and non-living matter; it merely rests upon the fact that in *most* cases *ordinarily* met there is essentially universal agreement as to whether a portion of matter is to be classed in the first or in the second category. We will adopt the policy of Sir William Bayliss.

If asked to define *life* I should be inclined to do as Poinsot, the mathematician did, as related by Claude Bernard: 'If anyone asked me to define time, I should reply: Do you know what it is that you speak of? If he said Yes, I should say, Very well, let us talk about it. If he said No, I should say, Very well, let us talk about something else.'

The ideal definition is, undoubtedly, the quantitative definition, one that tells us how to measure the thing defined; or, at the least, one that furnishes a basis for the quantitative treatment of the subject to which it relates.

JAN CHRISTIAAN SMUTS

Jan Christiaan Smuts (1870–1950) was a South African statesman, soldier and scholar. He was prime minister of South Africa 1919–24 and 1939–48. After completing his first stint in office, Smuts turned his attention once again to the issues of biology, evolution and philosophy that had so interested him as a student at Cambridge. The result was his book *Holism and Evolution* (1926), in which he coined the term 'holism', an idea that has since become common usage. Writing at the same time as Vernadsky, Lotka and others working on similar issues, Smuts contributed a powerful set of arguments to the non-reductionist school of the life sciences. But he also added a very practical and broadly social aspect to his ideas that would later find deep resonance with the environmental movement. Through his influential position as an African statesman, Smuts broadly promoted his ideas through his contacts and own actions.

HOLISM AND EVOLUTION

We are all familiar in the domain of life with what is here called wholes. Every organism, every plant or animal, is a whole, with a certain internal organisation and a measure of self-direction, and an individual specific character of its own. This is true of the lowest micro-organism no less than of the most highly developed and complex human personality. What is not generally recognised is that the conception of wholes covers a much wider field than that of life, that its beginnings are traceable already in the inorganic order of nature, and that beyond the ordinary domain of biology it applies in a sense to human associations like the state, and to the creations of the human spirit in all its greatest and most significant activities. Not only are plants and animals wholes, but in a certain limited sense the natural collocations of matter in the universe are wholes; atoms, molecules and chemical compounds are limited wholes; while in another closely related sense human characters, works of art and the great ideals of the higher life are or partake of the character of wholes. In popular use the word 'whole' is often made to cover some of these higher creations. A poem or a picture, for instance, is praised because it is a 'whole,' because it is not a mere artificial construction, but an organic whole, in which all the parts appear in a subtle indefinable way to subserve and carry out the main purpose or idea. Artistic creations are, in fact, mainly judged and appraised by the extent to which they realise the character of wholes. But there is much more in the term 'whole' than is covered by its popular use. In the view here presented 'wholes' are basic to the character of the universe, and holism, as the operative factor in the evolution of wholes, is the ultimate principle of the universe.

The creation of wholes, and ever more highly organised wholes, and of wholeness generally as characteristic of existence, is an inherent character of the universe. There is not a mere vague indefinite creative energy or tendency at work in the world. This energy or tendency has specific characters, the most fundamental of which is whole-making. And the progressive development of the resulting wholes at all stages—from the most inchoate, imperfect, inorganic wholes to the most highly developed and organised—is what we call evolution. The whole-making, holistic tendency, or holism, operating in and through particular wholes, is seen at all stages of existence, and is by no means confined to the biological domain to which science has hitherto restricted it. With its roots in the inorganic, this universal tendency attains clear expression in the organic biological world, and reaches its highest expressions and results on the mental and spiritual planes of existence. Wholes of various grades are the real units of nature. Wholeness is the most characteristic expression of the nature of the universe in its forward movement in time. It marks the line of evolutionary progress. And holism is the inner driving force behind that progress.

It is evident that if this view is correct, very important results must follow for our conceptions of knowledge and life. Wholes are not mere artificial constructions of thought, they point to something real in the universe; and holism as the creative principle behind them is a real *vera causa*. It is the motive force behind evolution. We thus have behind evolution not a mere vague and indefinable creative impulse or *élan vital,* the bare idea of passage or duration without any quality or character, and to which no value or character could be attached, but something quite definite. Holism is a specific tendency, with a definite character, and creative of all characters in the universe, and thus fruitful of results and explanations in regard to the whole course of cosmic development.

It is possible that some may think I have pressed the claims of holism and the whole too far; that they are not real operative factors, but only useful methodological concepts or categories of research and explanation. There is no doubt that the whole is a useful and powerful concept under which to range the phenomena of life especially. But to my mind there is clearly something more in the idea. The whole as a real character is writ large on the face of nature. It is dominant in biology; it is everywhere noticeable in the higher mental and spiritual developments; and science, if it had not been so largely analytical and mechanical, would long ago have seen and read it in inorganic nature also. The whole as an operative factor requires careful exploration. That there are wholes in nature seems to me incontestable. That they cover a very much wider field than is generally thought and are of fundamental significance is the view here presented. But the idea of the whole is one of the neglected matters of science and to a large extent of philosophy also. It is curious that, while the general viewpoint of philosophy is necessarily largely holistic, it has never made real use of the idea of the whole. The idea runs indeed as a thread all through philosophy, but mostly in a vague intangible way. The only definite application of the idea has been made by the Absolutists, who have applied the expression of 'the whole' to the all of existence, to the cosmic whole, to the *tout ensemble* of the universe, considered as a unity or a being. This particular use of the idea does not interest us at this stage of this inquiry. The great whole may be the ultimate terminus, but it is not the line which we are following. It is the small natural centres of wholeness which we are going to study, and the principle of which they are the expression. And I should have thought that the matter would be of profound interest to philosophers and scientists alike. But no real use has been made of this great concept even by philosophers, while by scientists it has been steadily neglected or ignored under the iron rule of the mechanistic regime. And yet the stone rejected by the builders may become the cornerstone of the building.

The stages in which holism expresses itself and creates wholes in the progressive phases of reality may therefore be roughly and pro-visionally summarised as follows:

- Definite material structure or synthesis of parts in natural bodies but with no more internal activity known at present than that of mere physical or chemical forces or energies: e.g. in a chemical compound.
- Functional structure in living bodies, where the parts in this specific synthesis become actively co-operative and function jointly for the maintenance of the body: e.g. in a plant.
- This specific co-operative activity becomes co-ordinated or regulated by some marked central control, which is still mostly implicit and unconscious: e.g. in an animal.
- The central control becomes conscious and culminates in personality; at the same time it emerges in more composite holistic groups in society.
- In human associations this central control becomes super-individual in the state and similar group organisations.
- Finally, there emerge the ideal wholes, or holistic ideals, or absolute values, disengaged and set free from human personality, operating as creative factors on their own account in the upbuilding of a spiritual world. Such are the ideals of truth, beauty and goodness, which lay the foundations of a new order in the universe.

Through all these stages we see the ever-deepening nature of the whole as a specific structural synthesis of parts with inner activities of its own which co-operate and function in harmony, either naturally or instinctively or consciously. The parts so co-operate and co-function towards a definite inherent inner end or purpose that together they constitute and form a whole more or less of a distinctive character, with an identity and an ever-increasing measure of individuality of its own. And the whole thus formed is creative at all stages, even at the first, although this is only an inchoate, immature stage. We thus arrive at the conception of a universe which is not a collection of accidents externally put together like an artificial patchwork, but which is synthetic, structural, active, vital and creative in increasing measure all through, the progressive development of which is shaped by one unique holistic activity operative from the humblest inorganic beginnings to the most exalted creations and ideals of the human and of the universal spirit.

We find thus a great unifying creative tendency of a specific holistic character in the universe, operating through and sustaining the forces and activities of nature and life and mind, and giving ever more of a distinctive holistic character to the universe. This creative tendency or principle we call holism. Holism in all its endless forms is the principle which works up the raw material or unorganised energy units of the world, utilises, assimilates and organises them, endows them with specific structure and character and individuality, and finally with personality, and creates beauty and truth and value from them. And it does all this through a definite method of whole-making, which it pursues with ever-increasing intensity from the beginning to the end, through things and plants and beasts and men. Thus it is that a scale of wholes forms the ladder of Evolution. It is through a continuous and universal process of whole-making that reality rises step by step, until from the poor, empty, worthless stuff of its humble beginnings it builds the spiritual world beyond our greatest dreams.

In the first place, holism is a creative factor, and as such shows itself in the upbuilding and differentiation of organic structures and their functions. These may be modifications or variations or mutations. They may be ordinary specific differences such as explain the origin of different species. These differences may include new organs and structures, or merely the general complexifying of existing structures which makes organisms as a whole more complex. This creative holism is, of course, responsible for the whole course of evolution, inorganic as well as organic. All the great main types of existence are therefore due to it, such as the atom, molecule, cell, organism, the great groups of plant types, the great groups of animal types, and finally the human type. Creative holism is thus responsible for all the great divisions of science.

In the second place, apart from the detailed structural and functional differentiations above referred to, holism is a general organising, co-ordinating or regulating factor in organisms over which it exercises a measure of guidance, direction and control. This regulation and control is exercised over the structures and functions of organisms generally, but sometimes special holistic organs are evolved, which seem especially destined to assist in the exercise of this regulation and control. Such special holistic organs are the ductless glands which pour regulative secre-tions into the general system, the nervous system, and especially the brain with its cor-relate mind. These and other holistic organs are special aids to holism in its regulative activity.

In the third place, in order to express and explain these activities of holism at the different grades of evolution and at the various levels of differentiation of type and structures, categories of the whole or holistic categories are necessary. Thus arise the physical, chemical, organic, psychical and personal categories, which are all expressive of holistic activity at its various levels and reducible to terms of holism. Holism thus appears in this scheme as the fundamental activity of the universe from which all others are derived; and the concept of holism is the ultimate category of description and explanation from which likewise all other categories are derived. Holism therefore constitutes the ultimate viewpoint from which to orient our survey of all the various forms and departments of reality.

There is one more aspect of creative holism which I must for the sake of completeness mention, although its exposition falls outside the plan of this work. We have seen that holism is creative of all structures, inorganic as well as organic. Thus all the types of structure in the worlds of matter and life are its work. But more; as we proceed upward in the course of evolution we find holism the source of all values. Love, beauty, goodness, truth: they are all of the whole; the whole is their source, and in the whole alone they find their last satisfying explanation. Holism not only prescribes the law in the world of structures, forms and organisms—it is the very ground and principle of the ideal world of the spirit. It is in the sphere of spiritual values that holism finds its clearest embodiment in fact and its most decisive vindication as an ultimate category of explanation. Its creative-ness will nowhere be found more fruitful than in that last and highest reach of its evolution. Here it would be premature to do more than merely refer to this aspect of creative holism. The exposition of its creative activity in shaping the great ideals of the whole is, however, too large a task to be undertaken in this introductory work.

This is not a treatise on philosophy; not even on the philosophy of nature; not even on the philosophy of evolution. It is an exploration of one idea, an attempt to sketch in large and mostly vague, tentative outline the meaning and the consequences of one particular idea. But that is a seminal idea; indeed it is here presented as more than an idea, as a fundamental principle operative in the universe. As such it is bound to affect our general view of the nature of the universe. I therefore come [in conclusion] to consider what holism means for our general world view, our *Weltanschauung,* and as briefly as possible to sum up the bearing which the argument must have on such a general conception of the universe.

Holism has been our theme—holism as an operative factor in the universe, the basic concept and categories of action of which can be more or less definitely formulated. I have in the broadest outline sketched the progress of holism from its simple mechanical inorganic beginnings to its culmination in the human personality. All through we have seen it at work as the fundamental synthetic, ordering, organising, regulating activity in the universe, operating according to categories which, while essentially the same everywhere, assume ever more closely unified and synthetic forms in the progressive course of its operation. Appearing at first as the chemical affinities, attractions and repul-sions, and selective groupings which lie at the base of all material aggregations, it has accounted for the constitution of the atom, and for the structural organising of atoms and molecules in the constitution of matter. Next, after some gaps which are being energetically explored by biology and biochemistry, and still operating as a fundamental synthetic selective activity, it has emerged on a much higher level of organisation in the cell of life, and has again been responsible for the ordered grouping of cells in the life-structures of organisms, both of the plant and the animal type, and in the progressive complexifying of these structures in the course of organic evolution. The synthetic activity in these organic structures has been so far-reaching that the independent existence of the original unit cells has sometimes been questioned, and the organism has been taken as the synthetic unit, of which the cell is but a defined portion of nucleated protoplasm. In other words, the organic synthesis of cells has been such as practically to lead to the suppression of the individual cells as such. Next, in the higher animals and especially in man, holism has emerged in the new mutation or series of mutations of mind, in which its synthetic co-ordinating activity has risen to an unheard-of level, has turned in upon itself and become experience, and has achieved virtual independence in the form of consciousness. Finally, it has organised all its previous structures, including mind, in a supreme structural unity in human personality, which has assumed a dominating position over all the other structures and strata of existence, and has in a sense become a new centre and arbiter of reality. Thus the four great series in reality—matter, life, mind and personality—apparently so far removed from each other, are seen to be but steps in the progressive evolution of one and the same fundamental factor, whose pathway is the universe within us and around us. Holism constitutes them all, connects them all and, so far as explanations are at all possible, explains and accounts for them all. Holism is matter and energy at one stage; it is organism and life at another stage; and it is mind and personality at its latest stage. And all its protean forms can in a measure be explained in terms of its fundamental characters and activities, as I have tried to show. All the problems of the universe, not only those of matter and life, but also and especially those of mind and personality, which determine human nature and destiny, can in the last resort only be resolved—in so far as they are at all humanly soluble—by reference to the fundamental concept of holism. For this reason I have called our universe 'the holistic universe', as holism is basic to its constitution, its multitudinous forms and its processes, its history in the past, and its promise and potency for the future.

VLADIMIR I. VERNADSKY

THE BIOSPHERE

The surface of the Earth, seen from the depths of infinite celestial space, seems to us unique, specific and distinct from that of all other heavenly bodies. The surface of our planet, its biosphere, separates the Earth from its cosmic surroundings. The terrestrial face becomes visible where it receives light from celestial bodies, particularly the Sun. From all points of space it receives an infinite diversity of radiations, of which the luminous ones that we can see form only an insignificant part. At present only a few of the invisible radiations are known to us. We have hardly begun to realise their variety, or to appreciate how incomplete and defective are our representations of the world of these radiations which surround us and penetrate us in the biosphere.

Not only the biosphere, but all conceivable space is penetrated by this immaterial substance, radiation. It is ceaselessly diffused everywhere, round about us and through us. The waves of radiation, ranging in length from the millionth part of an inch up to several miles, cross and re-cross one another continually. The whole of space is full of them, leading us to draw a distinction between cosmic space and the geometrical idea of space as mere emptiness.

These radiations from the cosmos continually play upon the Earth's crust, conferring a completely novel and peculiar character to those parts of the planet bordering on cosmic space and rendering them quite different from the other parts.

The substance of this boundary region, the biosphere, becomes active under the influence of the stream of energy. It accumulates and distributes the energy received and finally transforms it into free energy in the biosphere. Hence, this exterior crust must not be considered as the domain of matter alone, but as a region of energy also, a place of transformation of the planet by external cosmic forces.

These forces mould and transform the face of the Earth. The face of the Earth is not a feature characteristic only of the substance of the planet; it is at the same time a creation of the external forces of the cosmos. The history of the biosphere is therefore sharply distinguished from that of the rest of the planet, and the role it plays in the mechanism of the planet is quite exceptional. The phenomena in the biosphere cannot lead to an understanding of the biosphere unless one takes into account the bond which unites it with the entire cosmic mechanism.

Living matter is the totality of all organisms present on the Earth at any one time. It is usually such a totality that is important, though in dealing with the effect of man on the processes of this planet, a single individual may be of importance. The living matter of the Earth may be regarded as the sum of the average living matter of all the taxonomically recognisable groups. Each of these groups is said to consist of *homogeneous* living matter.

Living matter exists only in the *biosphere.* This includes the whole atmospheric troposphere, the oceans and a thin layer in the continental regions, extending down three kilometres or more. Man tends to increase the size of the biosphere.

The biosphere is distinguished as the domain of life, but also, and more fundamentally, as the region where changes due to incoming radiation can occur. Within the biosphere, matter is markedly heterogeneous and may be distinguished as inert matter or living matter. The inert matter greatly predominates in mass and volume. There is a continual migration of atoms from the inert matter to living matter and back again. All the objects of study in the biosphere are to be regarded as the *natural bodies* of the biosphere. They may be of varying complexity, inert, living, or big-inert as in the case of soil or lake water. The study of all phenomena has a unity, leading to the production of a body of systematised knowledge, the *corpus scien-tiarum,* which tends to grow like a snowball; this corpus includes all systematised knowledge, and is contrasted with the results of philosophy, religion and art, where truth may be revealed intuitively; the systematised history of these activities belongs to the corpus.

Two concepts have been inadequately stressed in the past: (1) Pasteur was correct in regarding the preponderance of optically active compounds as the most characteristic general property of living matter and its products; this idea is of immense importance; (2) the functions of living organisms in the energetics of the biosphere have been seriously neglected. Biogeochemical energy may be expressed in the velocity with which the biosphere could be colonised by a given species. For certain bacteria, the limiting velocity of extension of a dividing chain of cells tending to embrace the whole circumference of the Earth would tend to approach the velocity of sound.

In everyday life one used to speak of man as an individual, living and moving freely about our planet, freely building up his history. Until recently the historians and the students of the humanities, and to a certain extent even the biologists, consciously failed to reckon with the natural laws of the biosphere, the only terrestrial envelope where life can exist. Basically man cannot be separated from it; it is only now that this in-dissolubility begins to appear clearly and in precise terms before us. He is geologically connected with its material and energetic structure. Actually no living organism exists on Earth in a state of freedom. All organisms are connected indissolubly and uninterruptedly, first of all through nutrition and respiration, with the circumambient material and energetic medium. Outside it they cannot exist in a natural condition.

In our century the biosphere has acquired an entirely new meaning; it is being revealed as a planetary phenomenon of cosmic character. In biogeochemistry we have to reckon with the fact that living organisms actually exist not on our planet alone, and not in the terrestrial biosphere only. It seems to me that so far this has been established beyond doubt only for all so-called 'terrestrial planets', that is, for Venus, the Earth and Mars.

The thought of life as a cosmic phenomenon was alive long ago, as evidenced by the archives of science, including Russian science. At the end of the seventeenth century, the Dutch scientist Christian Huygens (1629–1695) put forward that problem in his last work, 'Cosmotheoros', which was published after his death. This book, upon the initiative of Peter the Great, was twice published in Russian in the first quarter of the eighteenth century, under the title, 'The Book of Contemplation of the World'. In it Huygens established the scientific generalisation that 'life is a cosmic phenomenon somehow sharply distinct from inert matter.' I have recently called this generalisation the 'Huygens principle'.

Living matter, by weight, constitutes an insignificant part of our planet. Presumably, this is observed in the whole course of geological time; in other words, this relation is *geologically eternal.* Living matter is concentrated in a thin but more-or-less continuous film on the surface of land, in the troposphere, in the forests and fields, and it permeates the whole ocean. Its quantity is calculated to be of the order of 0.25 percent of the weight of the biosphere. On land it descends under the surface in non-continuous accumulations, probably down to an average depth of less than 3 km.

PROBLEMS OF BIOGEOCHEMISTRY

In the biogeochemical work which I have conducted systematically and uninterruptedly since the beginning of 1916, I have lately come to conclusions pointing to an irreconcil-able difference separating the energetic and material characters of life from those of all other processes taking place in the biosphere. The difference, on the one hand, may be expressed in precise quantitative terms, and on the other, requires new mathematical research in the domain of geometry. A new approach to the problems of the study of living phenomena is thus revealed, which discloses new possibilities for investigation.

The foundations of biogeochemistry rest on a few basic concepts free from hypothesis and representing precise and clear scientific ideas, empirical generalisations derived from experiment and observation. To begin with, the very concept of the *living matter* of the biosphere is such an empirical scientific generalisation. The living matter of the biosphere is the sum of its living organisms. Hereinafter this concept will be employed rather than the concept of 'life'. Usually, in the examination of the biosphere, the single living organism recedes from view; the sum of all organisms, i.e. living matter, is what is important. However, even in biogeochemistry, in certain strictly defined cases, one has, at times, to consider the individuality of single organisms. This is inevitable in cases involving the activities of modern man, when a single personality sometimes clearly manifests itself in large-scale phenomena of planetary character, by changing and accelerating certain geological processes of immense importance.

We live in an unprecedented, geologically significant epoch. Man by his work, and his conscious attitude towards life, is remaking a terrestrial envelope, the geological domain of life, the biosphere. He is transforming it into a new geological state, the noosphere (Le Roy 1927:196). He creates within the biosphere new biogeochemical processes that did not exist before. A planetary phenomenon, the biogeochemical history of the chemical elements, is becoming notably changed. For example, previously non-existent free metals, such as aluminium, magnesium and calcium, and their alloys, are now created in enormous quantities. Vegetable and animal life is radically modified and disturbed, new races and species being created. The face of the planet is being deeply changed. A process of turbulent blossoming is now going on in the biospheral envelope of the Earth, and the subsequent development of this process may be expected to assume tremendous proportions.

In biogeochemical processes the sum of all living beings plays the leading role. It may be characterised as the sum of all organisms, reducible in turn to a mathematically expressed sum of average living organisms. It is the manifestation of the sum and not that of the average individual which is studied in biogeochemistry. In most of the other biological sciences we study mainly the average individual, while in the medical and zootechnical sciences, as in all humanistic sciences, primary importance is to be attributed to the individual as such, to the personality that has come to the fore during the past thousands of years.

We may differentiate between homogeneous living matter as a genus or a species, etc., and heterogeneous living matter, as a forest, a steppe, or any biocoenosis at large, consisting of different kinds of homogeneous living matter in certain proportions. In line with the concept of living matter, two more ideas may be put forward, the notion of the *biosphere* as the medium of life, and that of the living organism as a *living natural body.*

Living matter exists on our planet in the biosphere only, which is thus the domain of life. The limits of this domain are defined with precision. The whole of the atmospheric troposphere belongs to the biosphere. Moreover, at present living organisms, man and his inevitable companions, insects, plants, and bacteria, are penetrating, by themselves or with the help of apparatus, even higher, into the stratosphere. Simultaneously, civilised man, as well as his inevitable companions, penetrates deep below the relief, in contact with the troposphere, for several kilometres down below the land surface. The planetary importance of the existence of bacterial, mainly anaerobic, living matter, in the depths of the Earth, down to three kilometres and possibly even more, has moreover now become apparent. The lower boundary of the biosphere thus lies several kilometres below the level of the geoid. The whole world ocean is included in it.

The biosphere represents a definite geological envelope markedly distinguished from all the other geological envelopes of our planet. This is so not only because it is inhabited by living matter, which reveals itself as a geological force of immense importance completely remaking the biosphere and changing its physical, chemical and mechanical properties, but also because the biosphere is the only envelope of the planet into which cosmic energy penetrates in a noticeable way, changing it even more than does living matter. The chief source of this energy is the Sun. The latter's energy, radiant and chemical, working in conjunction with the energy of chemical elements, is the primary source of the creation of living matter.

Living matter accumulates the energy of the biosphere, chiefly the light and chemical energy of solar radiation and the chemical energy of terrestrial atoms. It is possible that radioactive energy plays a certain role. Materially and energetically, the matter which builds the biosphere is sharply heterogeneous. We have to distinguish between the main mass of the biosphere, which I shall call inert, and the living matter. With regard to weight, the inert part of the biosphere consists mostly of rocks. But with regard to volume, liquid and gaseous bodies predominate. It is in these bodies, the ocean and the atmosphere, that living matter exists.

Between the inert and the living matter of the biosphere there is a unique material and energetic connection, proceeding incessantly in the processes of respiration, nutrition and reproduction of living matter, which are basic functions permitting its existence. We thus have a migration of atoms from the inert bodies of the biosphere into living natural bodies and back.

All these manifestations of biogenic migration and biogeochemical energy are determined by the volume, chemical composition and energy of the biosphere. Because of this, the properties of all existing organisms are strictly determined by the structure of the biosphere. It is usually forgotten that living organisms are a regular function of the biosphere. The living organism, chiefly in philosophical speculation, but also in biology, is erroneously contrasted with its medium, as if the two were independent objects.

It is essential to direct scientific work into these domains of biogeochemistry not only in view of their great theoretical importance, but also in view of their indubitable importance in regard to the tasks of governmental administration. Statesmen should be aware of the present elemental process of transition of the biosphere into the noosphere.

The fundamental property of biogeochemical energy is clearly revealed in the growth of the free energy of the biosphere with the progress of geological time, especially in relation to its transition into the noosphere.

G.EVELYN HUTCHINSON

G.Evelyn Hutchinson (1903–1991), an English-born US zoologist known for his ecological studies of freshwater lakes, was an early and leading supporter of Vernadsky's concept of the biosphere (as evidenced by many of his articles) and integrated a similar perspective into his teaching and research as a faculty member at Yale University, where he taught students such as H.T.Odum and William C.Clark, who later continued pioneering work on the biosphere as well as global change. Hutchinson was instrumental in helping to publish Vernadsky's final article on the noosphere in 1945 in the United States, but with little apparent impact. In recognising the crucial role of micro-organisms on global processes, Hutchinson's work foreshadowed some of the underlying ideas of the Gaia hypothesis.

THE BIOSPHERE

The idea of the biosphere was introduced into science rather casually almost a century ago by the Austrian geologist Eduard Suess, who first used the term in a discussion of the various envelopes of the Earth in the last and most general chapter of a short book on the genesis of the Alps published in 1875. The concept played little part in scientific thought, however, until the publication, first in Russian in 1926 and later in French in 1929 (under the title *La Biosphere*), of two lectures by the Russian mineralogist Vladimir Ivanovitch Vernadsky. It is essentially Vernadsky's concept of the biosphere, developed about fifty years after Suess wrote, that we accept today. Vernadsky considered that the idea was ultimately derived from the French naturalist Jean Baptiste Lamarck, whose geochemistry, although archaically expressed, was often quite penetrating.

The biosphere is defined as that part of the Earth in which life exists, but this definition immediately raises some problems and demands some qualifications. At considerable altitudes above the Earth's surface the spores of bacteria and fungi can be obtained by passing air through filters. In general, however, such 'aeroplankton' do not appear to be engaged in active metabolism. Even on the surface of the Earth there are areas too airy, too cold or too hot to support metabolising organisms (except technically equipped human explorers), but in such places also spores are commonly found. Thus as a terrestrial envelope the biosphere obviously has a somewhat irregular shape, inasmuch as it is surrounded by an indefinite 'parabiospheric' region in which some dormant forms of life are present. Today, of course, life can exist in a space capsule or a space suit far outside the natural biosphere. Such artificial environments may best be regarded as small volumes of the biosphere nipped off and projected temporarily into space.

What is it that is so special about the biosphere as a terrestrial envelope? The answer seems to have three parts. First, it is a region in which liquid water can exist in substantial quantities. Second, it receives an ample supply of energy from an external source, ultimately from the Sun. And third, within it there are interfaces between the liquid, the solid and the gaseous states of matter. All three of these apparent conditions for the existence of a biosphere need more detailed study and discussion.

Cloud and his associates have recently found evidence of eukaryotic cells—cells with a fully developed mitotic mechanism and with mitochondria—1.2 to 1.4 billion years old. It is reasonable to regard the rise of the modern eukaryotic cell as a major consequence of the new conditions imposed by an oxygen-containing atmosphere. Moreover, Lynn Margulis of Boston University has assembled most convincingly the scattered but extensive evidence that this response was of a very special kind, involving a multiple symbiosis between a variety of pro-karyotic cells and so constituting an evolutionary advance quite unlike any other known to have occurred.

If the first eukaryotes arose 1.2 to 1.4 billion years ago, there would be about half of this time available for the evolution of soft-bodied multicellular organisms, since the first fossil animal skeletons were deposited around 600 million years ago at the beginning of the Cambrian period. Although most of the detailed history consists of a series of blanks, we do have a time scale that seems sensible.

Without taking too seriously any of the estimates that have been made of the expectation of the life of the Sun and the solar system, it is evident that the biosphere could remain habitable for a very long time, many times the estimated length of the history of the genus *Homo,* which might be two million years old. As inhabitants of the biosphere, we should regard ourselves as being in our infancy, particularly when we throw destructive temper tantrums. Many people, however, are concluding on the basis of mounting and reasonably objective evidence that the length of life of the biosphere as an inhabitable region for organisms is to be measured in decades rather than in hundreds of millions of years. This is entirely the fault of our own species. It would seem likely that we are approaching a crisis that is comparable to the one that occurred when free oxygen began to accumulate in the atmosphere.

Admittedly there are differences. The first photosynthetic organisms that produced oxygen were probably already immune to the lethal effects of the new poison gas we now breathe. On the other hand, our machines may be immune to carbon monoxide, lead and DDT, but we are not. Apart from a slight rise in agricultural productivity caused by an increase in the amount of carbon dioxide in the atmosphere, it is difficult to see how the various contaminants with which we are polluting the biosphere could form the basis for a revolutionary step forward. Nonetheless, it is worth noting that when the eukaryotic cell evolved in the middle Precambrian period, the process very likely involved an unprecedented new kind of evolutionary development. Presumably, if we want to continue living in the biosphere we must also introduce unprecedented processes.

Vernadsky, the founder of modern biogeochemistry, was a Russian liberal who grew up in the nineteenth century. Accepting the Russian Revolution, he did much of his work after 1917, although his numerous philosophic references were far from Marxist. Just before his death on 6 January, 1945, he wrote to his friend and former student Alexander Petrunkevitch: 'I look forward with great optimism. I think that we undergo not only a historical, but a planetary change as well. We live in a transition to the noosphere.' By noosphere, Vernadsky meant the envelope of mind that was to supersede the biosphere, the envelope of life. Unfortunately, the quarter-century since those words were written has shown how mindless most of the changes wrought by man on the biosphere have been. Nonetheless, Vernadsky's transition in its deepest sense is the only alternative to man's cutting his lifetime short by millions of years.

LYNTON K.CALDWELL

Lynton K.Caldwell (b. 1913) is professor emeritus at the School of Public and Environmental Affairs, Indiana University, USA. Since the early 1960s, his interests have concentrated on public policy for science and the environment, and his *In Defense of Earth* (1972) was one of the first books to provide a detailed account of the development of the concept of the biosphere.

DISCOVERING THE BIOSPHERE

The roughly five hundred years between the discovery of America in 1492 and the landing of the Apollo XI astronauts upon the Moon will surely appear in retrospect as a distinct and decisive era in the history of man and the Earth. In our times, this half-millennium is called *modern*—whatever name future eras may give it. The Earth can never again be what it was when the era began, nor can prospects for the era to come be forecast by precedents that have given reliable predictions in the past.

'In the twentieth century, man, for the first time in the history of the Earth, knew and embraced the whole biosphere, completing the geographic map of the planet Earth, and colonised its whole surface. *Mankind became a single totality in the life of the Earth*.' Thus the Russian scientist V.I.Vernadsky in 1938 summarised the end of a process of discovery which began at least five thousand years earlier, when man began to leave behind records of his impressions and descriptions of the natural world.

At the beginning of modern times, large areas of the world had no permanent human settlements. The major areas of human habitation were isolated and had developed distinctive cultures. Farming and herding relied largely upon the natural operations of natural systems, modified only marginally by public works for water supply, flood control and irrigation. Today, large urban concentrations of man are absolutely dependent for survival on the continuous operation of artificial systems. Without a steady flow of electricity and fossil fuels, millions of men would die. As population has grown, the world's peoples have become increasingly homogenised physically and culturally. All major premodern cultures have been extinguished or acculturated by the dominant civilisation.

The modern age has been characterised by an explosive increase in not only human population but also knowledge, especially in technology. Through technology, the impact per human individual upon the biosphere has increased exponentially, accelerating towards the end of our century. Distinctive among the many forms of human dominion, the nation-state has been the characteristic structure for extending human pre-emption of the Earth. It was developed in Europe and accompanied the expansion of the European peoples into the Americas, into South Africa and Australia, and across northern Asia to the Pacific Ocean.

The unifying and distinguishing work of this era has been the human pre-emption and discovery of the biosphere. This is a simple way of stating a complex paradox: the biosphere was occupied and its exploitation well advanced before its true nature—vulnerable and finite—was even vaguely perceived. Before AD 1500, man's knowledge of the nature of the Earth and its relationship to the rest of the universe was very limited, and much of what he believed was wrong. By the end of the era, man had won an experiential knowledge of the Earth and its place in space, and had gathered many clues as to its evolution in time.

The discovery of the biosphere in the latter half of the twentieth century has come none too soon for the survival of man. By the late 1960s, it was becoming evident that the uncontrolled impact of human activity upon the biosphere could not long continue without endangering the basis of life itself. How ever opinions differed about the imminence of danger and the prospects for avoiding it, few who read the evidence could discount the potential catastrophe pointed to by existing trends.

In 1807, the naturalist Alexander von Humboldt wrote 'In the great chain of causes and effects no thing and no activity should be regarded in isolation.' This interconnectedness of the living world had been recognised over the centuries, but not until the twentieth century did the terminology to designate the specific, systematic interconnections of the natural world come into general use. In 1867, Ernst Haeckel had put forward the word 'ecology' to designate the study of living systems in relation to their environment, but, like 'biosphere', it was slow to find common usage. The term 'ecosystem' does not appear to have been used commonly before an essay by A.G.Tansley published in 1935 in the journal *Ecology*. The ecosystem has also been known by other names, notably 'biogeocoenose', especially in the Russian literatures. It means a definable or bounded system of complex and dynamic biological and physical relationships that vary greatly in size and complexity from the minute or simple to the very large and infinitely complex. The term 'ecosphere' has been used to summarise the totality of living systems that envelop the Earth and is synon-ymous with 'biosphere'.

In the course of discovering the interdependencies of the living world, the organisms of which it was comprised were located and described. Taxonomy and systematics, description and classification of species, were thus major concerns of biological science in the eighteenth and greater part of the nineteenth centuries, a work particularly associated with the name of the Swedish botanist Carl von Linné (Linnaeus, 1707– 1778). Exploration of the continents and the seas and the collection of plant and animal specimens laid foundations for the geography of plants and animals and for more sophisticated understandings of habitat requirements and competition between species.

The distribution of plants and animals was discovered to be neither random nor static. The reasons that a particular species was found to be where it was often proved to be complex. Spatial locations were frequently found to be related to biological dependencies, of which symbiosis, parasitism and territoriality represented special cases. At any given time, the network of interdependencies in the living world was found to be in a state of approximate, although dynamic, equilibrium. This homeostatic state was subject to change through forces acting, not only in the physical environment external to organisms, but also through genetic changes in the organisms themselves. The consequences of this process of change were discovered to result in the evolution of the species, and theoretical mechanics of this process were described by Charles Darwin in 1859 in *The Origin of Species,* by Alfred Russell Wallace in 1870 in *Contribution to a Theory of Natural Selection,* and by the science of genetics after 1900.

The transplanting of species into areas in which they had not naturally occurred, if it did not fail, frequently had disruptive and calamitous results. The homogenising and impoverishing of the ecosystems of the Earth was an easily measurable consequence of human interference with natural interdependencies. At almost no time and place in the expansion of populations, and especially of European populations in modern times, did an ecological awareness or an ecologically oriented policy guide the behaviour of the explorers and settlers. By the mid-twentieth century, however, the disastrous record of untested and unguided human intervention had been well documented, and there was a growing popular awareness of the dangers of uninformed disruptions of natural systems. Nevertheless, individual and institutionalised human behaviour was slow to catch up with human understanding.

Less readily understood than the interconnectedness of things in space was their interconnectedness in time. The theory of evolution dealt with intervals of time far greater than the experience of any human individual and beyond the comprehension of most of them. Yet, in part because of the work of Albert Einstein (1879–1955) showing the relativity of time and space, the significance of time in human affairs was changing. Past expectations in relation to time were becoming less and less reliable as guides for expectations in the future. Cultural change, based heavily upon innovation in science and technology, was accelerating throughout the nineteenth and twentieth centuries. This artificial speeding up of history not only contributed to man's disruptive impact upon the natural world but also created tensions and discontinuities in his personal life and in society.

Curiously, the pinnacle of technological effort, space exploration, led in the 1960s to a new appreciation of the interdependencies of the biosphere. Space travel required man to devise a minimum personal artificial ecosystem, the spaceship, and to do this he was required to learn how he must accommodate to those interdependencies, which he could not change. The effort to discover, through space biology and medicine, what was required for human survival beyond the limits of the Earth's biosphere inevitably clarified and emphasised the conditions necessary to life on Earth. So the voyages into space had an effect similar to that of the sea voyages of preceding centuries—they added cumulatively to the process of discovering the true nature of the Earth.

The discovery of the biosphere inevitably involved man in a process of self-discovery. As man's profound and often destructive impact upon the Earth became more obvious, the need to know more about man became ever more evident. The seeming growth of aberrant behaviour among individuals and societies strongly suggested that the human adjustments required by man-made changes in the modern world might be exceeding the ability of many individuals to accommodate them.

It may seem strange that so radical a departure from historical views of man-environment relationships as are implicit in our present knowledge of the biosphere should not have had more profound effects upon human attitudes and institutions. Perhaps it is man's long and intimate association with the physical world that has caused him to be contemptuous of it or negligent towards it. The growth of knowledge concerning the biosphere has been slow, even in modern times, and has been the product of findings and theories in nearly every science. Scientific theories regarding the biosphere, supported by sufficient evidence, may in time be accepted as conventional wisdom and thereafter be taken for granted. But the discovery of the biosphere, unlike the splitting of the atom, has not been a dramatic event which can be located precisely in time. Perhaps that is why many intelligent individuals cannot understand how the incremental accumulation of knowledge about the biosphere may add up to an interpretation of man's environment relationships that holds absolutely fundamental and revolutionary implications for the future of human behaviour patterns and institutions.

As one may not see a forest for the trees, very large ideas may be lost in the specific arguments of which they are composed. The human mind, moreover, tends to see what it wants to see or what it has been trained to see. The notion of inexorable limitations has not been congenial to modern men. Even when the finiteness of the world is admitted intellectually, the concept will often be rejected emotionally. The traditionalist will feel that God will intervene somehow, and the unimpressed scientist, deep in his own speciality, will merely ask, 'So what?'

But as more is learned about the grand-scale cycles of energy and chemical processes that sustain the biosphere, processes that man can disrupt but not control, fewer sceptical questions are voiced. A more pertinent question has been asked by George Woodwell: 'How much of the energy that runs the biosphere can be diverted to the support of a single species: man?' The answer to that question will be found, with or without searching for it, in the years ahead. But it is not sufficient that scientists alone understand the requirements of a self-regenerative biosphere; there must be a general recognition that there are requirements which man cannot modify.

Man's beliefs and attitudes are in some measure the product of his experience. If his behaviour and institutions are to be reorganised consistent with the requirements of the biosphere, his life experience must somehow be modified to make those requirements a part of his operating assumptions. Something must be added to his experience that did not exist in the pre-scientific past and is consis-tent with what he knows today about the natural world, something that confirms this knowledge with great emotional power, Knowledge to support such a change of attitude exists and is growing, but a dramatic event may be needed to symbolise the new concept.

NICHOLAS POLUNIN AND JACQUES GRINEVALD

Nicholas Polunin (1909–1997) was, at various times and in different capacities, a scholar, explorer, educator, philanthropist and environmentalist. A botanist by training, Polunin studied at Oxford (under Sir Arthur Tansley) and taught at many leading universities around the world. After establishing himself as an academic he became increasingly interested in global ecology and settled in Geneva, Switzerland, from where he later launched the journal *Environmental Conservation,* the International Conferences on Environment Future and the World Council for the Biosphere. From the early 1980s, Polunin was a leading promoter of the concepts of the biosphere and the noosphere through his various activities and remained active until the end of his 88 years. Jacques Grinevald (b. 1946), a French natural philosopher and teacher at the University of Geneva, was the first scholar to trace the rich and important history behind the concept of the biosphere and clearly show its links to contemporary issues such as global change and Gaia. The writings of these two pioneers provide a good example of their efforts to both promote the concept of biosphere and situate it in the broader context of global ecology.

VERNADSKY AND BIOSPHERAL ECOLOGY

For most people, the rise of global ecology (e.g. Budyko 1980)—the ecology of the whole of Earth's Biosphere—dates mainly from the earlier 1970s (Polunin 1972), as it was at that time of 'environmental revolution' that the realisation of our complete dependence on our planetary biospheral environment started to become at all widespread in enlightened circles. Such realisation of the truth has latterly gathered more and more momentum, but never in sufficient volume or quickly enough to satisfy its most dedicated adherents or, we fully believe, the best interests of our world.

During the 1980s, the idea that The Biosphere could be seriously, even drastically, disturbed by a nuclear conflict or mere accident became a new subject of international concern. Interdisciplinary study by ICSU's SCOPE, and others, of the global environmental consequences of nuclear war followed, with much-needed international scientific collaboration. The so-called 'nuclear winter' is a resultant, important argument emphasising the interconnections of all the parts of The Biosphere. The human demo-mass thus turned some of its concern from the face of the Earth to the fate of Earth's Biosphere.

But, as we know, The Biosphere—the initial letters of which we capitalise thus to dignify our only known natural habitat in the cosmos—is also threatened with many other major ecological disasters, such as that of stratospheric ozone depletion, the increasing concentration of carbon dioxide and other 'greenhouse' gases in the atmosphere (with probable effects on global climate, heightened by deforestation and other devegetation), the continued destruction of the world's tropical forests, with extinction of many plant and animal species at an unprecedented rate and concomitant dramatic losses of genetic diversity, and yet other looming ecodisasters.

There can be no question of the vital and vast significance of the concept of Biosphere in our modern world, even as its actuality provides almost all the components of the life support of man and nature. Yet, looking back historically, it seems extraordinary indeed that nobody appears to have had, or anyway developed and published, these ideas until they were so clearly enunciated by Vladimir Ivanovich Vernadsky less than seventy years ago. And now The Biosphere is emerging as a vital overall reality that we need to maintain intact and cherish perhaps even more ardently than any particular part or factor of our planet's terrestrial or aquatic surface.

To be sure, the approximate limits (Vernadsky 1929) to which life extends naturally up in the atmosphere as spores and yeasts, etc. (e.g. Polunin 1951) and down in the lithosphere as chemosynthetic bacteria (e.g. Winogradsky 1949; Margulis and Sagan 1997b) have only become known relatively recently, and, from their very nature, must remain imprecise. So must the dependent limits of our Biosphere, though it has long been known that they include the deepest depths of the oceans and ocean trenches. There has also been the unfortunate confusion of other interpretations, to which we have already referred. But such questions are largely academic and do not detract from the vast importance of the concept of the great thinker.

Suffice it to say here that, after the universe, The Biosphere is in several respects probably the greatest reality with which we, as humans, have to deal; and yet we are threatening it in many ways, most of which stem basically from our increasingly too great numbers and profligacy. We should also beware that, from some of the changes wrought by humans, the dangers lie in their subtlety, so that they are liable to be overlooked until the period is too late for remedy, whereas others appear drastically, even suddenly, after reaching a threshold or being triggered unexpectedly.

KENNETH STOKES

Kenneth Stokes (b. 1952) is an associate professor of political economy of the Graduate School of International Relations at the International University of Japan, and was previously attached to York University in Canada. The book *Man and the Biosphere* (1992) examines the concepts of biosphere and noosphere in relation to the economy through a broad co-evolutionary perspective, calling for replacement of the closed, mechanical paradigm of current economic thought.

MAN AND THE BIOSPHERE

The development of the biosphere into the noosphere is a phenomenon more profound and powerful in essence than all of human history. However, mankind is confronting a vital challenge that will be registered as one of the most crucial in its history. It has now reached a critical phase in the conscious evolution of the noosphere at which mankind will either realise itself or destroy itself. For the present period in the history of both the human race and the planet, as a whole, is marked by an intense acceleration of all evolutionary processes, not only by the consolidation of a highly interdependent world system, but also by an erosion of the boundaries between human evolution and human ecology. Mankind's entry into the noosphere epoch means that the Earth's further evolution has also entered a new channel wherein its further flow should ensure the co-evolution of man and the biosphere as an indispensable condition of society's continued development.

The emergence of the noosphere refers to a stage in the further evolution of the biosphere in which man becomes aware of his capacity to influence the course of evolution. Moreover, it represents a stage in which the power of technological systems is restructured to renounce that form of rationality that has elicited the technological imperative in favour of a rationalisation of rationality supporting the cultivation of the inner aspirations of life. Consequently, priority now attaches to evaluations of alternative 're-inverted' institutional modes of human activity that will not disrupt the homeostasis of mankind as a species, and that instead of destroying man's co-evolution with the biosphere will enhance it.

The well-being of both present and future generations depends on whether ethically and morally sound ways are found to solve these dilemmas. The challenge of the technosphere in the epoch of the noosphere demands that we seek a substantive political economy—a political economy in the broad sense. It is in the attempt to fashion and adapt institutions appropriate for man in the epoch of the noosphere that mankind may well meet its ultimate test.

The emergence of the noosphere calls for a re-evaluation of the closed mechanical paradigm of economic thought. For it has become increasingly apparent that the role of market-oriented analysis may be appropriate for a select subset of problems confronting mankind in the epoch of the noosphere. However, the abandonment of traditional forms of analysis for more substantive modes has raised the issue of the appropriate paradigm for economic thought. Some analysts are turning to energy analysis, while others seek broader terms of reference in general systems theory and find sustenance in selected aspects of classical economic analysis.

While this theme is maturing, a major obstacle to its development has been the orientation of economic analysis of the cybernetics of the self-regulating market conceptualised as a closed mechanical system. This understanding opposes that which informed the physiocrats. Their materialist representation of the economic process was a holistic vision of reproduction of material wealth. It presented an image of the economy whose spirit we find again in emerging modern systemic approaches. For the reproduction of the economic sphere within the biosphere, the physiocrats' central preoccupation, is an emergent problem of co-evolutionary economic analysis.

Marx also sought to give a materialist and systematic survey of the whole of economic science, whose scope extended beyond the analysis of Ricardo. His open-systems model departed from the artifice of naturalism in Quesnay's discourse and the linear causality present in Ricardo's work. Anticipating elements of open-systems theory, Marx referred to the complex inter-penetrations of the nature—society nexus. The close similarity of the life process as an open metabolically interactive phenomenon to that of the economic process was present in the analyses of Quesnay and Marx. They, nonetheless, shared an, albeit flawed, view of the livelihood of man as an open metabolically interactive system, which today is the hallmark of the economy in the broad sense.

In the first quarter of this century, and contiguous to Marx's totality theory and Engels's search for the unity of scientific knowledge, a number of seminal and rigorous contributions to the understanding of the economy in the broad sense were made. However, the corresponding philosophical and methodological concepts were not fated to endure. In particular, the promising advances of A.A.Bogdanov, who saw beyond the economistic and social energetic forms of reductionism, were obscured. When elements of these analyses re-emerged, the analytical categories adopted were those of Ludwig von Bertalanffy rather than those of A.A. Bogdanov. But, whereas Bogdanov's analysis embodied dimensions of critical social theory, Bertalanffy's contribution was narrower in its scope.

The recent and growing awareness of the biophysical dimensions of the economic process has led to a resurrection of a number of fundamental ethical and moral issues identified by the physiocrats and by Marx. This marks a departure from economistic perspectives and symbolises a return to substantive economic thought. In particular, an alternative paradigm for economic thought based on the dynamics of open systems is re-emerging.

But having rejected mechanicalism and embraced an open-system model, a broad re-conceptualisation of production is required in which low entropy is appropriated from the environment and the degraded high-entropy matter-energy is expelled. Thus, replenishment of the physical basis of life is not a circular self-sustaining phenomenon. In this re-conceptualisation, production is conceived as a thermodynamic phenomenon. And, although it is analytically useful to refer to the production process as a thermodynamic phenomenon transforming low entropy into high entropy, yielding a service thereby, these categories appear as limiting factors rather than determining ones. The production process may be technically described as one of the 'informing' of low-entropy matter—energy by some 'structuring information' into a use-value.

But the thermodynamic qualities of the economic process are generating a heightened level of complexity—a complexity to which it must respond. In other words, the economic system is experiencing its own negativity. Indeed, the growing complexity of technified society, in contravening the norms of the biosphere, represents an inversion of finalities that normally attaches to open living systems. In this connection, the formal categories of systems theory and cybernetics are of particular value. For the analytical categories of political economy in the broad sense must not only incorporate biophysical co-ordinates but also aspects of the general theory of organisation, including the cybernetics of autopoiesis. These analytical categories facilitate an understanding of problems of the organisation of technified society in ways that transcend earlier analyses.

From the general theory of organisation, the very phenomenon of organisation is interpreted as a dialectical response to complexity. The dialectics of problem and solution cumulatively stimulates further organisational differentiation. Each rationalisation integrates specific functions into a new set of system/environment co-ordinates and produces types of problem and problem solutions that would not, and could not, arise at the level of the encompassing system. In this connection, organisational differentiation is a viability-seeking response which attaches to the principle of requisite variety. In these terms, the functional differentiation of society is a manifestation of society's adaptive response to technology. From an Ashbian perspective, this defines capitalism and socialism as merely different variety-absorbing institutions.

Clearly the autonomous evolution of the technosphere is a problem of world complexity which has assumed a leading position. However, neither market nor technocratic plan fetishistic responses are consistent with the vital integrity of the biosphere and with democratic aspirations. Consistent with these aspirations, a growing number of analysts assume as their point of departure the first principle of co-evolution analysis: that it is necessary to subordinate technospheric elements to appropriate institutional mechanisms in ways that limit the exercise of inappropriate forms of social power. How we address the co-evolutionary problem of the complexity of technified society and democracy enters as the dilemma of the political economy in the epoch of the noosphere.

In face of an uncertain future, the political economist must assume particular responsibility. For it has fallen to him to overcome misplaced concreteness and fetishisms in order to participate in the work of life that is carried through the human species and which alone may lend meaning to the co-evolution of man in the biosphere.

3

THEORIES: THE EVOLUTION OF THE CONCEPT OF 'NOOSPHERE'

PROCESS PHILOSOPHY

If the concept of noosphere was born of the biosphere, it is also indebted to the organicist school of thought, closely linked to 'process philosophy', which gained broad support at the beginning of the nineteenth century. One of this school's most influential thinkers was the French philosopher Henri Bergson, who suggested that the universe is 'creative' and more aptly described in terms of an organism rather than a machine (*Evolution Créatrice,* 1909). Bergson was a cosmologist who argued that mind directs human affairs and that this process is upheld by a constant vital force (*élan vital*) that permeates evolution. He argued (Bergson 1911:87) for 'an *original impetus* of life, passing from one generation of germs to the following generation of germs through the developed organisms which bridge the interval between the generations.' Bergson's ideas were therefore at odds not only with Darwinian evolution, but also with the powerful claim of separation of mind and body made from the time of René Descartes through to current thinkers such as Daniel Dennett (1995) that 'one thinks metaphysically, but lives physically.' According to M.Bartelemy-Madaule (1963:525) Bergson was faithful to the sociological tradition of Emile Durkheim in viewing the centrality of the social fact and the social construction of reality, but his work remained firmly in the scientific idiom and the secular.

Bergson's ideas—which paved the way for the school of thought known as 'vitalism'—attracted as many critics as it did supporters. Although a thoroughgoing rationalist, Bergson was derided not only for being too poetic (he did win a Nobel Prize in literature) but also for the substance of his ideas. Critics such as Edmund Noble (1926:510–11) accused him of 'reading psychism into nature' and equated the idea of *élan vital* with that of 'saying that an organism is alive because it has been vitalized.' While Bergson's arguments for the 'original impetus of life' were never developed much beyond his use of metaphors and analogies, he was broadly convincing on his insistence of the co-existence and interdependence of matter and spirit (consciousness). Many scientific critics differed with Bergson on the specifics, but he may be credited with helping to launch a critical debate concerning humans and evolution. Most importantly, Bergson's ideas drew attention to the role of the ideas, information and non-material influences in this process—later having influence on the development of 'cybernetics' (Wiener 1948). More immediate, however, is the fact that this debate took place at precisely the same time—the mid-1920s to early-1930s—that Vernadsky, Teilhard de Chardin and Le Roy were first conceptualising their notions of biosphere and noosphere, and this context is therefore important for these discussions.

Box 3.1 Selected works, Henri Bergson (1859–1941)

Time and Free Will (1889), *Matter and Memory* (1896), *Laughter* (1900), *Creative Evolution* (1909), *Mind Energy* (1919), *The Creative Mind* (1934)

Dates are those of first publication (in French)

C.Lloyd Morgan (1927), a leading proponent of 'emergent evolution', rejected Bergson's notion of life force yet sought to address essentially the same question, seen to be left unanswered in Darwin's theory of evolution: how could a temporal succession of natural phenomena marked by an increase of complexity (including mind) come about? Morgan and his supporters suggested that, contrary to Darwin's theory, some of the most interesting changes in living things occurring through evolution were in fact largely *discontinuous* with the past. In other words, these changes did not uniquely take place through the gradual means of natural selection. Instead, emergent evolution sought to explain the relatively sudden appearance of reflexive consciousness, the nature of which was unprecedented in the Earth's history. Not only are these notions of the 'unique' and 'unprecedented' phenomenon of the minds and actions of *Homo sapiens* central pillars behind Le Roy's, Teilhard de Chardin's and Vernadsky's concepts of 'noosphere', but they also remain important in current discussions on evolution. For example, the theory of 'punctuated equilibrium' as an important event in the discontinuity of the evolutionary record (Eldridge 1985) suggests some similarity in this regard. More generally, work on the 'science of complexity' stresses the importance of initial conditions and small, chance occurrences in determining the fate of larger, future events. Finally, religious and cultural traditions and myths provide powerful foundations here: Shiva, the Hindu god of destruction and recreation, predicts episodic mass catastrophes. These topics are addressed in later chapters.

There is no doubt that Bergson had a significant impact on the thinking with regard to the noosphere of Le Roy, Teilhard de Chardin and Vernadsky. All three men frequently cited Bergson as an important source of inspiration in their work and they were all in contact—in varying degrees—with him in Paris. In particular, Le Roy was Bergson's protégé and later succeeded him at the Collège de France.

The 1920s were a crucial period in the development of the noosphere concept. In addition to the Bergsonian school of thought, an understanding of planetary geochemical cycles and the biosphere was growing—as discussed in Chapter 2 —and the horrors of the First World War and general political instability in Europe prompted some soul-searching by many intellec-tuals for new hope or at least new ideas for society. Perhaps also, scientists like Teilhard de Chardin and Le Roy found it increasingly difficult to reconcile their beliefs in modern science with traditional religious belief. Moreover, the attraction of Marxist ideas—if not a direct ingredient—were certainly a crucial general influence.

EDOUARD LE ROY

Edouard Le Roy was trained as a mathematician and later, under the guidance of Bergson, finished his career at the Collège de France and the Académie française as a widely respected natural philosopher. Le Roy is an important, if neglected, figure in the history of the concept of noosphere (and biosphere). During the 1920s in Paris, especially during the winter of

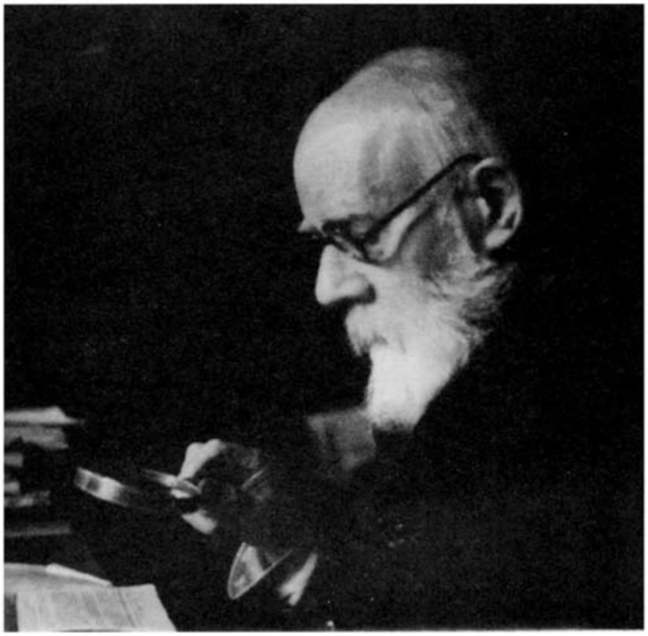

Figure 3.1 Edouard Le Roy at work

1925–26, Le Roy became one of Teilhard de Chardin's closest associates and friends (Grenet 1960:21). As scientists and deeply committed Catholics, they found common concern with issues that could potentially bridge science and religion. Working together, the two discussed a number of concepts, including what they saw as the unique evolution of *Homo sapiens* toward the noosphere. Their work was intricately connected during this period, for the two appear to have presupposed the existence of Christian values in their moral quest. Le Roy (1927:82) noted that 'I have actively discussed with P.Teilhard so often and in such depth…[that] we no longer know ourselves where to separate our respective parts.' Indeed, the extent of collaboration and shared thought is apparent in comparing these two authors' texts. Although it is unclear what exact form their contact took, Le Roy also met Vernadsky during the latter's lectures and research in Paris from 1922 to 1924. Le Roy specifically cites Vernadsky's work on geochemistry and the biosphere in his work discussing the noosphere. It is possible that Le Roy provided the connection between Teilhard de Chardin and Vernadsky during this period, but detailed records from this period, if available, have not been consulted (Grinevald 1998).

Although Le Roy is sometimes cited as a co-founder (with Teilhard de Chardin and Vernadsky) of the concept of noosphere, his broader work remains largely forgotten. This is undoubtedly partly due to the fact that Le Roy's work has only been accessible in French, but more importantly because he has been overshadowed by the broader work of both Teilhard de Chardin and Vernadsky. Although Le Roy is cited by both Vernadsky and Teilhard de Chardin for his work on the noosphere (and Vernadsky even credits him for it) he probably merits more recognition for his broader contribution. As noted above, Le Roy was the first of the three to publish on the noosphere (1927), and he achieved a level of synthesis and clarity that, although faithful to Teilhard de Chardin's underlying thought, also pays close attention to Vernadsky's emerging biogeochemistry, even foreshadowing geophysiology and what is now called the 'Gaia hypothesis' (see Chapter 4):

Box 3.2 Selected works, Edouard Le Roy (1870–1954)

A New Philosophy: Henri Bergson (1912), *The Idealist Argument and the Facts of Evolution* (1927), *The Origins of Humanity and the Evolution of Mind* (1928).

None of these works has been translated into English.

> Perhaps the living maintain themselves, above all, between themselves through their common insertion in the biosphere; at least this is a clear part of their interdependence. The notion of biosphere must therefore, without a doubt, play a major role in the explication of life, and furthermore that similar notions control the physical globe because the biosphere, itself alive, possesses a more real individuality.
>
> (Le Roy 1927:111)

Le Roy published his Sorbonne courses, which he reproduced as books in 1927 and 1928 (see Box 3.2). Both of these works address similar themes of natural philosophy: the unique place of humankind in the natural world and the related consequences for evolution. Drawing on Bergson, Le Roy sought to revisit the classification of humans in the animal kingdom, taking into account this power to chart the course of human destiny. He moved beyond this view to see humankind as a global force, totally unique in the history of evolution; an evolution leading eventually to the noosphere. Elaborating on Bergson, he envisaged a progression from *Homo faber* (toolmaker) to *Homo sapiens* (thinker) to *Homo spiritualis* (superhuman).

Following his two books on the noosphere, Le Roy moved increasingly toward his religious work. He remained friends with Teilhard de Chardin, but was not one of his principal correspondents after their close discussions in the mid-1920s.

PIERRE TEILHARD DE CHARDIN

It was Pierre Teilhard de Chardin who did most to elaborate and popularise (particularly amongst the public audience) the concept of the noosphere even if he was not allowed to publish much in his lifetime and was prevented by his order from taking up the chair of palaeontology in Paris—although he has now been proposed for canonisation. His ideas were anathema not only to his Church. As noted earlier, Peter Medawar (1961) and George G. Simpson (1960) denied that his theories were based on science—a claim that Teilhard de Chardin had explicitly stated in his work. The FBI had a file on him because of his contacts with the Chinese communists in the 1940s. More recently, some evolutionary biologists such as Steven Jay Gould (1980) have blamed him, unjustly it now seems, for the Piltdown forgery (Gee 1996). Only a handful of people came to his funeral in New York in 1955, but he was soon to be lionised by new age movements (Ferguson 1980) and had already become a guru for key figures in the United Nations.

So much has been written on Teilhard de Chardin that it is unnecessary to add much here apart from his ideas that directly relate to the idea of noosphere. Teilhard de Chardin's friend, sometime associate and biographer Claude Cuénot has provided an authoritative account of the thinker's life and work (1965). Equally useful in penetrating the complex personality and interesting life of Teilhard de Chardin as well as clearly discussing and defining his concepts is Demoulin's work, *Let Me Explain* (1969).

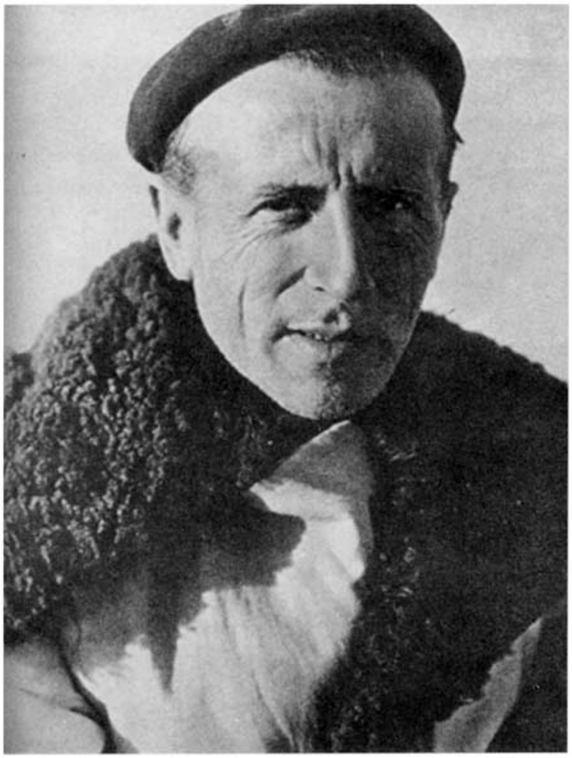

Figure 3.2 Pierre Teilhard de Chardin in Asia during the early 1930s

Box 3.3 Selected works, Pierre Teilhard de Chardin (1881–1955)

The Phenomenon of Man (1959), *The Future of Man* (1964), *Vision of the Past* (1966), *The Antiquity and World Expansion of Human Culture* (1956).
Dates indicate first publication in English. Many of the manuscripts were essentially completed during the 1920s and 1930s but were barred from publication by the Church and ultimately were printed only posthumously.

Teilhard de Chardin defined the noosphere as the sphere of thought above and beyond the biosphere with both mental and spiritual dimensions—the soul of the Earth (Teilhard de Chardin 1970:17). But he was also a pragmatic man, and Julian Huxley, a leading evolutionary biologist, brought him into UNESCO, where he famously influenced the UNESCO constitution where it states that war and peace are in the 'minds of men'. Several secretaries general (Hammarskjöld and U Thant among them) were influenced by him. As Huxley (1960: 23), ten years after Teilhard de Chardin's death, remarked 'from my first meeting with Father Teilhard—in '46 when I had just arrived in Paris to direct UNESCO—I realised that I had not only found a friend, but an intellectual and spiritual companion.' Apparently, Robert Muller, the first vice president of the United Nations University of Peace and long-time, high-ranking UN functionary, thought of the UN as a noospheric body: a collective brain reflecting planetary concerns and consciousness; a global society emerging as a co-operative entity, even the 'Omega point' of a wider love and spirituality (Muller

1985). Although many have seen Teilhard de Chardin's ideas as essentially religious, he described himself as a geobiologist and insisted that his works such *The Phenomenon of Man* were strictly scientific. However, his image was certainly used for secular aims. In 1988, the late French President François Mitterand employed Teilhard de Chardin's ideas to create a dialogue between world religions, issued a postage stamp with his picture and named a Paris square after him.

VLADIMIR I.VERNADSKY

Vladimir Ivanovich Vernadsky was born in tsarist Russia and died in the Soviet Union, aged 82 years. In spite of living through several periods of intense political turbulence—including the revolution, Stalin's purges and the Second World War—his scientific career prospered throughout. He was a mineralogist by training, a pioneer interdisciplinary scientist by vocation and a philosopher at heart. He consistently refused to label himself a dialectical materialist, instead describing himself as a 'cosmic realist' and firmly believing that mankind's greatest hope lay in the development of scientific thinking and knowledge across the globe. Before his premature death, the American historian Kenneth Bailes thoroughly researched Vernadsky's life, and his work was published posthumously (1990). While comprehensive, it is likely that renewed interest in Vernadsky in post-communist Russia will bring further data regarding his life to light.

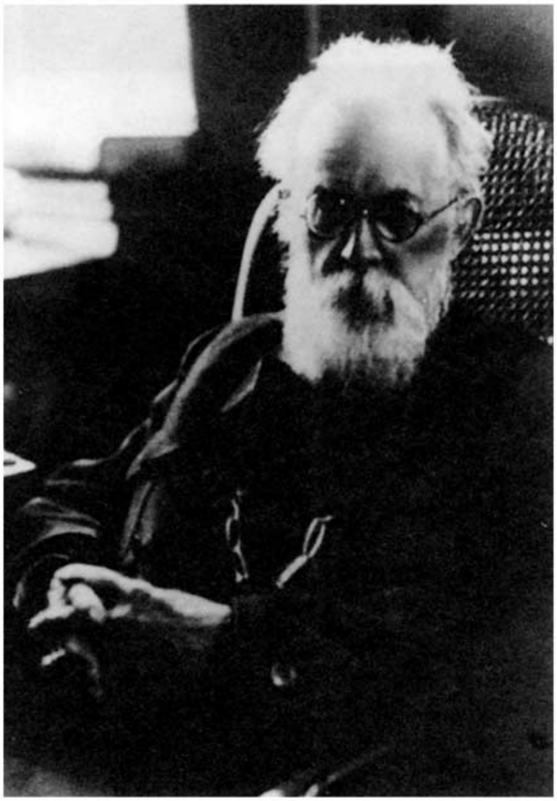

Figure 3.3 Vladimir I.Vernadsky in the 1930s

Box 3.4 Selected works, Vladimir I.Vernadsky (1863–1945)

Geochemistry (1924), *The Biosphere* (1926/29), *Scientific Thought as a Planetary Phenomenon* (1938), *Problems of Biogeochemistry* (1944), *The Biosphere and the Noosphere* (1945).

Vernadsky was a great unheralded founder of modern environmentalism and global thinking. Not only did he contribute significantly to founding geochemistry as a discipline, he was also a pioneer in biogeochemistry. He may therefore be regarded as one of the intellectual catalysts behind the emerging science of global environmental thinking (as discussed in Chapter 4). Huxley, Needham, Simpson, Medawar, Dobzhansky, Toynbee and most other leading scientists and other scholars, who were familiar with Teilhard de Chardins's work, were apparently less aware of Vernadsky's, even that which had appeared in English. It has taken more than half a century for Vernadsky's work to be rediscovered, only emerging as the backdrop to global environmental change and the Gaia hypothesis. The Russian schools of geochemistry and biogeochemistry continue his life's work, and his pupils and scientific heirs dominate Soviet science to the present. Vernadsky's scholarly legacy, however, contains much more than the body of his scientific research. Never one to focus exclusively on a specific topic or area of research, Vernadsky pursued broad scientific and philosophical questions that led him to contemplate not only how global processes worked but also what this implied for the future of humanity. He did not use the term 'noosphere' until the 1930s (Vernadsky 1998: 162), and in using it he directly credited its origin to Le Roy (who, as noted above, clearly stated that he developed it with Teilhard de Chardin). He did hint at the term though, and the groundwork was clearly set for a higher link to his scientific ideas.

At the age of seventy-two, Vernadsky wrote a series of essays on science and the relationship of scientific knowledge to philosophy. As Bailes (1990) noted: 'he clearly believed that humanity was becoming the dominant form of living matter in the biosphere and was transforming it into something essentially new: what he called the noosphere…. By noosphere he meant a geosphere dominated by human reason and conscious work activity, which were rapidly changing the chemical structure of the biosphere. His final work provides only a few suggestive passages on a subject that clearly occupied his thoughts in the years immediately preceding his death.' Yet these ideas were never fully developed, or at least not fully expressed. As Borisov *et al.* (1993:443) notes:

> the 'obscurity' of Vernadsky's notion of noosphere, coupled with the fact that his prognostic statements contained somewhat utopian elements, as well as the distortions and exclusions committed when publishing his texts, promoted the spread of both deliberate and unintentional falsifications, whereby 'Vernadsky's concept of noosphere' was adulterated with the extremes of communist and technocratic ideology or drawn into the fantasies of the so-called Russian cosmism.

In a similar manner to the Jesuit Teilhard de Chardin, Vernadsky too was a victim of censorship. Although he did enjoy considerable privileges for his day (Vernadsky remained one of the few Soviet scientists allowed to travel abroad during the 1930s), he was never at ease with any orthodoxy, Leninist, Stalinist or tsarist.

To the list of founding fathers we should probably add Nikita Moiseev (b. 1917), a mathematician who worked at the Computing Centre of the former USSR Academy of Sciences and established an international reputation in spacecraft dynamics, a field where the Soviets led the world. Moiseev closely followed Vernadsky's concepts of biosphere and noosphere, but he emphasised and elaborated the need for development to be guided by reason. This aim involved a much closer liaison between scientists and the public: a science based on 'new ethics and new morals' (Moiseev 1987:93). He consistently promoted these ideas in various branches of scientific research, a trend that continued at the International Institute for Applied Systems Analysis, an Austrian-based body that hosted some of the most important scientific collaboration between East and West during the Cold War (Moiseev *et al.* 1985).

Moiseev pointed out that the co-evolution of humankind and biosphere was not a spontaneous process. Movement in this direction held an inherent danger of stepping over the 'threshold' beyond which society might be destroyed. He was particularly concerned about an ice age that might follow nuclear war. To preserve the biosphere required careful mathematical modelling and close scientific collaboration across cultures, an endeavour that Moiseev undertook through his involvement in UNESCO and the Club of Rome. In this way, he built a view of mathematical biology that included a built-in futurology promoting the process of directed development, conflict resolution and broad co-operation. An important point of the emphasis on mathematics was to remove this pressing issue from the larger political debates tied up in the Cold War to a zone of rational discussion and analysis.

Moiseev played a practical role in introducing Vernadsky's ideas into the process of international negotiation and co-operation. He was a founding member of the Ecoforum for Peace (1987), which was created with the blessing of Mikhail Gorbachev and which brought together (in Varna) not only leading scientists from East and West but also representatives from the United Nations and NGOs. The stage was widened in the Moscow Forum of 1987 on 'A World without Nuclear Arms' (Turner and Pitt 1989), when eminent persons from the humanities also attended, including Graham Greene and Arthur Miller, as well as dissidents represented by Andrei Sakharov. Gorbachev (1987:28), in addressing this meeting, pointed to the warning that Vernadsky had issued in 1922, predicting that man would master nuclear energy but wondering whether the consequences could be controlled. Later, Gorbachev was instrumental in setting up Green Cross International, where he currently serves as president. Through the promotion of 'global value' change as the key to achieving a sustainable future for humanity, the Green Cross has created a broad cross-cultural and international network of individuals loosely based on the idea of a co-evolving biosphere and noosphere. To this end, the organisation's international board has included Moiseev (who is president of Green Cross Russia), the late Carl Sagan, and others who support the idea that society will need to embrace these ideas in order to ensure sustained progress.

HENRI BERGSON

Henri Bergson (1859–1941), a French philosopher, was the first to elaborate what came to be called a process philosophy—an approach that rejected static values in favour of values of motion, change, and evolution. Bergson was a prominent literary stylist, of both academic and popular appeal, winning the 1927 Nobel Prize in literature. *Creative Evolution* (*L'Évolution créatrice,* 1907) is Bergson's most famous book, and it reveals process thinking most clearly while at the same time showing the influence of the biological sciences upon his ideas. Bergson's work strongly contributed to the ideas that would later be expressed as the noosphere by Le Roy, Teilhard de Chardin, Vernadsky and others—notably the idea that the whole evolutionary process should be seen as the endurance of an *élan vital* or 'vital impulse' that continually develops and generates new forms of matter. Similarly, there are parallels between this idea and recent discussions concerning the dynamics of self-organising systems.

CREATIVE EVOLUTION

The universe is an assemblage of solar systems which we have every reason to believe analogous to our own. No doubt they are not absolutely independent of one another. Our sun radiates heat and light beyond the farthest planet, and, on the other hand, our entire solar system is moving in a definite direction as if it were drawn. There is, then, a bond between the worlds. But this bond may be regarded as infinitely loose in comparison with the mutual dependence which unites the parts of the same world among themselves; so that it is not artificially, for reasons of mere convenience, that we isolate our solar system: nature itself invites us to isolate it. As living beings, we depend on the planet on which we are, and on the sun that provides for it, but on nothing else. As thinking beings, we may apply the laws of our physics to our own world, and extend them to each of the worlds taken separately; but nothing tells us that they apply to the entire universe, or even that such an affirmation has any meaning; for the universe is not made, but is being made continually. It is growing, perhaps indefinitely, by the addition of new worlds.

Let us extend, then, to the whole of our solar system the two most general laws of our sciences: the principle of conservation of energy and that of its degradation limiting them, however, to this relatively closed system and to other systems relatively closed. Let us see what will follow. We must remark, first of all, that these two principles have not the same metaphysical scope. The first is a quantitative law, and consequently relative, in part, to our methods of measurement. It says that, in a system presumed to be closed, the total energy, that is to say the sum of its kinetic and potential energy, remains constant. Now, if there were only kinetic energy in the world, or even if there were, besides kinetic energy, only one single kind of potential energy, but no more, the artifice of measurement would not make the law artificial. The law of conservation of energy would express indeed that something is preserved in constant quantity. But there are, in fact, energies of various kinds, and the measurement of each of them has evidently been so chosen as to justify the principle of conservation of energy. Convention, therefore, plays a large part in this principle, although there is undoubtedly, between the variations of the different energies composing one and the same system, a mutual dependence which is just what has made the extension of the principle possible by measurements suitably chosen. If, therefore, the philosopher applies this principle to the solar system complete, he must at least soften its outlines. The law of the conservation of energy cannot here express the objective permanence of a certain quantity of a certain thing, but rather the necessity for every change that is brought about to be counterbalanced in some way by a change in an opposite direction. That is to say, even if it governs the whole of our solar system, the law of the conservation of energy is concerned with the relationship of a fragment of this world to another fragment rather than with the nature of the whole.

It is otherwise with the second principle of thermodynamics. The law of the degradation of energy does not bear essentially on magni-tudes. No doubt the first idea of it arose, in the thought of Carnot, out of certain quantitative considerations on the yield of thermic machines. Unquestionably, too, the terms in which Clausius generalised it were mathematical, and a calculable magnitude, 'entropy', was, in fact, the final conception to which he was led. Such precession is necessary for practical applications. But the law might have been vaguely conceived, and, if absolutely necessary, it might have been roughly formulated, even though no one had thought of measuring the different energies of the physical world, even though the concept of energy had not been created. Essentially, it expresses the fact that all physical changes have a tendency to be degraded into heat, and that heat tends to be distributed among bodies in a uniform manner. In this less precise form, it becomes independent of any convention; it is the most metaphysical of the laws of physics since it points out without interposed symbols, without artificial devices of measurements, the direction in which the world is going. It tells us that changes that are visible and heterogeneous will be more and more diluted into changes that are invisible and homogeneous, and that the instability to which we owe the richness and variety of the changes taking place in our solar system will gradually give way to the relative stability of elementary vibrations continually and perpetually repeated. Just so with a man who keeps up his strength as he grows old, but spends it less and less in actions, and comes, in the end, to employ it entirely in making his lungs breathe and his heart beat.

All our analyses show us, in life, an effort to remount the incline that matter descends. In that, they reveal to us the possibility, the necessity even, of a process the inverse of materiality, creative of matter by its interruption alone. The life that evolves on the surface of our planet is indeed attached to matter. If it were pure consciousness, *a fortiori* if it were supra-consciousness, it would be pure creative activity. In fact, it is riveted to an organism that subjects it to the general laws of inert matter. But everything happens as if it were doing its utmost to set itself free from these laws. It has not the power to reverse the direction of physical changes, such as the principle of Carnot determines it. It does, however, behave absolutely as a force would behave which, left to itself, would work in the inverse direction. Incapable of stopping the course of material changes downwards, it succeeds in retarding it.

With man, consciousness breaks the chain. In man, and in man alone, it sets itself free. The whole history of life until man has been that of the effort of consciousness to raise matter, and of the more or less complete overwhelming of consciousness by the matter which has fallen back on it. The enterprise was paradoxical, if, indeed, we may speak here otherwise than by metaphor of enterprise and effort. It was to create with matter, which is necessity itself, an instrument of freedom, to make a machine which should triumph over mechanism, and to use the determinism of nature to pass through the meshes of the net which this very determinism had spread. But, everywhere except in man, consciousness has let itself be caught in the net whose meshes it tried to pass through: it has remained the captive of the mechanisms it has set up. Automatism, which it tries to draw in the direction of freedom, winds about it and drags it down. It has not the power to escape, because the energy it has provided for acts is almost all employed in maintaining the infinitely subtle and essentially unstable equilibrium into which it has brought matter. But man not only maintains his machine, he succeeds in using it as he pleases.

From our point of view, life appears in its entirety as an immense wave which, starting from a centre, spreads outwards, and which on almost the whole of its circumference is stopped and converted into oscillation: at one single point the obstacle has been forced, the impulsion has passed freely. It is this freedom that the human form registers. Everywhere but in man, consciousness has had to come to a stand; in man alone it has kept on its way. Man, then, continues the vital movement indefinitely, although he does not draw along with him all that life carries in itself. On other lines of evolution there have travelled other tendencies which life implied, and of which, since everything interpenetrates, man has, doubtless, kept something, but of which he has kept only very little. It is as if a vague and formless being, whom we may call, as we will, man or superman, had sought to realise himself, and had succeeded only by abandoning a part of himself on the way. The losses are represented by the rest of the animal world, and even by the vegetable world, at least in what these have that is positive and above the accidents of evolution.

Life as a whole, from the initial impulsion that thrust it into the world, will appear as a wave which rises, and which is opposed by the descending movement of matter. On the greater part of its surface, at different heights, the current is converted by matter into the vortex. At one point alone it passes freely, dragging with it the obstacle which will weigh on its progress but will not stop it. At this point is humanity; it is our privileged situation. On the other hand, this rising wave is consciousness, and like all consciousness it includes potentialities without number which interpenetrate and to which consequently neither the category of unity nor that of multiplicity is appropriate, made as they both are for inert matter. The matter that it bears along with it, and in the inter-stices of which it inserts itself, alone can divide it into distinct individualities. On flows the current, running through human generations, subdividing itself into individuals. This subdivision was vaguely indicated in it, but could not have been made clear without matter. Thus souls are continually being created which, nevertheless, in a certain sense preexisted. They are nothing else than the little rills into which the great river of life divides itself, flowing through the body of humanity. The movement of the stream is distinct from the river bed, although it must adopt its winding course. Consciousness is distinct from the organism it animates, although it must undergo its vicissitudes. As the possible actions which a state of consciousness indicates are at every instant beginning to be carried out in the nervous centres, the brain underlies at every instant the motor indications of the state of consciousness; but the interdependency of consciousness and brain is limited to this; the destiny of consciousness is not bound up on that account with the destiny of cere-bral matter. Finally, consciousness is essentially free; it is freedom itself; but it cannot pass through matter without settling on it, without adapting itself to it: 'this adaptation is what we call intellectuality; and the intellect, turning itself back toward active, that is to say free, consciousness, naturally makes it enter into the conceptual forms into which it is accustomed to see matter fit.' It will therefore always perceive freedom in the form of necessity; it will always neglect the part of novelty or of creation inherent in the free act; it will always substitute for action itself a mutation artificial, approximative, obtained by compounding the old with the old and the same with the same. Thus, to the eyes of a philosophy that attempts to reabsorb intellect in intuition, many difficulties vanish or become light. But such a doctrine does not only facilitate speculation; it gives us also more power to act and to live. For, with it, we feel ourselves no longer isolated in humanity, humanity no longer seems isolated in the nature that it dominates. As the smallest grain of dust is bound up with our entire solar systems drawn along with it in that undivided movement of descent which is materiality itself, so all organised beings, from the humblest to the highest, from the first origins of life to the time which we are, and in all place as in all times, do but evidence a single impulsion, the inverse of the movement of matter, and in itself indivisible. All the living hold together, and all yield to the same tremendous push. The animal takes its stand on the plant, man bestrides animality, and the whole of humanity, in space and in time, is one immense army galloping beside, before and behind each of us in an overwhelming charge able to beat down every resistance and clear the most formidable obstacles, perhaps even death.

EDOUARD LE ROY

Edouard Le Roy (1870–1954) was a French mathematician turned natural philosopher who taught at the Sorbonne and finished his career at the Académie française, following closely in Bergson's footsteps and philosophy. Le Roy was committed, like his friend Teilhard de Chardin, to reconciling his scientific views with those of Catholicism. To this end, he worked, with Teilhard de Chardin, in conceptualising *Homo sapiens* as a unique phenomenon in both the biosphere and, more broadly, the universe, which would ultimately escape physical constraints through an evolutionary form of spiritual liberation. Le Roy was the first person to publish on the noosphere (1927), but his work has received little attention and has remained obscure despite its rigour and eloquence. The following section is reprinted from *The Origins of Humanity and the Evolution of Mind* (1928) and appears here in English for the first time.

THE ORIGINS OF HUMANITY AND THE EVOLUTION OF MIND

THE NOOSPHERE AND HOMINISATION[1]

I undertake to define a new point of view to discuss the problem of mankind: a point of view from which appears a double relation-ship—captured by the two terms used in the title of this lesson—between the human group and the ensemble of nature. First, these terms will be explained, as their slightly strange singularity requires. To this end, it will be useful to begin with several general remarks on an obstacle of classification.

The systematic position of humanity constitutes a real and quite difficult problem—a sort of enigma. In order to see this, it suffices to compare the flagrant disproportion which exists between the weak morphological variation from which comes the appearance of reflective thought, and the tremendous weakness that the appearance of this new faculty has produced in the breast of the living world. Taking into account only the first part of this, mankind would remain confined to his little corner of the zoological system, whilst the prodigious extension of his reign leads to a entirely different conclusion. Thus, at the very heart of the human phenomenon there is a latent paradox. It would seem that humanity is systematically much more biologically potent than it should be.

For this problem, we have already discovered a sketch—the beginning of a solution—once we have recognised that the morphological homogeneity of the human layer, which, at first glance, is so extraordinary when compared with the internal diversification shown by the other great animal layers. This homogeneity is not in the end that apparent and to be precisely appreciated it must be intimately linked with the invention of artificial tools. To proceed otherwise would be to commit a serious error in the matter of applying the rules of the systematic to the case of mankind and not joining the considerations of behaviour to those of structure. Just as every living group who, in the past, has dominated the Earth one after the other, humanity actually has multiple internal specialisations itself, equivalent to the 'radiations' or 'flowering' of types observed elsewhere. However, one less rapidly discerns this richness of type and it becomes more concealed, because it remains in certain respects a disseminated, diffuse and indivisible property of the group, instead of dividing itself between its members, being defined and constituted not finally by genealogical phyla or by organically differentiated lines of beings, but by some categories of instruments detached from the body and therefore available for use turn by turn. This is without a doubt a new form, but one that will only fool the superficial or partial observation or narrow inattention to what, in reality, is natural in the artificial. If we want to capture the full biological reality, we should not separate mankind from his tools, his real organs or his technology: his real functions. Following this, the whole that we call the 'human species' reveals itself to be a bit less paradoxical. In spite of the weak morphological gap in comparison with other primates and despite his apparent lack of individual differentiation, the human being—provided that one views him from a broad point of view — has the dimensions, the value and the complexity not only of an order, but of a natural group even more vast. Zoologically, he stands by himself, and I would not say as much for the carnivores or the rodents, but I would for the mammals taken together and perhaps even others. So this is a first truth, which is unquestionably observable as soon as observation unveils the prejudiced covers that blind it. The human paradox is eased by this. Nonetheless, because humanity—to clearly see things—merits an order or even a class, does this necessitate making a separate order or class? Moreover, would this reshaping of categories suffice? This is a totally different thing, the study of which necessitates recalling a remark already made earlier in the first lesson.

What did I state earlier? A classification is essentially an instantaneous configuration diagram that has only a tangential relationship to a single moment of reality. Neither does this method ever express the whole depth of the concrete, nor is it always uniformly appropriate. This has a consequence: all classification should be dynamically interpreted, being valid for a specific epoch and then submitted to necessary adjustment when it is transported in time. This is because one fact is certain: that infra-human forms of life have hardly changed (if not here and there by some extinctions and regres-sions) since the Tertiary period, and even since the early Tertiary period in the case of mankind. Therefore the classification that is based on the observation of the present is, in reality—how ever else it may seem—a classification of the past. As a consequence, we are justified in doubting that a truly new form, if it is indeed more recent, can be represented using this classification.

I come back to the issue that concerned us earlier. Can we resolve the question relating to the systematic position of mankind by making humanity its own order or class while at the same time keeping it in the general table of life forms, such as it is, that has been established to represent the present state of the animal kingdom? Without a doubt, a new method of positioning mankind, including a sense and definition of systematic relationships, would be of more objective value in some respects: 'This would better represent the grandeur of the human reality that attempts to submerge our group to a sub-order or family in the category of monkeys.' On the other hand, however, this would have a great drawback: the deformation of the lines of earlier zoological divisions, dislod-ging and disrupting the edifice constructed from our earlier classification and without sufficiently disengaging the importance and the new characteristic of the human group. On the contrary, nothing obliges such disorder. Simply to raise humanity to the dignity of an order or class would be to admit implicitly that, as unique as it is, it nonetheless enters, without mutilation or force, into a system of classification expressly created for a zone of life where each change of activity has meaning, expressed by a change in the organs. Not only does humanity escape this law thanks to the invention of artificial tools, ultimately it escapes by means of its psychic energy capacities—in short, by the interplay of experimental properties that are precisely at the base of his exceptional biological importance. To make humanity a kingdom, symmetrically juxtaposed or superimposed on the plant and animal kingdoms, would perhaps accord him too much and too little at the same time: too much for the past, especially with regard to his origins, and too little for the present, not to mention the future.

'This is where we discover the gravity of the problem confronted in the natural sciences by the existence of mankind. We should kindly note it! When we speak of raising the systematic value of the human group, this is not to suggest to magnify it flippantly in the light of several more or less spiritualist propositions.' It merely concerns respect for the hard facts: protecting pure positivist science from ruinous disequilibrium. Is it possible to safeguard both the value of the purely corporeal aspects adopted so far by the systematic in creating a hierarchy of beings and the supreme uniqueness of the human phenomenon, and the profound entrenchment of the latter in the experimental world? Such is, most definitely, the problem.

To find a way to resolve this problem we need to return—in order to complete it—to one of the principal notions of the previous course: the notion of the biosphere, or the notion of the real component that possesses the living layer that surrounds the globe, and that in many circumstances and as a whole, functions like a real organism of a higher order. I have already made allusion to this several times and we recall how often science must take recourse to a concept of this type. But the time has come to specify further and to introduce intentionally a henceforth necessary complement in a more intelligible form.

Need I restate the series of steps that lead to the notion in question? There is much related background material. In this way, pure physico-chemical matter appears to be less and less comprehensible—that is exclud-ing some deep life forms operating under corpuscular plurality by a sort of common matrix that we now call ether and space-time. Of course, we continue to debate the how of the unifying and motoring function that this principle carries out—but this fact itself is no longer contested. At a lower level, the great telluric zones are defined in terms of consistent and positive realities to explain a basic connection between certain phenomena. One can observe almost everywhere the effects of groups where the whole acts in this way—effects of mass and competition for which simple analysis, oriented towards the differentiating element, does not suffice for comprehension. In particular, as I would have formerly called it, that which signifies notions like pryosphere, barysphere, lithosphere, hydrosphere and atmosphere to which recourses the physics of the globe when it studies the central heat, deep gravity, constitution or elasticity of the core, the distribution of the continents and mountains, the cycles of the oceans, the circulation of wind, the phenomenon of meteors, etc. Well! The notion of the biosphere is the same: it captures similar necessities and stands out as a yet stronger reason.

We can group our considerations on three principal keys, which provide the foundation, support for and necessity of this concept. I have discussed these in great detail in a preceding work and therefore it suffices here to provide a résumé:

1 Monsieur Bergson has clearly shown the reality of 'life' in its earlier and even higher forms to that of transitory entities that the former animates in its course. 'At a certain moment, in a certain space of time, a very visible current was born: this current of life, cutting across bit by bit the bodies it has organised, passes from generation to generation, divides itself between species and between individuals without losing its force, but rather inten-sifying itself relative to its advance.' For the rest, the division of the stream into multiple arms carries with it no rupture of unity for the flux. This flux remains undivided. Not that it is necessary to come back to the overly adventurous hypotheses of Weismann. But 'if germinal plasma is not continuous, there is at least a continuity of genetic energy…. Everything happens as if the organism itself was nothing more than excrescence like a bud that blossoms the old germ, working to continue itself in a new germ.' That which life offers is exactly this sense of uninterrupted and trans-individual becoming of which the concrete unity catches the eye and is so much better visible that it is precisely located in a certain concentric zone to the Earth, the zone of water, oxygen and carbon dioxide [original citation of Vernadsky].

2 From this living layer, we begin today to glimpse its anatomy and next its physiology. In starting with the study of its structure a real organism appears: a vast system of co-ordinated and interdependent complexities, comparable to the appendages and organs from which life (in the proper sense) is manifest by specific phenomena—as uncontestedly positive as those we discover in the interior of a living individual. Between these complexities a correlation designs itself through homo-logies, symbiotic relationships and a 'complementarity' about which I gave various very significant examples when I was analysing the holistic functions of living groups and their respective contributions to the common task. Moreover, if we follow the flow of the duration in light of the history of evolving forms the same conclusion emerges. The successive phases show better and better a vital growth so that we extend it further. A balancing compensator provides equilibrium for developments of standard, of species, or of fauna and flora, and in such a way reveals their interrelation. In particular, the fact that each new genesis lowers the pressure of the sap in the oldest branches — this curious fact—of which palaeontological evidence testifies, showing clearly that the phylogenesis is, in its way, an ontogenesis. To which it is convenient to add, as a confirmation, a double characteristic no less suggestive of life when one envisages it from a global and synthetic view: it carries a role in the economy of the planet, and it achieves a task that signifies a progression.

3 Finally, I merely recall that the discussion of transformism forced us to conclude that without the effects of biospheral res-

> onance we can neither comprehend the birth of major variations nor the durable transmission of change. The notion of the biosphere therefore serves as an expressive and essential factor in the evolution of species.

As such, this notion seems inevitably to point to competition along numerous paths. I would say that it emerges even more strongly than the analogue notions of physics. This holds—the remark has already been made — in so far that brute matter possesses an existence only on the surface and outside, without anything similar anywhere, with the implication of profound tendencies that constitute true individuality. From where, in this, it follows to take things with rigour and the absence of natural, elementary entities and by consequence also, the entities of a higher order. The criticism of reductionism does not leave any room for doubt on this point: the matter object still has something of an abstract entity about it, relative to a level of analysis, to a form of approximation. At least one exception is apparent: the Earth itself, the structure of which, taken together, evokes the idea of a distinct organism, and just like an organism, presents an evolving and definite structure. All things considered, this exception only appears to be so, because if the Earth really has these traits does it not mean that the Earth is inseparable from life? That, in essence, the Earth is alive? Such a postulation may seem bizarre or unbeliev-able. It is justified, however, as soon as one examines the situation. Take a living individual, in the ordinary sense of the term. What exactly is there living in him? A very clear response has been suggested by Mr Nageotte on the grafts of living tissues. That which is really alive in a living being is definitely quite little, at least if we judge this from the point of view of 'quantity'. First, the cells alone—not the conjunctive substances, where they merely reside and which represent a sort of excretion. Next, at a second level of analysis, inside the cell itself, the mitochon-dria and not the intergranular substance. This low proportion of elements that we can really call alive does not prevent us from calling the entire body living.

Well! The same thing holds for the Earth, where life admittedly occupies but a small place, but where the biosphere is divisible only through abstraction from the other constitutive layers and plays so considerable a role among them. As such we are not abusing a metaphor by declaring that the Earth is alive and that this is why there really is a terrestrial individuality. But, from all this it also results that the biosphere does have an individuality more real than its distant and purely material counterparts, at least as far as it is necessary to go until we recognise, in relation to the latter, an individualist function, all other individuality being perhaps no more than participatory.

Whatever the case, let us remember only the solid, positive value that the notion of the biosphere holds. It opens before us a new perspective to situate mankind. And there we are, the point of view whereby we finally try to resolve the difficulty of classification to which I referred earlier.

Man is original and new enough in the history of living forms that, in sum, there is nothing so strange that we cannot find him a natural place in the bosom of a hierarchical system of categories that represent the biosphere at an age where it did not yet behave as such. However, we do not know how to leave it up in the air without a frame. To the embarrassment of the problem so posed, there is but a sole way to really get out of it without damaging one part or the other. That is to express, by creating a supreme category, that mankind, if it be linked to the general development of life, thus marks, at the present phase of this development (and the final phase in a certain sense), the opening of an absolutely new phase. In other words, to assimilate his apparition, not point merely to the genesis and to the relative isolation of a great part of the biosphere, but rather to the inclusion even of this. Through its importance—have I not already stated—the apparition of mankind is comparable only to that of life. This is the moment to specify this view.

This view completely corresponds to a positive body of facts. In fact, let us examine the history of life forms. At certain epochs we begin to see, one inside the other and in order of growing particularity, the types of animal organisation, vertebrate, mammal and pri-mate. Each time it is about a set of habits definitely contracted by life and that constitute a number of plateaux in a progressive ascension. All of these prepare, from near or far, freedom from the immanent growth of the process of vitalisation. But with the force of reflective thought that conquer and emerge in man, a decisive step is accomplished. Henceforth, it seems, it is no longer a corporeal organism that elaborates or perfects itself: it is achieved perhaps and, in any case, evolution accedes to the use of new means, those of a real psychic order. In truth, such a fact represents something just as considerable as the first assertion about life in matter. That is the essential data of the problem.

In order to take account of this, it is necessary finally to resolve to see the human envelope of the biosphere as being of the same order of grandeur, as the same importance in the total economy of things, as that of the biosphere itself. That will not be a component but a counterpart. The more we detail this extreme solution, the more it seems to be the only acceptable one. As it happens in a number of other cases, the conflict of science and philosophy battle it out without trouble on the condition that we follow up the double movement without hesitation to the end, that we do not minimise their exigencies, that we do not abstain to pretend to accord them diplomatically, in mediocre and puny compromise, the right fit. How does the problem present itself? If we wish to achieve the inclusion of man in the universal history of life—without distorting the former and without disrupting the latter—it is absolutely necessary to place man above lower forms of nature in a position of domination while assuring nonetheless no uprooting; and this brings us, in one way or another, to imagine, higher than the animal biosphere and as a next step, a human sphere, the sphere of reflection, of conscious and free invention, of thought in its pure sense: the sphere of the mind or noosphere. Following this, it is necessary to concede, at the origin of this great and new unit, a *sui generis* phenomenon of vital transformation, affecting the entire biospheral whole: hominisation. Humanity thus appears as a new order of reality, binding with the lower forms of nature in a relationship equivalent to that discerned lower still between life and matter. Taken as a 'phenomenon', humanity prolongs life; but it alone constitutes, however, an ensemble that is also vast, original and new. It is impossible to see less there than that. 'Or perhaps humanity is a fact without precedent or measure, and so does not fit into our natural frameworks, which leads us to say that our science is in vain, has failed or is bankrupt, at least concerning Man. Or perhaps humanity represents a new turn in the rising spiral of things; and, in this case, we shall discover other turns which correspond to the former, if not to the highest organisation of matter: in magnitude to be compared to the emergence of reflexive conscience, it is only the appearance of life, or in other words, consciousness itself.' Thus two great facts, in front of which all others seem to practically disappear, dominate the Earth's past history: the vitalisation of matter and the hominisation of life. Moreover, there are some analogies and differences between these two; each illuminates the other by similarity and contrast; their study is therefore inseparable, and it must proceed by alternative oscil-lations. Vitalisation, as an antecedent, has conditioned hominisation; but the latter, closer to us, can as such better help us to understand the former. As such, we see, once again, the close relation between our previous research and that which we undertake at present.

An indispensable digression is needed here because I must respond in one word, without further delay, to a possible objection. Earlier, I used these two expressions: vitalisation of matter and hominisation of life. Well! Are these not, the first above all, in contradiction with what we have formerly concluded on the subject of the idealistic exigency? From this perspective, it seems that one can never speak of an epoch of pure, crude materiality. I do not deny it. But this proposition is of a metaphysical order. Because—should I repeat it?—for the moment, I position myself at the only point of view of the phenomenon. From this point of view, it seems incontestable that an age came about where life—even if metaphysically we can already affirm its pre-existence, for example in terms of tendency and virtual diffusion—had not at least started to take form as defined chemical phenomena, therefore not yet belonging to the phenomenal level where positive science is confined. Without a doubt this is but a relative truth, not a definitive interpretation. But it is nevertheless necessary to retain this for its time and place. Under these conditions a real problem exists concerning the origin of life: we have already seen in which sense and to what extent. A similar description would be acceptable with regard to hominisation. I can therefore return without scruples to our idea of the noosphere and pursue its applications.

The relative problem of the place of mankind in nature, when oriented this way, leads back to the relationship between the biosphere and noosphere: two wholes of equal amplitude. Given this, which traits are now most precipitous to look at things?

Usually, we imagine the design of life in terms of an arborescence: it is a tree with its limbs, branches and twigs to which life is compared when we seek to describe progressive differentiation. I do not condemn this botanical comparison; it beautifully represents certain partial phenomena and some structural and developmental relationships. But does it still suffice? Whether one applies it inside the biosphere or the noosphere, I am not able to restate this. Simply, the question is to determine whether this comparison holds to the same extent with regard to the holistic relationship between the biosphere and the noosphere. Is it perhaps necessary to choose another type of image or analogy: a type of hydro-dynamical comparison. Take the biosphere. Let us imagine in it a few points here and there where spurts, strictly limited and hardly surpassing above the middle level, and where jets grow little by little, open up and finally link up their spouts, spreading a layer that covers the Earth. The layer is ultimately superimposed on the primitive layer and covers it like multiple currents. This is the noosphere, spurting and emanating from the biosphere, and finishing by having the same amplitude and same importance as its generator. In this way, I would be pleased to represent the passage from one to the other, instead of making the second a branch of the first, and by consequence making the former less voluminous. From here it becomes easy to see how to resolve the problem of classification relative to mankind. We are no longer obliged, by the very nature of the images we use, to leave mankind forever inside the biosphere. However, mankind keeps an attachment to the latter. Let us look at ourselves from a strictly zoological point of view —thus at the level of the biosphere. In other words, let us place ourselves at the spurting points in order to consider mankind. These spurting points, as I said, are assumed to be sparse; let us suppose there is only one. In any case, they take up only a minimal portion, tightly localised, of the biosphere, where they form only a weak turgescence. And so here is humankind, at its source, confined to a small corner of classification relative to infra-human life. But it does not stop here; and if we follow its progress to higher destina-tions we see that it ends in a real division even more important than a law and only comparable with the total system of other forms of life. Through this change in basic perspective, the difficulty to which I have alluded is resolved and appearances to the contrary duly reconciled. We note in passing that this is the same manner by which I earlier represented the relationship between life and basic matter. I admit that these are simple metaphors; nevertheless, they are important in the attitude they suggest to thought and the manner that they seek to consider problems.

With regard to knowing whether or not there is deep-rooted continuity at the spurting points that attach the noosphere to the biosphere like so many peduncles, this is a question that remains to be debated. It is very likely that continuous appearance covers a true creation. Why can we not apply once again, perhaps even in a stronger sense, that which we formerly had to conclude on the subject of life in general? From our perspective, nothing prevents the idea that the birth of mankind was the result of an authentic invention; a genesis of irreducible novelty. On the contrary, all these analogies push us to admit this in advance. I do not need to underline that this phenomenon of invention can correspond, in the metaphysical sense, to a creation in the true sense. It will be necessary to come back to this point, and I shall do so at the end of this section. But for the time being let us note that the human sheet, once enclosed and formed, once across the decisive threshold, is soon differentiated. The multiplication of instruments and techniques or behaviour determine the counterpart of specialist groups in which the biosphere has been shared. To which we can add that this movement of diversification stretches itself out extensively and completes itself by the influence of a thousand factors: division of work, game of association and habit, culture and training, exercise of all types; from where come social classes, types of mind, forms of activity, new powers: in short, a disengagement of consciousness increasingly free and pure, and the constitution of a superior order of existence; the order of spirituality, reaching a point of perfection where the noosphere would strain to detach itself from the biosphere as a butterfly sheds its cocoon.

Be this as it may, we have reached what will be the apogee of our study. The specific goal of this course is, first and foremost, to submit the above views to a rigorous, critical analysis, showing the most positive facts as closely as possible. This is an enduring task, one that can only be developed level by level and through successive steps. We undertake here a mere beginning of proof—a few plausible ideas that merit conjecture but not more. There are some who would perhaps refuse to go farther on grounds that this conjecture is nothing but a dream. This, as I believe like P.Teilhard, is because 'that they have not sufficiently opened their eyes to the extraordinary singularity of the advent of mankind.' In this case, I would ask them to reflect harder on the undeniable data already available, and accept the inevitable length of the discussions, which is the only way to bring out the necessary proof. Moreover, 'let us admit that it actually is about a dream.' We would still not have less interest to follow its course to the end, a principal inspiration of research plentiful in realities of detail even if it does not gradually transform the initial dream into demonstrated conception or from myth to theory, as is often the case. We benefit in any case in trying harder to see 'how much the profundity and immensity of the world is full of intelligible harmony, coherence and of light in such dream that, if it really is one, better to keep ourselves there than in an overly restricted reality.' I say that 'to put a natural demarcation of the first importance at the base of the human layer[2] in our representation of the terrestrial world, is, first of all, a non-abrupt way to explain the principal properties of this layer. And furthermore, to clarify in a penetrating light, in a retrospective sense, the most intimate stages of biological evolution.'

Let us take a closer look at the problem related to the birth and structure of the human layer in relation to its links with the animal biosphere—in other words the issue of hominisation. Was there a brusque jump or merely development? One principle dominates the debate: the apparition of a new quality that does not necessarily signify a rupture of continuity. The entire perspective, of which I affirm here its objective character, assumes the clear vision of this elementary truth, that a thousand analogies, borrowed from changes of physical state of bodies or generation of geometric figures, already appear indisputable and suggest in full force to the mind, from the lower levels of what is real, to levels of phenomenality that precede life. 'For example, let us consider a cone, and inside it let us observe the gradual reduction of the right sections as we guide our view from the base to the summit. Nothing is more different from a point than a surface. However, in the sense of our chosen motion and the properties of the cone, it results in progression following the axis of the object—after long having resulted in a mere reduction of surface area without a modification in its nature—at a certain moment will suddenly reach the point at the surface: in its apogee the cone will engender a new qualitative order or reality becomes established by continuous evolution.' Likewise, a body with continuous warming or cooling varies, at first, only the volume without changing its solid or liquid state. A moment comes when its fusion or freezing occurs. Once again a new quality has surged from the effect on continuous evolution. In the physico-chemical world we could find innumerable examples of very analogous circumstances. It could even happen that the hatching of the quality is almost sudden: such as with the phenomenon of crystallisation.

Without a doubt these are mere images. However, let us apply them to the question at hand. 'The difficulty to understanding humanity scientifically is due to the fact that it presents a troubling mix of both ancient and new characteristics.' Given these associations, we hesitate to make up our mind and remain divided in our judgement. From one side, too exclusively zoological, submerges us in the lower animal mass, and we see only continuity of evolution. The other side, naively spiritual, isolates us at first glance and makes our group a sort of bloom-ing flower from who knows where, and which floats without roots on the great waters of the world: they take into account only the qualitative discontinuities. These are clearly two contrary excesses due to an incomplete inven-tory of types of change—and as a consequence of the number of zoological degrees—possible in the universe. 'We persist obsti-nately in wanting to choose, to explain the real, between only two terms; two terms which we assume form a brutal dilemma without conceivable intermediary: immobile numerical diversity or homogenous continuing of becoming.' I have discussed in detail elsewhere the necessity to come to richer intuition about this, a synthesis of the two proceeding conceptual abstractions or rather a matrix from which they emerge symmetrically. Continuity does not exclude hetero-geneity in qualitative order: the image of the spectre is there to show just this; and moreover, the real is less an edifice of made qualities than a movement of qualification at varied rhythm. This is the case here to take on such a point of view. 'Let us decide, under the weight of the facts, to introduce, in natural history as well, the notion of singular points or changes of state. A moment ago, we considered the geometric point without limitations like a limit engendered by the slow concentration of a volume, of a surface: in an analogous fashion, let us try now to conceive of humanity scientifically as nascent, passing through a critical point, from the maturation of the biosphere in its totality.' Likewise, the example of changes of physical state, let us apply to understanding that the human quality—so original and irreducible once born—was able to hatch by passing through a continuity of generating evolution. There is a brusque leap to bring them together after the shock of the start and end points; but a passage—gradual although perhaps rapid—links the extreme elements, the whole length of a path that remains without disruption at the level of phenomena. Only the introduction of such views has a strong impact on dogma. It is not through the enlargement that old frameworks will find a suitable place, because this enlargement achieved without a renewal of perspective would carry with it—like all conceptual generalisations—a dilution of a specific qualitative nature, directly resulting contrary to the desired effect. The image of the singular, critical point, transitional link or central switch suggests contrarily that the hetero-genesis orders punctually touch and join through points where entire layers contract in order to come into contact with one another. Therefore it is a concerted step towards the concrete that is necessitated as a starting point to define the contact zone between the lower and the upper, a double strengthening bottom-up and top-down to give access to a bridge opening the frontier—in brief, a dynamic condensation capable only of qualifying synthesis. And from this, within the issue at hand the position to take. Let us create, unequivocally, in our map of reality a new compartment, consecutive to that of pure animal life, continuously linked and not less than heterogeneous to it and also as large as the latter. But we do not see here a category that fits alongside its precedents, kept in mind as if it completed a single and unique system. It is rather the symbol of a second layer of reality, of which the link to the former is found only in a small region, quasi-punctual. 'Let us admit, in other terms, that, in the structure of the terrestrial world, there are not only classes, branches and kingdoms, but that one must also recognise some spheres,' of which the noosphere is the most recent and of which the common relationships offer the aspect described below.[3] 'Just as soon—and it is not easy to imagine — as human anatomy weakens itself, the trouble vanishes from sight.'

Pierre Teilhard de Chardin has observed this fact just right: 'If we cease to put an absolute barrier between that which we call the natural and the artificial, the structure of the lower zoological groups appear in a form at the heart of the human system.' This is a continuity that takes a hold. 'Not only by their form, allure and their individual instincts, but also through the collective associations and ramifications of their activities, mankind constitutes a real phytological and zoological whole.' Such is the cone and its complicated system, which extends itself along the condensation of the summit to the higher layer and blossoms beyond that singular point.

'But, in addition, if it is reliable in the natural as well as the artificial, it is profoundly different: the artificial is a reflection of the natural, accompanied by this mysterious force of thought cohesion between individuals that allows the start of organised union in a unique layer, while being conscious of this liaison.' This time a qualitative discontinuity appears at the very heart and term of genetic continuity. 'All lower forms of life are renewed, and as especially evident in mankind, recognisable and unrecognisable at the same time,' subsistent but raised up to a new force. 'This is the unequalled simpli-city of the summit, combining in its rich unity the pluralism of the lower layer which is re-bent in it,' and then spread out once more in the higher layer on the higher system, that it is necessary to conceive this stage as heterogeneous to the precedent one, having gained a new quality from its passage through the critical intermediary point—in short, the state is so changed.

For once, geometry will be taught to see better, perhaps even to understand better, the phenomena of creation. Thanks to this, we will put our finger on that which is both absurd and true together in the statement misused by many an incompetent: mankind descended from the monkey. This statement is true (under certain reservations that we shall come back to), if by it we mean that, from a geological perspective, mankind appeared at the end of the movement that mixed and organised the lower zones of life—in short, that which is originally integrated in the biosphere. But this statement becomes absurd if, as happens too often, it is taken to mean that mankind was born as an accessory and remains in a narrow corner of the biosphere, and that his coming has not launched a single power of reality radically and irredu-cibly new.

It is useless to insist more from here on. I have said enough to trace a path as to how evolution can be both creative and continuous, the latter from a genetic and the former from a qualitative view. From this double regard everything appears definitive like the facts of invention: another very cogent analogy even closer to things than to physical analogies, but on which I shall have better occasion to come back to in the course of a future lesson. For the moment, it only remains to conclude in terms where I find myself in complete agreement with P.Teilhard to the point of using identical phrases.

Envisaged in zoological terms, humanity constitutes a new level, perhaps a supreme one, in the series of progressive states that traverse life. As such, and despite the trace appearance of biospheral roots, it alone represents one of the great zones of reality, one of the principal factors necessary to the equilibrium of the whole. In a nutshell, we come to the true scientific conception to which we have just led an objective inspection of the graspable experimental properties of mankind; and hereby we also come to the overblowing of the conception that might best help us to understand the dynamics of vital invention outside even of humanity. Once we have recognised the positive reality and the specificity of the phenomenon we have called hominisation—that is, the passage from the biosphere to the noosphere—not only does man in this world cease to be a paradoxical excrescence, a type of anomaly; but mankind becomes the key itself of tranformist explanations: the last point to clarify by this attempted study of a double relationship where mankind is explained by nature and, reciprocally, nature by mankind.

Notes

1 Translator's note: The French term 'hominisation' is difficult to translate. Although it is usually left untranslated, its use is similar to the contemporary concept of 'globalisation'. Teilhard de Chardin and Le Roy used the term to demarcate the critical point of evolution at which time upright, thinking *Homo sapiens* emerged and henceforth dominated the future course of evolution.

2 This demarcation is of a qualitative nature that does not exclude, as we shall see, notions of continuity and generation.

3 Need I state that in spite of some inevitable words, the biosphere and the noosphere are not spatially distinguishable? In many respects, they both contain each other; but the second is a transfiguration of the first.

PIERRE TEILHARD DE CHARDIN

Pierre Teilhard de Chardin (1881–1955) was a French palaeontologist, Jesuit and philosopher known for his theory that man is evolving, mentally and socially, towards a final spiritual unity, which he called the 'omega point'. As a means of reaching this goal from humankind's current position in the biosphere, he developed the concept of the noosphere (along with Le Roy). Forbidden to publish his work by the Church, he continued his scientific work in China and ultimately retired to the United States, where he spent his last days at the Wenner-Gren Foundation for Anthropological Research. His complete works were published posthumously, launching a massive and often polemic debate, which continues today. The passages below are from his most famous work, *The Phenomenon of Man* (1959) and one of his last major contributions, 'The Antiquity and World Expansion of Human Culture' (1956).

THE PHENOMENON OF MAN

When compared with all the living verticils, the human phylum is not like any other. But because the specific orthogenesis of the primates (urging them towards increasing cerebralisation) coincides with the axial orthogenesis of organised matter (urging all living things towards a higher consciousness) man, appearing at the heart of the primates, flourishes on the leading shoot of zoological evolution. It is easy to see what privileged value that unique situation will confer upon the transit to reflection.

The biological change of state terminating in the awakening of thought does not represent merely a critical point that the individual or even the species must pass through. Faster than that, it affects life itself in its organic totality, and consequently it marks a transformation affecting the state of the entire planet. Such is the evidence—born of all the other testimony we have gradually assembled and added together in the course of our inquiry—that imposes itself irresistibly on both our logic and observations.

We have been following the successive stages of the same grand progression from the fluid contours of the juvenile Earth. Beneath the pulsations of geochemistry, of geotectonics and of geo-biology, we have detected one and the same fundamental process, always recognisable—the one that was given material form in the first cells and was continued in the construction of nervous systems. We saw geogenesis promoted to biogenesis, which turned out in the end to be nothing else than psychogenesis.

With and within the crisis of reflection, the next term in the series manifests itself. Psychogenesis has led to man. Now it effaces itself, relieved or absorbed by another and a higher function—the engendering and subsequent development of the mind, in one word 'noogenesis'. When for the first time in a living creature instinct perceived itself in its own mirror, the whole world took a pace forward. As regards the choices and responsibilities of our activity, the consequences of this discovery are enormous. As regards our understanding of the Earth they are decisive.

Geologists have for long agreed in admitting the zonal composition of our planet. We have already spoken of the barysphere, central and metallic, surrounded by the rocky lithosphere, which is in turn surrounded by the fluid layers of the hydrosphere and the atmosphere. Since Suess, science has rightly become accustomed to add another to these four concentric layers, the living membrane composed of the fauna and flora of the globe, the biosphere, so often mentioned in these pages, an envelope as definitely universal as the other 'spheres' and even more definitely individualised than them. For, instead of representing a more-or-less vague grouping, it forms a single piece, of the very tissue of the genetic relations which delineate the tree of life.

The recognition and isolation of a new era in evolution, the era of noogenesis, obliges us to distinguish correlatively a support propor-tionate to the operation—that is to say, yet another membrane in the majestic assembly of telluric layers. A glow ripples outwards from the first spark of conscious reflection. The point of ignition grows larger. The fire spreads in ever-widening circles till finally the whole planet is covered with incandescence. Only one interpretation, only one name can be found worthy of this grand phenomenon. Much more coherent and just as extensive as any preceding, it is really a new layer, the 'thinking layer', which, since its germination at the end of the Tertiary era, has spread over and above the world of plants and animals. In other words, outside and above the biosphere there is the noosphere.

With that it bursts upon us how utterly warped is every classification of the living world (or, alternatively, every construction of the physical one) in which man figures only logically as a genus or a new family. This is an error of perspective which deforms and uncrowns the whole phenomenon of the universe. To give man his true place in nature it is not enough to find one more pigeonhole in the edifice of our systematisation or even an additional order or branch. With hominisation, in spite of the insignificance of the anatomical leap, we have the beginning of a new age. The Earth 'gets a new skin'. Better still, it finds its soul.

Therefore, given its place in reality in proper dimensions, the historic threshold of reflection is much more important than any zoological gap, whether it be the one marking the origin of the tetrapods or even that of the metazoa. Among all the stages successively crossed by evolution, the birth of thought comes directly after, and is the only thing comparable in order of importance to the condensation of the terrestrial chemism or the advent of life itself.

The paradox of man resolves itself by passing beyond measure. Despite the relief and harmony it brings to things, this perspective is at first sight disconcerting, running counter as it does to the illusion and habits which incline us to measure events by their material face. It also seems to us extravagant because, steeped as we are in what is human like a fish in the sea, we have difficulty in emerging from it in our minds so as to appreciate its specificness and breadth. But let us look around us a little more carefully. This sudden deluge of cerebralisation, this biological invasion of a new animal type which gradually eliminates or subjects all forms of life that are not human, this irresistible tide of fields and factories, this immense and growing edifice of matter and ideas—all these signs that we look at, for days on end—to proclaim that there has been a change on the Earth and a change of planetary magnitude.

There can indeed be no doubt that, to an imaginary geologist coming one day far in the future to inspect our fossilised globe, the most astounding of the revolutions undergone by the Earth would be that which took place at the beginning of what has so rightly been called the psychozoic era. And even today, to a Martian capable of analysing sidereal radiations psychically no less than physically, the first characteristic of our planet would be, not the blue of the seas or the green of the forests, but the phosphorescence of thought.

The greatest revelation open to science today is to perceive that everything precious, active and progressive originally contained in that cosmic fragment from which our world emerged is now concentrated in a 'crowning' noosphere. And what is so supremely instructive about the origins of this noosphere (if we know how to look) is to see how gradually, by dint of being universally and lengthily prepared, the enormous event of its birth took place.

What has made us in four or five generations so different from our forebears (in spite of all that may be said), so ambitious too, and so worried, is not merely that we have discovered and mastered other forces of nature. In the final analysis it is, if I am not mistaken, that we have become conscious of the movement which is carrying us along, and have thereby realised the formidable problems set us by this reflective exercise of the human effort.

We have seen that without the involution of matter upon itself, that is to say, without the closed chemistry of molecules, cells and phyletic branches, there would never have been either biosphere or noosphere. In their advent and their development, life and thought are not only accidentally, but also structurally, bound up with the contours and destiny of the terrestrial mass. But, on the other hand, we now see ahead of us a psychic centre of universal drift, transcending time and space and thus essentially extraplanetary, to sustain and equilibrate the surge of consciousness.

The idea is that of noogenesis ascending irreversibly towards Omega through the strictly limited cycle of a geogenesis. At a given moment in the future, under some influence exerted by one or the other of these curves or of both together, it is inevitable that the two branches should separate. How ever convergent it be, evolution cannot attain to fulfilment on Earth except through a point of dissociation.

With this, we are introduced to a fantastic and inevitable event which now begins to take shape in our perspective, the event which comes nearer with every day that passes: the end of all life on our globe, the death of the planet, the ultimate phase of the phenomenon of man.

No one would dare to picture to himself what the noosphere will be like in its final guise, no one, that is, who has glimpsed, how ever faintly, the incredible potential of unexpectedness accumulated in the spirit of the Earth. The end of the world defies imagination. But if it would be absurd to try to describe it, we may nonetheless—by making use of the lines of approach already laid down—to some extent foresee the significance and circumscribe the forms.

What the ultimate Earth cannot be in a universe of conscious substance; how it will take shape; and what it will probably be—those are the questions I want to raise, coldly and logically, in no way apocalyptically, not so much for the sake of affirming anything as to give food for thought.

In its present state, the world would be unintelligible and the presence in it of reflection would be incomprehensible unless we supposed there to be a secret complicity between the immense and the infinitesimal to warm, nourish and sustain to the very end—by dint of chance, contingencies and the exercise of free choice—the consciousness that has emerged between the two. It is upon this complicity that we must depend. Man is irreplaceable. Therefore, how ever improbable it might seem, he must reach the goal, not necessarily, doubtless, but infallibly.

What we should expect is not a halt in any shape or form, but an ultimate progress coming at its biologically appointed hour; a maturation and a paroxysm leading even higher into the improbable from which we have sprung. It is in this direction that we must extrapolate man and hominisation if we want to get a forward glimpse of the end of the world.

THE ANTIQUITY AND WORLD EXPANSION OF HUMAN CULTURE

How and how much does man, by his presence and his activities, transform the face of the Earth? As a common background to the various technical answers, dealing with soil conservation, water distribution, city building, etc., we should like to mention and to emphasise a still deeper and more general change which our zoological group has brought to the terrestrial world. This change would betray and characterise the presence of man on Earth to an observer on Sirius, namely, the progressive expansion of a special layer of thinking and cultured substance all around the globe.

More than half a century ago the great geologist Suess took a bold and lucky step when, in addition to describing our planet by the classical sequence of concentric, spherical shells (barysphere, lithosphere, atmosphere, etc.), he decided to add the biosphere, in order to affirm, in a concise and vivid way, that the frail but super-active film of highly complex, self-reproducing matter spread around the world was of decidedly geological significance and value. Since Suess's times, the notion of a special planetary envelope of organic matter distinct from the inorganic lithosphere has been accepted as a normal basis for the rapidly growing structures of geobiology (a new branch of science). But, then, why not take one step more and recognise the fact that, if the appearance of the Earth has undergone a major alteration by turning chlorophyll-green or life-warm since the Palaeozoic period, an even more revolutionary transformation took place at the end of Tertiary time, when our planet developed the psychically reflexive human surface, for which, together with Professor Edouard Le Roy and Professor Vernadsky, we suggested in the 1920s the name 'noosphere'?

Ultimately, neither Earth nor man can be fully understood except with regard to the marvellous sheet of humanised and socialised matter, which, despite its incredibly small mass and its incredible thinness, has to be regarded positively as the most sharply individualised and the most specifically distinct of all the planetary units so far recognised.

As a natural introduction to the problem, devoted precisely to the study of the relations existing between Earth and man in the course of their respective developments, let us therefore summarise the essence of what can be scientifically stated today concerning (1) the historical establishment of the noosphere; (2) the cultural structure; and, finally, (3) the present comportment, as well as the possible future, of mankind considered as a biological whole on a planetary scale.

HISTORICAL DEVELOPMENT OF THE NOOSPHERE

Scarcely more than a century has elapsed since living man, realising that he too was a product of biological evolution, began to hunt not only for animal fossils but also and predominantly for 'fossil man'. In spite of intensive research, we are still far from having gained a complete vision of the history of our zoological group. Yet, as we consider its main features, the reconstruction of our past is by now sufficiently advanced to have taken what may be regarded as its final general shape. The main lines of the picture have gradually come to light through the joint efforts of prehistory and palaeoanthropology.

Most surely, for stringent geological and palaeontological reasons, the mysterious phenomenon of initial 'hominisation' (that is, the mutational emergence in nature of a reflexive, or 'self-conscious', type of consciousness) must have taken place, by the end of the Pliocene, within the tropical or subtropical areas of the Old World in which there happened to be concentrated, at the closing of the Tertiary, the most advanced representatives of the higher, tail-less chimpanzee- or gorilla-like primates currently included by zoologists in the Pongidae family.

What were the number, the physical appearance and the comportment of these first true Hominians? That, we perhaps shall never know. Owing to the fact that the first stages of any organised system are constitutionally of a fragile structure, the traces of any 'beginning' are selectively erased by the passage of time. There is still, and probably there will almost always remain, a blank in our vision of the past at the place occupied by the origins of man, though no more or less, in fact, than in the case of the birth of any other animal species or of any human civilisation.

Several hundred thousand years had been spent on the mere preparation, mainly in Africa, of a human planetary invasion. Thirty thousand years more had been required for the actual occupation of the extra-African lands. Approximately ten thousand years (that is, the whole combined Neolithic and historical times) were necessary before a preliminary consolidation of the human envelope had been realised all around the Earth.

But today, after so many aeons of hominisation, the great accomplishment pursued by life since its first emergence on Earth two or three billion years ago is over, namely, the achievement of an unbroken, co-conscious organism, coextensive with the entire area of the globe. Definitely cemented on itself in the course of the last century by the powerful forces of industry and science, the new-born noosphere is now spread right before our eyes and is caught already in the first grip of an irresistible totalisation.

Before trying to investigate this final phase of the development of the noosphere, let us first analyse the secret of its internal structure in order to discover the deep reasons why man represents so obviously (judging merely from his biological success) a revolution in the very process of natural evolution.

CULTURE OF THE NOOSPHERE

By human culture, I refer to the manifold process according to which any human population, whenever left to itself, immediately starts spontaneously to arrange itself at a social level into an organised system of ends and means, in which two basic components are always present: first, a material component, or 'increase in complexity,' which includes both the various types of implements and techniques necessary to the gathering or the production of all kinds of food or supplies and the various rules or laws which provide the best conditions for an optimum birth rate or for a satisfactory circulation of goods and resources within the limits of the population under consideration. Second, a spiritual component, or 'increase in consciousness,' namely, some particular outlook on the world and life (an approach which is at once philosophical, ethical, aesthetic and religious), the function of which is to impart a meaning, a direction and an incentive or stimulus to the material activities and development of the community.

For the many fragments of mankind that have become isolated or have gained their independence in the course of time, just so many tentative technico-mental systems of the world as a whole—that is, just so many cultures—have gradually come into existence. This is one of the major lessons taught by the universal history of man, from the earliest known stages until the present time.

Understood thus as a collective answer to the general biological problem of survival and growth, the typically human phenomenon of culture is of course foreshadowed, to some extent, at the pre-human levels of life. In the case of animals, too, the struggle for life leads each different species forcibly towards the discovery of some constructive adjustment between germinal forces of reproduction and multiplication, on the one hand, and quasi-social forces of collective arrangement, on the other.

But whereas, in the case of non-reflexive life, social and germinal have been persistently unable to combine into a definite and unlimited creative process, in the case of man, on the other hand (and clearly in some sort of connection with the newly acquired human power of 'thinking'), both social and germinal have given rise, by their conjunction, to a decidedly superior type of evolution—a 'new evolution' in fact— special to the noosphere and characterised at the same time by a new and more efficient form of invention, by a new and more efficient form of heredity, and by a new and more efficient form of speciation.

A NEW AND MORE EFFICIENT FORM OF INVENTION

Since its earliest beginnings, life has never stopped 'inventing' and perfecting new organic contraptions along the most amazing variety of lines. But for a very long time this continuous advance seems to have been achieved much more through a patent expectation and utilisation than by a positive pursuit and control of chances. Before man, the evolution of animal life was unquestionably directional and preferential. But in its mechanism it did not show any real purpose. Since the appearance of man, however, the living individual being becomes able to plan. And this power of planning, when focused on research and when brought socially to the dimensions of a concerted effort for discovery, opens a new era in the development of terrestrial life. Without escaping the general conditions and 'servi-tudes' of every organic substance in the universe, man has introduced, and is gradually expanding at the very core of nature through his collective power of reflexive invention, a new method for arranging matter: no longer the old random arrangement but an active arrangement through self-evolution.

A NEW AND MORE EFFICIENT FORM OF HEREDITY

Germinal heredity, so deeply investigated by our modern geneticists, proved to be a marvellous instrument of progress during the earlier, pre-human stages of the development of life. But owing to the very nature of its chromosomic mechanism, germinal heredity is affected, in fact, by a triple basic weakness which makes it unable to insure, if left to itself, any further advance of evolution in the case of such a complicated and rapidly changing type of organism as man, especially collective man. First, the characters transmitted by genes are by their very nature restricted to a category of rather elementary features, namely, those which control the material arrangement of the cells in the course of embryogenesis. Second, the number of these elementary characters is drastically limited in the germ by the exiguous size of the chromosomes. Third (if we except the possible case of some social instincts among the insects), there is no observable chromosomic transmission to the species of the characters eventually acquired by the industrious activity of each individual in the course of its life.

Now, remarkably enough, it is precisely on these three different grounds that a decided improvement becomes manifest in the cultured zones of life, in so far as the registra-tion and the transmission of human experience are concerned. Thanks to language, to information and to education, an unlimited number of unlimitedly complex ideas or techniques accumulate continuously, and organise themselves permanently, in the unlimited capacity of collective human memory.

Thus, duplicating the history of the old chromosomic heredity, an incomparably more sensitive and receptive educational heredity is now at work in the noosphere. This is precisely the more needed power to collect the over-abundant products and to feed the constantly accelerated progress of a self-evolving process.

A NEW AND MORE EFFICIENT FORM OF SPECIATION

Considered over a sufficiently protracted span of time, every animal population shows a tendency to split, under a statistical effect of genetic mutations, into branching systems of varieties, subspecies and, ultimately, true, new, specific forms. In the case of man, things proceed in much the same way, except that, as a consequence of the specifically human association between germinal and social, the splitting and branching operation results in the formation of new, mainly cultural, instead of new, mainly anatomical, types.

Fundamentally, according to my point of view, culturation is nothing but a 'hominised' form of speciation. Or to express the same thing differently: cultural units are for the noosphere the mere equivalent and the true successors of zoological species in the biosphere. True successors, we insist. And how much better fitted than their predeces-sors to satisfy the new requisites of an advanced type of evolution.

Let us dwell briefly on this important point. Considered as an instrument for evolution, zoological speciation, in addition to being very much slowed down by the non-inheritance of acquired characters, is seriously handicapped by the rapidly increasing estrangement observable between the products of its operation. In the very process of becoming itself, each newly formed zoological type becomes more and more separated and isolated from the surrounding species in the process of its inner development. Growing aloneness, mutual impermeability and consequent basic incapacity for any sort of interspecific synthesis were the common fate of animal phyla under the 'old' regime of evolution.

In contrast, with the rise of self-evolution, not only does the speed of transformation increase rapidly, because of the cumulative transmission of planned inventions, but, and more important, a remarkable capacity emerges among the socialised offspring of the new evolution for keeping in close inner touch with one another—and even for fusing with one another—in the course of their development. On the one hand, the various human cultural units spread all over the world at a given time never cease (even during the most acute phases of their differentiation) to react mutually on one another at the depth of their individual growth. Whatever may be the degree of their mutual divergence, they still form, when taken together, an unbroken sheet of organised consciousness. And, moreover, on the other hand, they prove able (provided they happen to be sufficiently active and sufficiently compressed on one another) to penetrate, to metamorphose and to absorb one another into something fundamentally new. This is the well-known process of acculturation—a process possibly bound to culminate some day in a complete 'mono-culturation' of the human world, but a process, in any case, without which no formation of any continuous human shell would ever have been physically possible on the surface of the Earth.

From the preceding analysis of the cultural nature of human expansion one might conclude erroneously that the so-called 'noosphere' is nothing more than an uninteresting kind of pseudo- or para-organism, since, according to a widespread opinion, it would be dangerously confusing to identify what is really natural and what is simply cultural (that is, 'artificial') in the world. Here, we confess to touch upon a point still hotly debated even among anthropologists; namely, to decide whether the word 'biological' can or cannot be applied correctly (in a non-allegorical way) to the workings and to the products of human culture. And yet, in our opinion, a decisive and final positive answer to the problem is already forced upon our mind by the three following joint considerations:

1 Whatever may be the ultimate physical nature of psychological awareness, increasing consciousness—traceable by increasing cerebration—is overwhelmingly proved by general palaeontology and comparative zoology to be a safe and absolute parameter (or index) of biological evolution.
2 Aside from any undue anthropocentrism, but from the inescapable evidence derived from the revolutionary effects of hominisation, reflexive awareness must be held, not as a mere variety, but as a super-stage of consciousness.
3 Judging from the very mechanism of its operation, which is ultimately reducible to a process of co-cerebration and co-reflexion, culturation cannot be regarded as anything less than a direct prolongation of hominisation.

Obviously, if they are linked with one another in their natural order, these three successive steps scientifically detected in the terrestrial development of life—(1) direct (or simple) consciousness; (2) reflexion (consciousness raised to its second power; for man, to know that he knows); and (3) culture (co-reflexion)—have one, and only one, possible meaning. They show in an unmistakable way by their mere natural sequence that man, through culturation, is not drifting away along some side path and towards some blind corner of the universe but that he is still moving directly along the major axis of cosmic development. From all that we know most certainly from the entire history of the past, culturation, because it biologically expresses a collective advance in reflexion, is decidedly not an inferior or reduced form of evolution but rather represents a super-type. This evidence, far from being of merely speculative interest, turns out to be of the utmost importance, both for our power of vision and for our power of action.

It is of importance for our power of action, of course, because it is tremendously necessary to the security of man and to his sense of values to be sure at last, in his effort to become more human ('ultra-human'), that he is responsible for, and supported by, the main and most central forces of a growing universe. It is important for our power of vision too, because, if the full impact of evolution is actually concentrating at present on the achievement of the noosphere, then we can understand better the terrific energies at work and the incredible potentialities still awaiting us in the process and in the progress of human acculturation.

PRESENT STATUS AND POSSIBLE FUTURE OF THE NOOSPHERE

A common attitude today, one repeatedly expressed in the statements of highly intellectual and religious people, is that man and mankind are regarded as being a practically stabilised product of evolution and even as a disintegrating and decaying one. Under the influence of science and techniques, man is supposedly not improving but even regressing biologically. Hence 'progress' is a myth and an illusion. In many quarters this is the new and fashionable way of thinking 'realistically'.

For anyone who is aware of the basic evolutionary significance of any increase in consciousness through complexity inside the noosphere, such a pessimistic view of the present status of the world is so incredibly wrong scientifically, and at the same time so dangerously depressing psychologically, that we believe that the time has come to react against it openly and vigorously. And this can best be done, it seems to us, by presenting a more objective and more comforting interpretation of the major crisis which we have been going through since the beginning of the twentieth century.

Something very deep and very wide is certainly taking place, these days, at the core of the humanised zones of the planet. But what? To this question the only satisfactory answer, in our opinion, is as follows. Up to a very recent date the phenomenon of 'hominisation', because it was continuing (for perhaps about a million years) to operate on a relatively unpopulated world, was predominantly a process of expansional and diverging directions. Just as in any given animal species the main rule of life is to propagate and to differentiate at a maximum, so the chief occupation of man during this first period was to invade all the free parts of the Earth and, at the same time, to attempt every possible form of cultural arrangement.

At present, however (that is, for less than a century!), owing to the coincidence of a sharp demographic jump with an incredible progress in intercommunication, the development of mankind has suddenly become compressional and converging in its direction. The movement has completely reversed its phase, with the result that, under a tremendous and incoercible rapprochement and compression of both human bodies and human minds, co-arrangement and co-reflexion are now rising towards astronomical values at the interior of the noosphere. Even if humanity is not becoming either better or happier in the course of the process, it is today forced, more than ever, in its entirety and under two irresistible factors (that is, by the double curvature of our rounded mother planet and of our converging minds) to move towards unheard-of and unimaginable degrees of organised complexity and of reflexive consciousness.

To become ultra-reflexive (that is, 'ultra-human') by reaching some stage of monoculturation—or else to resign and to die on the way—this, aside from any temperamental or philosophical considerations, must on purely scientific grounds be regarded as the biological fate of man.

For conventional and conservative reasons we dislike, and try to weaken, the growing evidence that, judged by the best standards of biological evolution, our species is still far from being zoologically mature. Instead of closing our eyes to the stupendous technicomental acceleration of anthropogenesis in our modern times, why not rather try to face the situation and to guess how far the process is likely to carry us and how it is going to end eventually?

Whenever we speculate on the future of civilisation, we generally assume that, except for the unlikely case of some physical, physiological or psychological accident of planetary dimensions, man will survive practically unchanged as long as the Earth will supply him with a sufficiency of food and energy. But, in our opinion, we should consider another idea that is both more interesting and more probable: namely, that the whole human adventure, in so far as it turns out to represent a rapidly converging process, is bound to end some day, not by exhaustion from external causes, but climactically for internal reasons, just because there is a critical upper limit (or threshold) to the planetary development of co-reflexion.

If we follow this line of thought to the end, we are led to the suspicion that every 'thinking planet' in the universe (like a psychic nova) must culminate sooner or later, through protracted inner maturation, in some implosive concentration of its cultural noosphere. And this specific event should possibly coincide with some escape of the fully 'co-reflected' parts of the *weltstoff* outside and beyond the apparent boundaries of time and space. Strangely enough, such a wild hypothesis of a transhuman universe con-forms perfectly to the general pattern of a physical world in which absolutely nothing can grow indefinitely without meeting ultimately some critical level of emergence and transformation. From the inflexible point of view of energetics, the process fulfils, we believe, a condition *sine qua non* for the steady continuation of human effort during the next million years towards an ever-greater culture and acculturation.

So far, man has accepted blindly (just as the industrial workers of a century ago) the pushing ahead of the terrestrial development of life without asking himself whether it was a paying game to play at being Atlas. But this phase of instinctive co-operation is decidedly over. The time can be foreseen when the human drive for climbing always higher towards consciousness through complexity will die out, unless it is stimulated by growing scientific evidence that, through ever-intensified hominisation, we are really moving somewhere and for ever.

That some definite Everest should really be there ahead of us, behind the clouds, an Everest from which there is no return to the plain; that through a stubborn confluence of our minds and hearts we should eventually succeed in breaking the barrier of darkness and mutual exteriority that still separates life as we know it from some higher and more stable form of knowledge and unanimity; and to become actually and acutely conscious of the imperative craving of our deepest ego for some definitely irreversible type of achieve-ment—might well be, we venture to say, the next step which man will take (very soon, perhaps) in the process of his co-reflexive self-evolution.

JULIAN S.HUXLEY

Sir Julian Huxley (1887–1975) was an English biologist, philosopher, educator and author who greatly influenced the modern development of embryology, systematics, and studies of behaviour and evolution. He was a grandson of the prominent biologist and Darwinian bulldog T.H.Huxley and the oldest son of the biographer and man of letters Leonard Huxley. Apart from his academic achievements, notably as a leading contributor to the 'modern evolutionary synthesis', Huxley was also active in international science and was a founder and first director general of UNESCO. Importantly, it was Huxley who introduced Teilhard de Chardin's most famous work to the English-speaking world, and he remained a promoter of the noosphere concept throughout the rest of his life.

INTRODUCTION TO *THE PHENOMENON OF MAN*

The Phenomenon of Man is a very remarkable work by a very remarkable human being. Père Teilhard de Chardin was at the same time a Jesuit father and a distinguished palaeontologist. In *The Phenomenon of Man* he has effected a threefold synthesis—of the material and physical world with the world of mind and spirit; of the past with the future; and of variety with unity, the many with the one. He achieves this by examining every fact and every subject of his investigation *sub specie evolutionis,* with reference to its development in time and to its evolutionary position. Con-versely, he is able to envisage the whole of knowable reality not as a static mechanism but as a process. In consequence, he is driven to search for human significance in relation to the trends of that enduring and comprehensive process; the measure of his stature is that he so largely succeeded in the search. I would like to introduce *The Phenomenon of Man* to English readers by attempting a summary of its general thesis, and of what appear to me to be its more important conclusions.

I make no excuse for this personal approach. As I discovered when I first met Père Teilhard in Paris in 1946, he and I were on the same quest, and had been pursuing parallel roads ever since we were young men in our twenties. Thus, to mention a few signposts which I independently found along my road, already in 1913 I had envisaged human evolution and biological evolution as two phases of a single process, but separated by a 'critical point', after which the properties of the evolving material underwent radical change. This thesis I developed years later in my *Uniqueness of Man,* adding that man's evolution was unique in showing the dominance of convergence over divergence: in the same volume I published an essay on Scientific Humanism (a close approximation to Père Teilhard's Neo-Humanism), in which I independently anticipated the tide of Père Teilhard's great book by describing humanity as a phenomenon, to be studied and analysed by scientific methods. Soon after the First World War, in *Essays of a Biologist,* I made my first attempt at defining and evaluating evolutionary progress.

In my *Romanes Lecture on Evolutionary Ethics,* I made an attempt (which I now see was inadequate, but was at least a step in the right direction) to relate the development of moral codes and religions to the general trends of evolution; in 1942, in my *Evolution, the Modern Synthesis,* I essayed the first comprehensive post-Mendelian analysis of biological evolution as a process; and just before meeting Père Teilhard I had written a pamphlet entitled *UNESCO: its Purpose and Philosophy,* where I stressed that such a philosophy must be a global, scientific and evolutionary humanism. In this, I was searching to establish an ideological basis for man's further cultural evolution, and to define the position of the individual human personality in the process—a search in which I was later much aided by Père Teilhard's writings, and by our conversations and correspondence.

Père Teilhard starts from the position that mankind in its totality is a phenomenon to be described and analysed like any other phenomenon: it and all its manifestations, including human history and human values, are proper objects for scientific study.

His second and perhaps most fundamental point is the absolute necessity of adopting an evolutionary point of view. Though for certain limited purposes it may be useful to think of phenomena as isolated statically in time, they are in point of fact never static: they are always processes or parts of processes. The different branches of science combine to demonstrate that the universe in its entirety must be regarded as one gigantic process, a process of becoming, of attaining new levels of existence and organisation, which can properly be called a genesis or an evolution. For this reason, he uses words like 'noogenesis', to mean the gradual evolution of mind or mental properties, and repeatedly stresses that we should no longer speak of a cosmology but of a 'cosmogenesis'. Similarly, he likes to use a pregnant term like hominisation to denote the process by which the original proto-human stock became (and is still becoming) more truly human, the process by which potential man realised more and more of his possibilities. Indeed, he extends this evolutionary terminology by employing terms like ultra-hominisation to denote the deducible future stage of the process in which man will have so far transcended himself as to demand some new appellation.

With this approach he is rightly and indeed inevitably driven to the conclusion that, since evolutionary phenomena (of course including the phenomenon known as man) are processes, they can never be evaluated or even adequately described solely or mainly in terms of their origins: they must be defined by their direction, their inherent possibilities (including of course also their limitations), and their deducible future trends. He quotes with approval Nietzche's view that man is unfinished and must be surpassed or completed; and proceeds to deduce the steps needed for his completion.

Père Teilhard was keenly aware of the importance of vivid and arresting terminology. Thus in 1925 he coined the term 'noosphere' to denote the sphere of mind, as opposed to, or rather superposed on, the biosphere or sphere of life, and acting as a transforming agency promoting hominisation (or as I would put it, progressive psychosocial evolution). He may perhaps be criticised for not defining the term more explicitly. By 'noosphere' did he intend simply the total pattern of thinking organisms (i.e. human beings) and their activity, including the patterns of their interrelations: or did he intend the special environment of man, the systems of organised thought and its products in which men move and have their being, as fish swim and reproduce in rivers and the sea? Perhaps it might have been better to restrict 'noosphere' to the first-named sense, and to use something like 'noosystem' for the second. But certainly 'noosphere' is a valuable and thought-provoking word.

He usually uses convergence to denote the tendency of mankind, during its evolution, to superpose centripetal on centrifugal trends, so as to prevent centrifugal differentiation from leading to fragmentation, and eventually to incorporate the results of differentiation in an organised and unified pattern. Human convergence was first manifested on the genetic or biological level: after *Homo sapiens* began to differentiate into distinct races (or subspecies, in more scientific terminology) migration and intermarriage prevented the pioneers from going further, and led to increasing interbreeding between all human variants. As a result, man is the only successful type which has remained as a single interbreeding group or species, and has not radiated out into a number of biologically separated assemblages (like the birds, with about 8,500 species, or the insects with over half a million).

Cultural differentiation set in later, producing a number of psychosocial units with different cultures. However, these 'interthinking groups', as one writer has called them, are never so sharply separated as are biological species; and with time, the process known to anthropologists as cultural diffusion, facilitated by migration and improved communications, led to an accelerating counter-process of cultural convergence, and so towards the union of the whole human species into a single interthinking group based on a single self-developing framework of thought (or noosystem).

In parenthesis, Père Teilhard showed himself to be aware of the danger that this tendency might destroy the valuable results of cultural diversification and lead to drab uniformity instead of to a rich and potent pattern of variety in unity. However, perhaps because he was (rightly) so deeply concerned with establishing a global unification of human awareness as a necessary prerequisite for any real future progress of mankind, and perhaps also because he was by nature and inclination more interested in rational and scientific thought than in the arts, he did not discuss the evolutionary value of cultural variety in any detail, but contented himself by maintaining that East and West are culturally complementary, and that both are needed for the further synthesis and unification of world thought.

Before passing to the full implications of human convergence, I must deal with Père Teilhard's valuable but rather difficult concept of complexification. This concept includes, as I understand it, the genesis of increasingly elaborate organisation during cosmogenesis, as manifested in the passage from subatomic units to atoms, from atoms to inorganic and later to organic molecules, thence to the first subcellular living units or self-replicating assemblages of molecules, and then to cells, to multicellular individuals, to cephalised metazoa with brains, to primitive man, and now to civilised societies.

But it involves something more. He speaks of complexification as an all-pervading tendency, involving the universe in all its parts in an 'enroulement organique sur soimême,' or by an alternative metaphor, as a 'reploiement sur soi-même.' He thus envisages the world-stuff as being 'rolled up' or 'folded in' upon itself, both locally and in its entirety, and adds that the process is accompanied by an increase of energetic 'tension' in the resultant 'corpuscular' organisations, or individualised constructions of increased organisational complexity. For want of a better English phrase, I shall use convergent integration to define the operation of this process of self-complexification.

Père Teilhard also maintains that complexification by convergent integration leads to the intensification of subjective mental activity—in other words to the evolution of progressively more conscious mind. Thus he states that full consciousness (as seen in man) is to be defined as the specific effort of organised complexity. But, he continues, comparative study makes it clear that higher animals have minds of a sort, and evolutionary fact and logic demand that minds should have evolved gradually as well as bodies and that accordingly mind-like (or 'mentoid', to employ a barbarous word that I am driven to coin because of its usefulness) properties must be present throughout the universe. Thus, in any case, we must infer the presence of potential mind in all material systems, by backward extrapolation from the human phase to the biological, and from the biological to the inorganic. And according to Père Teilhard, we must envisage the intensification of mind, the raising of mental potential, as being the necessary consequence of complexification, operating by the convergent integration of increasingly complex units of organisation.

The sweep of his thought goes even further. He seeks to link the evolution of mind with the concept of energy. If I understand him right, he envisages two forms of energy, or perhaps two modes in which it is manifested—energy in the physicists' sense, measurable or calculable by physical methods, and 'psychic energy', which increases with the complexity of organised units. This view admittedly involves speculation of great intellectual boldness, but the speculation is extrapolated from a massive array of fact and is disciplined by logic. It is, if you like, visionary: but it is the product of a comprehensive and coherent vision.

It might have been better to say that complexity of a sort is a necessary prerequisite for mental evolution rather than its cause. Some biologists, indeed, would claim that mind is generated solely by the complexification of certain types of organisation, namely brains. However, such logic appears to me narrow. The brain alone is not responsible for mind, even though it is a necessary organ for its manifestation. Indeed an isolated brain is a piece of biological nonsense, as meaningless as an isolated human individual. I would prefer to say that mind is generated by or in complex organisations of living matter, capable of receiving information of many qualities and modalities about events both in the outer world and in itself, or synthesising and processing that information in various organised forms, and of utilising it to direct present and future action—in other words, by higher animals with their sense organs, nerves, brains and muscles. Perhaps, indeed, organisations of such complexity can arise in evolution only when their construction enables them to incorporate and interiorise varied external information: certainly no non-living, non-sentient organisation has reached anything like this degree of elaboration.

In human or psychosocial evolution, convergence has certainly led to increased complexity. In Père Teilhard's view, the increase of human numbers combined with the improvement of human communications has fused all the parts of the noosphere together, has increased the tension within it, and has caused it to become 'infolded' upon itself, and therefore more highly organised. In the process of convergence and coalescence, what we may metaphorically describe as the psychosocial temperature rises. Mankind as a whole will accordingly achieve more intense, more complex and more integrated mental activity, which can guide the human species up the path of progress to higher levels of hominisation.

Père Teilhard was a strong visualiser. He saw with his mind's eye that 'the banal fact of the Earth's roundness' the sphericity of man's environment—was bound to cause this intensification of psychosocial activity. In an unlimited environment, man's thought and his resultant psychosocial activity would simply diffuse outwards: it would extend over a greater area, but would remain thinly spread. But when it is confined to spreading out over the surface of a sphere, idea will encounter idea, and the result will be an organised web of thought, a noetic system operating under high tension, a piece of evolutionary machinery capable of generating high psychosocial energy. When I read his discussion of the subject, I visualised this selective web of living thought as the bounding structure of evolving man, marking him off from the rest of the universe and yet facilitating exchange with it: playing the same sort of role in delimiting the human unit of evolution and yet encouraging the complexification of its contents, as does the cell membrane for the animal cell.

Père Teilhard, extrapolating from the past into the future, envisaged the process of human convergence as tending to a final state, which he called 'point Omega', as opposed to the Alpha of elementary material particles and their energies. If I understand him aright, he considers that two factors are co-operating to promote this further complexification of the noosphere. One is the increase of knowledge about the universe at large, from the galaxies and stars to human societies and individuals. The other is the increase of psychosocial pressure on the surface of our planet. The result of the one is that the noosphere incorporates ever more facts of the cosmos, including the facts of its general direction and its trends in time, so as to become more truly a microcosm, which (like all incorporated knowledge) is both a mirror and a directive agency. The result of the other is the increased unification and the increased intensity of the system of human thought. The combined result, according to Père Teilhard, will be the attainment of point Omega, where the noosphere will be intensely unified and will have achieved a 'hyper-personal' organisation.

...

A developed human being, as he rightly pointed out, is not merely a more highly individualised individual. He has crossed the threshold of self-consciousness to a new mode of thought, and as a result has achieved some degree of conscious integration—integration of the self with the outer world of men and nature, integration of the separate elements of the self with each other. He is a person, an organism which has transcended individuality in personality. This attainment of personality was an essential element in man's past and present evolutionary success: accordingly its fuller achievement must be an essential aim for his evolutionary future.

...

With his genius for fruitful analogy, he points out that the process of evolution on Earth is itself now in the process of becoming cephalised. Before the appearance of man, life consisted of a vast array of separate branches, linked only by an unorganised pattern of ecological interaction. The incipient development of mankind into a single psychosocial unit, with a single noosystem or common pool of thought, is providing the evolutionary process with the rudiments of a head. It remains for our descendants to organise this global noosystem more adequately, so as to enable mankind to understand the process of evolution on Earth more fully and to direct it more adequately.

I had independently expressed something of the same sort, by saying that in modern scientific man, evolution was at last becoming conscious of itself—a phrase which I found delighted Père Teilhard. His formulation, however, is more profound and more seminal: it implies that we should consider interthinking humanity as a new type of organism, whose destiny it is to realise new possibilities for evolving life on this planet. Accordingly, we should endeavour to equip it with the mechanisms necessary for the proper fulfilment of its task—the psychosocial equivalents of sense organs, effector organs, and a co-ordinating central nervous system with dominant brain; and our aim should be the gradual personalisation of the human unit of evolution—its conversion, on the new level of co-operative inter-thinking, into the equivalent of a person.

...

As a result, he has helped us to define more adequately both our own nature, the general evolutionary process, and our place and role in it. Thus clarified, the evolution of life becomes a comprehensible phenomenon. It is an anti-entropic process, running counter to the second law of thermodynamics with its degradation of energy and its tendency to uniformity. With the aid of the Sun's energy, biological evolution marches uphill, producing increased variety and higher degrees of organisation.

It also produces more varied, more intense and more highly organised mental activity or awareness. During evolution, awareness (or if you prefer, the mental properties of living matter) becomes increasingly important to organisms, until in mankind it becomes the most important characteristic of life and gives the human type its dominant position.

After this critical point has been passed, evolution takes on a new character: it becomes primarily a psychosocial process, based on the cumulative transmission of experience and its results, and working through an organised system of awareness, a combined operation of knowing, feeling and willing. In man, at least during the historical and protohistorical periods, evolution has been characterised more by cultural than by genetic or biological change.

On this new psychological level, the evolutionary process leads to new types and higher degrees of organisation. On the one hand, there are new patterns of co-operation between individuals—co-operation for practical control, for enjoyment, for education, and notably in the last few centuries, for obtaining new knowledge; and on the other hand, there are new patterns of thought, new organisations of awareness and its products.

As a result, new and often wholly unexpected possibilities have been realised, the variety and degree of human fulfilment have been increased. Père Teilhard enables us to see which possibilities are in the long run desirable. What is more, he has helped to define the conditions of advance, the conditions which will permit an increase of fulfilment and prevent an increase of frustration. The conditions of advance are these: global unity of mankind's noetic organisation or system of awareness, but a high degree of variety within that unity; love, with goodwill and full co-operation; personal integration and internal harmony; and increasing knowledge.

Knowledge is basic. It is knowledge which enables us to understand the world and ourselves, and to exercise some control or guidance. It sets us in a fruitful and significant relation with the enduring processes of the universe. And, by revealing the possibilities of fulfilment that are still open, it provides an overriding incentive. We, mankind, contain the possibilities of the Earth's immense future and can realise more and more of them on condition that we increase our knowledge and our love. That, it seems to me, is the distillation of *The Phenomenon of Man*.

JOSEPH NEEDHAM

Joseph Needham (1900–1995) was an English biochemist, embryologist and social historian of science. After first working in his area of direct training, biochemistry, he became a leading Sinologist and worked on his major study, *Science and Civilisation in China,* over several decades at Cambridge University. Needham was the first director of natural sciences for UNESCO (1946–48) and later became a leading supporter of Teilhard de Chardin's work. He clearly recognised parallels between Teilhard de Chardin's cosmogenesis and his own study of Chinese cosmology and perhaps also biochemistry. The following extract featured in a newspaper review of *The Phenomenon of Man* following its publication in English in 1959.

COSMOLOGIST OF THE FUTURE

The world is composed of a series of envelopes. Protons and electrons make up atoms, atoms combine into molecules, these again into crystals or stars or living organisms, out of which in their turn are built solar systems or societies. There are in fact successive levels of integration and organisation, the higher containing the lower within themselves. But time is also of the essence; there was a time when there were atoms but no molecules, later on there were nucleoprotein molecules but no living cells, later fishes but no mammals, later man but no co-operative commonwealth. What are these propositions? Simply, the view of the universe held by the overwhelming majority of working scientists in our age. Implicit in it is the conviction that social evolution is continuous with biological evolution, and therefore that what materialist theologians have called the kingdom of God on Earth is not a desperate hope but a sure development with all the authority of evolution behind it. Individual men help or hinder. Sometimes cosmological philosophers take this world view seriously, in which case they are called emergent evolutionists, organic naturalists or Marxists and treated with disdain by their professional colleagues, whose lives are devoted to the sublime object of proving the statements of science meaningless, although it works.

This scientific faith, so far removed from blind belief, has never been more persuasively set forth than in the present book of Pierre Teilhard de Chardin. It is the work of a first-rate evolutionary biologist who knew his facts. But the interest lies rather in the author himself, for he was no Huxleyan rationalism stalwart. Teilhard de Chardin was a Jesuit priest, and at the same time a brilliant physical anthropologist who spent much of his life, with colleagues such as P'ei Wen-chung, in the service of the Chinese Palaeontological Survey—an entirely worthy successor of the great members of the Jesuit mission of the seventeenth century — and by Rome treated no better. For not very surprisingly Teilhard de Chardin's originality and free-ranging thought came into conflict with the dominant official interpretations of such doctrines as that of original sin, and he was silenced by his ecclesiastical superiors. Thus he died in exile from his native country, and could not see the publication of any of his books, such as that cosmic panorama of past and future which we now salute.

In October 1952 he wrote to me:

> Something is wrong—with anthropology, and something has to be done with, and for, anthropology. I wonder if my diagnosis is good, at least as a first approximation, and how one could tackle scientifically the study of what I call, lacking any better terms, the 'convergence of humanity upon itself.

We had met in Paris just after the war, when he was back after long years of 'solitude' under the Japanese occupation, and I was helping to develop UNESCO after four years in wartime China. I recognised in him immediately a man of the greatest intellectual honesty and sincerity combined with a prophetic Blake-like vision, and often at a loss to find words with which to express his insights. Alas, taken up later on with other endeavours, I could not find the time needed for following Teilhard de Chardin's unfamiliar thoughts and gave only a vaguely encouraging reply.

But actually his wrestling with the idea of 'convergent integration' (as Julian Huxley terms it in his admirable preface) was perhaps the most original part of all his work, because it was central to his effort to extrapolate the past forward and to discern something of the far future from what we know of the far past and the present. Seeing that the most highly organised entities we know, living beings with minds, have been formed by a kind of intense concentration in space, an 'inrolling upon themselves'; realising that man is the only successful biological species which has remained as a single interbreeding group, not radiating out in 'cladogenesis' into thousands of mutually infertile species; and impressed by the fact that the situation' of 'noospheres' can only be very thin tissues of organic interrelations mantling earths such as our own: his thought was irresistibly attracted to the future development of humanity. Here his speculations about the emergence of a 'world mind' or Great Being, the tending of human convergence to a final state, which he called 'point Omega', the possible equation of future hyper-personal psychosocial organisation with an emergent divinity in the growth of love as well as cosmic knowledge, a kind of 'Christogenesis'; all these difficult ideas are the strangest, because the most original of his work, and could not be orthodox, for they deal with matters inconceivable when orthodoxy was historically formed. They are abundantly worth pondering.

By choice or necessity, Teilhard de Chardin was a rather lonely thinker; hardly anyone but Bergson seems to have been important for him. Internal evidence yields a few other traces, but he seems not to have followed Lawrence J.Henderson's dissolution of vitalism in universal teleology, or to have known of such workers as A.I. Oparin on the probable events in the origin of life on the Earth; nor is there any sign of the inspiration which he could have gained from A.N.Whitehead's organic philosophy. The word 'emergence' does not appear until [near the end], and men such as Lloyd Morgan and Samuel Alexander are out of the picture. Curious too is the fact that Chinese culture, the most historically minded of all, seems to have made very little impression on our philosopher, and this might perhaps be the reason why it is only in the realm of history that his book is seriously out of focus. To say of a civilisation to which we owe the technology of cast iron and the first development of the mechanical clock that it remained throughout the centuries persistently 'neolithic', and to insist that 'during historic time the principal axis of anthropogenesis passed through the West' is simply to perpetuate a vulgar error still capable of doing great harm. Of course, history, for Teilhard de Chardin, was only a very thin slice of time intervening between the vast aeons of pre-history and the equally vast though dimly seen vistas of post-history yet to come, and his faltering touch concerning it therefore matters the less. But since without history social evolution cannot be properly conceived; this failing is to be regretted. Nor could he always rise above a too Christian bias, as for example where he denies the other ancient religions the possibility of adaptation to scientific knowledge.

Broadly speaking, *The Phenomenon of Man* is the most recent, and by no means the least interesting, of the long line of master-works of the organic evolutionary naturalists. But it is written by one who understood super-naturalism from the inside. Expressed in a style hardly less poetical than philosophical, it eloquently restates the scientific view of the world. But it adds something new: its courageous speculations about the future; the emergence of higher social and noetic organisms; the world mind-heart; the apotheosis of humanity—speculations sometimes almost reminiscent of Olaf Stapledon, a writer whom Teilhard de Chardin would surely have found sympathetic. What will always endear it to us is the personal epic of the writer, the China Jesuit silenced in his lifetime but never abandoning the mental fight, profoundly 'costing' as von Hügel would have said, and finding a reconciliation of science and religion only in the context of the whole universe of space and time.

ARNOLD J.TOYNBEE

Arnold J.Toynbee (1889–1975), an English historian, is author of the widely known twelve-volume *A Study of History* (1934–61), which examines the development and decline of the world's great civilisations. It is interesting that Toynbee, like Needham, enthusiastically embraced many of Teilhard's views as a form of unifying knowledge and grew to like them even more as time went on—evidenced in one his last efforts, *Mankind and Mother Earth* (1976). The following extract also featured in a newspaper review of *The Phenomenon of Man* shortly after its publication in English.

VISION OF THE UNITY

…

He sweeps away the barriers between the academic mandarins' specialised disciplines because he has a mind that sees beyond the conventional dichotomies of thought: e.g. between 'matter' and 'mind'.

In Teilhard's vision, matter and consciousness are the outward-facing and inward-facing facets of one and the same reality. He believes that the inwardness of reality has been asserting its independence of the outwardness. The universe is groping its way from the material manifestation towards the communion of saints. The material universe may run down, as some schools of scientific thought predict, but the City of God remaineth.

This belief of Teilhard's that spirit will survive matter, although it may have emerged from it, is illustrated poignantly in Teilhard's personal history. His synoptic vision of the objects of science and religion was a stumbling block for both the scientific and religious authorities. Although they may disagree about almost everything else, they concur—at any rate at the present moment— in liking to keep the universe divided up into watertight compartments.

Teilhard is an ardent exponent of the evolutionary view, but this on other than Darwinian lines. He does not combat the Darwinian account of evolution, but his attention is concentrated on another aspect of evolution which he finds more significant. As he sees it, the main movement in the universe has been, and is, a groping towards consciousness. Here he is wrestling with the problem of newness. He is convinced that the emergence of this new thing means that, in a sense, this new thing will have been there already, and indeed there from the beginning. Newness is, of course, a paradox for logic, although it is a commonplace of experience. This logical paradox appears in Teilhard's vision of God. For him, God is, in one sense, still in the future. He is the supreme conscious personality, in whom all other conscious personalities will achieve union and harmony. At the same time, God has been there from the beginning.

…

New words are needed to express new ideas, and the words that Teilhard has coined are the evocative words of a poet. 'The noosphere', the 'Omega point': these neologisms convey new visions, and for that reason they are hard to grasp. At the same time, the exposition of Teilhard's thought could not do without them. As one reads the book, one has the sensation of being carried along by a spirit that is evolution itself. Teilhard breaks through apparently impenetrable intellectual barriers, bruising his feet on the rubble from the fallen walls. His book is an act of spiritual liberation. His vision of unity meets a spiritual need of our time.

PETER B.MEDAWAR

Peter B.Medawar (1915–1987) was a British zoologist and joint recipient of the 1960 Nobel Prize in physiology or medicine. He taught at several British universities, being knighted in 1965 and awarded the Order of Merit in 1981. After being one of Teilhard de Chardin's (and the noosphere idea's) most authoritative and powerful critics, Medawar later believed that he had been too hard with Teilhard de Chardin (1982) and thought the noosphere concept to be valuable (1988). The following extract appeared in the academic journal *Mind* in 1961 and remains the best-known (and perhaps harshest) criticism of Teilhard de Chardin's philosophy. Medawar took particular exception to Teilhard de Chardin's assertion that the ideas presented in *The Phenomenon of Man* constituted science.

REVIEW, *THE PHENOMENON OF MAN*

In spite of all the obstacles that Teilhard perhaps wisely puts in our way, it is possible to discern a train of thought in *The Phenomenon of Man*. It is founded upon the belief that the fundamental process or motion in the entire universe is evolution, and evolution is 'a general condition to which all theories, all hypotheses, all systems must bow…a light illuminating all facts, a curve that all lines must follow.' This being so, it follows that 'nothing could ever burst forth as final across the different thresholds successively traversed by evolution…which has not already existed in an obscure and primordial way'. Nothing is wholly new: there is always some primordium or rudiment or archetype of whatever exists or has existed. Love, for example— 'that is to say, the affinity of being with being'—is to be found in some form throughout the organic world, and even at a 'prodigiously rudimentary level', for if there were no such affinity between atoms when they unite into molecules it would be 'physically impossible for love to appear higher up, with us, in "hominised" form.' But above all, consciousness is not new, for this would contradict the evolutionary axiom; on the contrary, we are 'logically forced to assume the existence in rudimentary form…of some sort of psyche in every corpuscle,' even in molecules; 'by the very fact of the individualisation of our planet, a certain mass of elementary consciousness was originally imprisoned in the matter of earth.'

What form does this elementary consciousness take? Scientists have not been able to spot it, for they are shallow superficial fellows, unable to see into the inwardness of things—'up to now, has science ever troubled to look at the world other than from without?' Consciousness is an interiority of matter, an 'inner face that everywhere duplicates the "material" external face, which alone is commonly considered by science.' To grasp the nature of the within of things we must understand that energy is of two kinds: the 'tangential', which is energy as scientists use that word, and a radial energy (a term used interchangeably with spiritual or psychic energy), of which consciousness is treated sometimes as the equivalent, sometimes as the manifestation, and sometimes as the consequence (there is no knowing what Teilhard intends). Radial energy appears to be a measure of, or what conduces towards, complexity or degree of arrangement; thus 'spiritual energy, by its very nature, increases in "radial" value… in step with the increasing chemical complexity of the elements of which it represents the inner lining.' It confers centricity, and 'the increase of the synthetic state of matter involves…an increase of consciousness.'

We are now therefore in a position to understand what evolution is (is nothing but). Evolution is 'the continual growth of …"psychic" or "radial" energy, in the course of duration, beneath and within the mechanical energy I called "tangential"'; evolution, then is 'an ascent towards consciousness.' It follows that evolution must have a 'precise orientation and a privileged axis', at the topmost pole of which lies Man, born 'a direct lineal descendant from the total effort of life.'

Let us fill in the intermediate stages. Teilhard, with a penetrating insight that Sir Julian Huxley singles out for special praise, discerns that consciousness in the everyday sense is somehow associated with the possession of nervous systems and brains ('we have every reason to think that in animals too a certain inwardness exists, approximately proportional to the development of their brains'). The direction of evolution must therefore be towards cerebralisation, that is, towards becoming brainier. 'Among the infinite modalities in which the complication of life is dispersed,' he tells us, 'the differentiation of nervous tissue stands out…as a significant transformation. It provides a direction; and by its consequences it proves that evolution has a direction.' All else is equivocal and insignificant; in the process of becoming brainier we find 'the very essence of complexity, of essential metamorphosis.' And if we study the evolution of living things, organic evolution, we shall find that in every one of its lines, except only in those in which it does not occur, evolution is an evolution towards increasing complexity of the nervous system and cerebralisation. Plants do not count, to be sure (because 'in the vegetable kingdom we are unable to follow along a nervous system the evolution of a psychism obviously remaining diffuse'), and the contemplation of insects provokes a certain shuffling of the feet; but primates are 'a phylum of pure and direct cerebralisation' and among them 'evolution went straight to work on the brain, neglecting everything else.' Here is Teilhard's description of noogenesis, the birth of higher consciousness among the primates, and of the noosphere in which that higher consciousness is deployed:

> By the end of the Tertiary era, the psychical temperature in the cellular world had been rising for more than 500 million years…. When the anthropoid, so to speak, had been brought 'mentally' to boiling-point some further calories were added…. No more was needed for the whole inner equilibrium to be upset…. By a tiny 'tangential' increase, the 'radial' was turned back on itself and so to speak took an infinite leap forward. Outwardly, almost nothing in the organs had changed. But in depth, a great revolution had taken place: consciousness was now leaping and boiling in a space of super-sensory relationships and representations.

The analogy, it should be explained, is with the vaporisation of water when it is brought to boiling point, and the image of hot vapour remains when all else is forgotten.

I do not propose to criticise the fatuous argument I have just outlined; here, to expound is to expose. What Teilhard seems to be trying to say is that evolution is often (he says always) accompanied by an increase of orderliness or internal coherence or degree of integration. In what sense is the fertilised egg that develops into an adult human being 'higher' than, say, a bacterial cell? In the sense that it contains richer and more complicated genetic instructions for the execution of those processes that together constitute development. Thus Teilhard's radial, spiritual or psychic energy may be equated to 'information' or 'information content' in the sense that has been made reasonably precise by modern communications engineers. To equate it with consciousness, or to regard degree of consciousness as a measure of information content, is one of the silly little metaphysical conceits I mentioned in an earlier paragraph. Teilhard's belief, enthusiastically shared by Sir Julian Huxley, that evolution flouts or foils the second law of thermodynamics is based on a confusion of thought; and the idea that evolution has a main track or privileged axis is unsupported by scientific evidence.

Teilhard is widely believed to have rejected the modern Mendelian—Darwinian theory of evolution or to have demonstrated its inadequacy. Certainly he imports a ghost, the entelechy or *élan vital* of an earlier terminology, into the Mendelian machine; but he seems to accept the idea that evolution is probationary and exploratory and mediated through a selective process, a 'groping', a 'billionfold trial and error; 'far be it from me,' he declares, 'to deny its importance.' Unhappily, Teilhard has no grasp of the real weakness of modern evolutionary theory, namely its lack of a complete theory of variation, of the origin of candidature for evolution. It is not enough to say that 'mutation' is ultimately the source of all genetic diversity, for that is merely to give the phenomenon a name: mutation is so defined. What we want, and what we are slowly beginning to get, is a comprehensive theory of the forms in which new genetic information comes into being. It may, as I have hinted elsewhere, turn out to be of the nature of nucleic acids and the chromosomal apparatus that they tend spontaneously to proffer genetic variants—genetic solutions to the problem of remaining alive— which are more complex and more elaborate than the immediate occasion calls for; but to construe this 'complexification' as a manifestation of consciousness is a wilful abuse of words.

Teilhard's metaphysical argument begins where the scientific argument leaves off, and the gist of it is extremely simple. Inasmuch as evolution is the fundamental motion of the entire universe, an ascent along a privileged and necessary pathway towards consciousness, so it follows that our present consciousness must 'culminate forwards in some sort of supreme consciousness.' In expounding this thesis, Teilhard becomes more and more confused and excited and finally almost hysterical. The Supreme Consciousness, which apparently assimilates to itself all our personal consciousnesses, is, or is embodied in, 'Omega' or the Omega point; in Omega, 'the movement of synthesis culminates.' Now Omega is 'already in existence and operative at the very core of the thinking mass,' so if we have our wits about us we should at this moment be able to detect Omega as 'some excess of personal, extra-human energy,' the more detailed contemplation of which will disclose the Great Presence. Although already in existence, Omega is added to progressively: 'All round us, one by one, like a continual exhalation, "souls" break away, carrying upwards their incommunicable load of consciousness,' and so we end up with 'a harmonised collectivity of consciousnesses equivalent to a sort of super-consciousness.'

Teilhard devotes some little thought to the apparently insuperable problem of how to reconcile the persistence of individual consciousnesses with their assimilation to Omega. But the problem yields to the application of 'remorseless logic'. The individual particles of consciousness do not join up any old how, but only centre to centre, thanks to the mediation of Love; Omega, then, 'in its ultimate principle, can only be a distinct Centre radiating at the core of a system of centres,' and the final state of the world is one in which 'unity coincides with a paroxysm of harmonised complexity.' And so our hero escapes from his dire predicament: with one bound Jack is free.

Although elsewhere Teilhard has dared to write an equation so explicit as 'Evolution = Rise of Consciousness', he does not go so far as to write 'Omega = God'; but in the course of some obscure pious rant he does tell us that God, like Omega, is a 'Centre of centres', and in one place he refers to 'God-Omega'.

How have people come to be taken in by *The Phenomenon of Man?* We must not underestimate the size of the market for works of this kind, for philosophy-fiction. Just as compulsory primary education created a market catered for by cheap dailies and weeklies, so the spread of secondary and latterly tertiary education has created a large population of people, often with well-developed literary and scholarly tastes, who have been educated far beyond their capacity to undertake analytical thought. It is through their eyes that we must attempt to see the attractions of Teilhard, which I shall jot down in the order in which they come to mind.

1 *The Phenomenon of Man* is anti-scientific in temper (scientists are shown up as shallow folk skating about on the surface of things), and, as if that were not recommendation enough, it was written by a scientist, a fact that seems to give it particular authority and weight. Laymen firmly believe that scientists are one species of person. They are not to know that different branches of science require very different aptitudes and degrees of skill for their prosecution. Teilhard practised an intellectually unexacting kind of science in which he achieved a moderate proficiency. He has no grasp of what makes a logical argument or of what makes for proof. He does not even preserve the common decencies of scientific writing, although his book is professedly a scientific treatise.
2 It is written in an all but totally unintelligible style, and this is construed as *prima facie* evidence of profundity. (At present this applies only to works of French authorship; in later Victorian and Edwardian times the same deference was thought due to Germans, with equally little reason.) It is because Teilhard has such wonderfully deep thoughts that he is so difficult to follow—really it is beyond my poor brain but does that not just show how profound and important it must be?
3 It declares that Man is in a sorry state, the victim of a 'fundamental anguish of being', a 'malady of space—time', a sickness of 'cosmic gravity'. The Predicament of Man is all the rage now that people have sufficient leisure and are sufficiently well fed to contemplate it, and many a tidy literary reputation has been built upon exploiting it; anybody nowadays who dared to suggest that the plight of man might not be wholly desperate would get a sharp rap over the knuckles in any literary weekly. Teilhard not only diagnoses in everyone the fashionable disease but propounds a remedy for it—yet a remedy so obscure and so remote from the possibility of application that it is not likely to deprive any practitioner of a living.
4 *The Phenomenon of Man* was introduced to the English-speaking world by Sir Julian Huxley, who, like myself, finds Teilhard somewhat difficult to follow ('If I understood him aright'; 'here his thought is not fully clear to me'; etc.). Unlike myself, Sir Julian finds Teilhard in possession of a 'rigorous sense of values', one who 'always endeavoured to think concretely'; he was speculative, to be sure, but his speculation was 'always disciplined by logic'. But then it does not seem to me that Huxley expounds Teilhard's argument; his Introduction does little more than to call attention to parallels between Teilhard's thinking and his own. Chief among these is the cosmic significance attached to a suitably generalised conception of evolution—a conception so diluted or attenuated in the course of being generalised as to cover all events or phenomena that are not immobile in time. In particular, Huxley applauds the, in my opinion, mistaken belief that the so-called 'psychosocial evolution' of mankind and the genetic evolution of living organisms generally are two episodes of a continuous integral process (though separated by a 'critical point', whatever that may mean). Yet for all this Huxley finds it impossible to follow Teilhard 'all the way in his gallant attempt to reconcile the supernatural elements in Christianity with the facts and implications of evolution.' But, bless my soul, this reconciliation is just what Teilhard's book is about!

I have read and studied *The Phenomenon of Man* with real distress, even with despair. Instead of wringing our hands over the Human Predicament, we should attend to those parts of it which are wholly remediable, above all to the gullibility which makes it possible for people to be taken in by such a bag of tricks as this. If it were an innocent, passive gullibility it would be excusable; but all too clearly, alas, it is an active willingness to be deceived.

GEORGE GAYLORD SIMPSON

George Gaylord Simpson (1902–1984) was a US palaeontologist known for his contributions to the 'modern evolutionary synthesis'. The following article appeared as a review of *The Phenomenon of Man*. Like Medawar, Simpson criticised the work for, in his view, falsely claiming to be scientific. However, this point aside, he was more sympathetic to the general ideas.

ON THE REMARKABLE TESTAMENT OF THE JESUIT PALAEONTOLOGIST TEILHARD DE CHARDIN

Teilhard's book is not, however, strictly or even mainly concerned with describing the factual course of evolution. That is the 'without' of things, and the author is here concerned rather with 'the within'. The within is another term for consciousness (the French conscience, another word without a really precise English equivalent), which in turn implies spontaneity and includes every kind of 'psychism'. Consciousness, in this sense, is stated to be a completely general characteristic of matter, whether in an individual atom or in man, although in the atom it is less organised and less evident. The origin of the cell was critical because it involved a 'psychic mutation' introducing a change in the nature of the state of universal consciousness. The origin of man was again critical because at this stage consciousness became self-consciousness, reflection or thought. Now this as yet highest stage of consciousness begins a concentration or involution that will eventually bring it into complete unity, although without loss of personality in that collective hyper-personal. Then the consciousness of the universe, which will have evolved through man, will become eternally concentrated at the 'Omega point', free from the perishable planets and material trammels. The whole process is intended; it is the purpose of evolution, planned by the God who is also the Omega into which consciousness is finally to be concentrated. Mystical Christianity is to be the path or the vehicle to ecstatic union with Omega.

Teilhard's first sentence is as follows: 'If this book is to be properly understood, it must be read not as a work on metaphysics, still less as a sort of theological essay, but purely and simply as a scientific treatise.'

In the last chapter (before the epilogue, the postscript and the appendix) he wrote: 'Man will only continue to work and to research so long as he is prompted by a passionate interest. Now this interest is entirely dependent on the conviction, strictly undemonstrable to science, that the universe has a direction and that it could—indeed, if we are faithful, it should — result in some sort of irreversible perfection. Hence comes belief in progress.'

But the direction of evolution toward an irreversible perfection is the whole theme, and not merely a philosophical appendage, of the book. Hence we have a book submitted purely as a scientific treatise and yet devoted to a thesis admittedly undemonstrable scientifically.

Now it is easy enough to show that, although evolution is directional as historical process must always be, it is multidirectional; when all directions are taken into account, it is erratic and opportunistic. Obviously, since man exists, from the primordial cell to man was one of the directions, or rather a variety of them in succession, for there was no such sequence in a straight line and therefore literally orthogenetic. Teilhard was well aware of the consensus to that effect, but he brushed it aside and refused to grapple with it in terms of the detailed evidence.

Here we come to the real crux of the problem: which are the premises and which the conclusions? One may start from material evidence and from interpretative probabilities established by tests of hypotheses, that is, from science. Despite the objections of some philosophers and theologians, it is then legitimate to proceed logically from premises to conclusions about the nature of man, of life or the universe, even if these conclusions go beyond the realm of science in the strictest sense, and that is not only legitimate but also necessary if science is to have value beyond serving as a base for technology. On the other hand, one may start from premises of pure faith, non-material and non-testable, therefore non-scientific, and proceed to conclusions in the same field of the nature of the material cosmos. It cannot be argued that this approach from metaphysical or religious premises is *ipso facto* illegitimate. It is, however, proper to insist that its conclusions should not be presented as scientific, and that when they are materially testable they should be submitted to that scientific discipline. Gradual recognition of that necessity has been evident in the historical change in the relationships between science and religions.

This book provides a fascinating glimpse into the mind of a great soul, a kindly man and a subtle mystic. It may prove to be psychologically and historically important if, as is quite possible, it eventuates in a new religious cult of mystical evolutionism. It may do good (but could conceivably do harm) in forcing theologians to face the fact of evolution more squarely. Despite its own claims and those of some of its sponsors and reviewers, it should not be taken either as a scientific treatise on evolution or as a derivation of religious conclusions from scientific premises.

VLADIMIR I. VERNADSKY

SCIENTIFIC THOUGHT AS A PLANETARY PHENOMENON

Incessantly, during all of geological time, the evolutionary process of the living matter embraced the whole biosphere and, in various ways, influenced (though less distinctly) its inert natural bodies. This alone allows us and makes us speak about the evolutionary process of the biosphere itself taking place in the inert mass of its abiotic and live natural bodies, evidently changing within the course of geological time.

Owing to species evolution, which proceeds incessantly and never stops, the reflection of living matter into the environment changes abruptly. Because of it, the process of evolution (alteration) is transferred over the natural big-inert and biogenic bodies playing the most important part in the biosphere; among them are such bodies as soils, surface and ground water (seas, lakes, rivers, etc.), coal, bitumens, limestones, organogenic ores, etc. For example, Devonian soils and rivers are not the same as the soils and rivers of the Tertiary or of our epoch. This is an area of new phenomena hardly taken into account by scientific thought. The evolution of species turns into the evolution of the biosphere.

The evolutionary process acquires a special geological significance because it has created a new geological force: the scientific thought of social humanity. Now we witness its manifest entering the geological history of our planet. During recent millennia, one observes an intense growth of influence of the living matter of one species (civilised humanity) upon the shift of the biosphere condition. Under the action of scientific thought and human labour, the biosphere goes over to a new state—to the noosphere.

Due to regular movement, which lasted one to two million years (at a rate constantly accelerating in its manifestations), humanity embraces the whole planet and becomes separated (isolated) from other living organisms as a new and unprecedented geological force. In this way, at a rate comparable with that of reproduction, which is expressed by a geometric progression with time, an incessantly growing set of new (for the biosphere) inert natural bodies and great new natural phenomena are created in the biosphere.

Before our eyes, the biosphere changes sharply. And there can hardly be any doubt that its reconstruction (which is being manifested in this way by scientific thought, through organised human labour) is not an occasional phenomenon depending upon the will of man, but an elementary natural process whose roots are deep and were prepared by an evolutionary process which has lasted for hundreds of millions of years.

When man is guided by a scientific (neither philosophical nor religious) concept of the world, he ought to understand that he is not an incidental, independent from the surrounding world—the biosphere or the noosphere—as a freely acting natural phenomenon. He is an inevitable manifestation of a great natural process having lasted in a regular way for at least two billion years.

At present, under the influence of the surrounding horrors of life, we often hear about the downfall of civilisation, about the self-destruction of humanity, and that along with an unprecedented blossoming of scientific thought. These attitudes and these judgements seem to be a consequence of an insufficiently deep penetration into the surrounding world. Scientific thought is not yet embodied in life; we live under the influence of philosophical and religious habits still persisting but irrelevant to present-day realities.

Scientific knowledge, manifesting itself as a geological force creating the noosphere, cannot lead to results contradicting the geological process that created it. It is not an incidental phenomenon: it is very deeply rooted.

This process is tied up with the origin of the human brain. In science history, this process was discovered (in the form of an empiric generalisation) by the profound American naturalist, eminent geologist, palaeontologist and mineralogist J.D.Dana (1813–1895) in New Haven. He published his conclusions as long as eighty years ago. Strangely enough, this generalisation still remains unrealised and rather forgotten. It was not appropriately developed. I shall speak about this later. Here, I may note that Dana presented his generalisation in a philosophical and theological language, and that it seemed to be tied up with now inadmissible (scientific) ideas.

THE BIOSPHERE AND THE NOOSPHERE

We are approaching the climax in the Second World War. In Europe, war was resumed in 1939 after an intermission of twenty-one years; it has lasted five years in Western Europe and is in its third year in our parts, in Eastern Europe. As for the Far East, the war was resumed there much earlier, in 1931, and is already in its twelfth year. A war of such power, duration and strength is a phenomenon unparalleled in the history of mankind and of the biosphere at large. Moreover, it was preceded by the First World War, which, although of lesser power, has a causal connection with the present war.

In our country, that First World War resulted in a new, historically unprecedented, form of statehood, not only in the realm of economics, but likewise in that of the aspirations of nationalities. From the point of view of the naturalist (and, I think, likewise from that of the historian) a historical phenomenon of such power may and should be examined as a part of a single great terrestrial geological process, and not merely as a historical process.

In my own scientific work, the First World War was reflected in a most decisive way. It radically changed my geological conception of the world. It is in the atmosphere of that war that I have approached a conception of nature, at that time forgotten and thus new for myself and for others, a geochemical and biogeochemical conception embracing both inert and living nature from the same point of view. I spent the years of the First World War in my uninterrupted scientific creative work, which I have so far continued steadily in the same direction.

Twenty-eight years ago, in 1915, a ‘Commission for the Study of Productive Forces’ of our country, the so-called KEPS, was formed at the Academy of Sciences. That commission, of which I was elected president, played a noticeable role in the critical period of the First World War. Entirely unexpectedly, in the midst of the war, it became clear to the Academy of Sciences that in tsarist Russia there were no precise data concerning so-called strategic raw materials, and we had to collect and digest dispersed data rapidly to make up for the lacunae in our knowledge. Unfortunately, by the time of the beginning of the Second World War, only the most bureaucratic part of that commission, the so-called Council of Productive Forces, was preserved, and it became necessary to restore its other parts in a hurry.

By approaching the study of geological phenomena from a geochemical and biogeochemical point of view, we may comprehend the whole of circumambient nature in the same atomic aspect. Unconsciously, such an approach coincides for me with what characterises the science of the twentieth century and distinguishes it from that of past centuries. The twentieth century is the century of scientific atomism.

At that time, in 1917–18, I happened to be, entirely by chance, in the Ukraine, and was unable to return to Petrograd until 1921. During all those years, wherever I resided, my thoughts were directed towards geochemical and biogeochemical manifestations in circumambient nature, the biosphere. While observing them, I simultaneously directed both my reading and my reflection towards this subject in an intensive and systematic way. I expounded the conclusions arrived at gradually, as they were formed, through lectures and reports delivered in whatever city I happened to stay, in Yalta, Poltava, Kiev, Simferopol, Novorossiysk, Rostov, and so on. Besides, in almost every city I stayed, I used to read everything available in regard to the problem in its broadest sense. I left aside as much as I could all philosophical aspirations and tried to rest only on firmly established scientific and empirical facts and generalisations, occasionally allowing myself to resort to working scientific hypotheses. Instead of the concept of 'life', I introduced that of 'living matter', which now seems to be firmly established in science. 'Living matter' is the totality of living organisms. It is but an empirical scientific generalisation of empirically indisputable facts known to all, observable easily and with precision. The concept of 'life' always steps outside the boundaries of the concept of 'living matter'; it enters the realm of philosophy, folklore, religion and the arts. All that is left outside the notion of 'living matter'.

In the course of geological time, living matter changes morphologically according to the laws of nature. The history of living matter expresses itself as a slow modification of the forms of living organisms, which genetically are uninterruptedly connected among themselves from generation to generation. This idea had been rising in scientific research through the ages, until in 1859, it received a solid foundation in the great achievements of Darwin (1809–1882) and Wallace (1822–1913). It was cast in the doctrine of the evolution of species of plants and animals, including man. The evolutionary process is a characteristic only of living matter. There are no manifestations of it in the inert matter of our planet. In the cryptozoic era the same minerals and rocks were being formed that are being formed now. The only exceptions are the big-inert natural bodies connected in one way or another with living matter.

The change in the morphological structure of living matter observed in the process of evolution leads unavoidably to a change in its chemical composition.

While the quantity of living matter is negligible in relation to the inert and big-inert mass of the biosphere, biogenic rocks constitute a large part of its mass and go far beyond the boundaries of the biosphere. Subject to the phenomena of metamorphism, they are converted, losing all traces of life, into the granitic envelope and are no longer part of the biosphere. The granitic envelope of the Earth is the area of former biospheres. In Lamarck's book *Hydrogéologie* (1802), containing many remarkable ideas, living matter, as I understand it, was revealed as the creator of the main rocks of our planet. Lamarck never accepted Lavoisier's (1743– 1794) discovery. But that other great chemist, J.B.Dumas (1800–1884), Lamarck's younger contemporary, who did accept Lavoisier's discovery, and who studied intensively the chemistry of living matter, likewise adhered for a long time to the notion of the quantitative importance of living matter in the structure of the rocks of the biosphere.

The younger contemporaries of Darwin, J.D.Dana (1813–1895) and J.Le Conte (1823–1901), both great American geologists (and Dana, mineralogist and biologist as well), expounded, even prior to 1859, the empirical generalisation that the evolution of living matter is proceeding in a definite direction. This phenomenon was called by Dana 'cephalisation' and by Le Conte the 'psychozoic era'. Dana, like Darwin, adopted this idea at the time of his journey around the world, which he started in 1838, two years after Darwin's return to London, and which lasted until 1842.

Empirical notions of a definite direction of the evolutionary process, without, however, any attempt theoretically to ground them, go deeper into the eighteenth century. Buffon (1707–1788) spoke of the 'realm of man', because of the geological importance of man. The idea of evolution was alien to him. It was likewise alien to Agassiz (1807–1873), who introduced the idea of the glacial period into science. Agassiz lived in a period of an impetuous blossoming of geology. He admitted that geologically the realm of man had come, but, because of his theological tenets, opposed the theory of evolution. Le Conte pointed out that Dana, formerly having a point of view close to that of Agassiz, in the last years of his life accepted the idea of evolution in its then usual Darwinian interpretation. The difference between Le Conte's 'psychozoic era' and Dana's 'cephalisation' thus disappeared. It is to be regretted that, especially in our country, this important empirical generalisation still remains outside the horizon of our biologists.

The soundness of Dana's principle, which happens to be outside the horizon of our palaeontologists, may easily be verified by anyone willing to do so on the basis of any modern treatise on palaeontology. The principle not only embraces the whole animal kingdom but likewise reveals itself clearly in individual types of animal. Dana pointed out that in the course of geological time, at least two billion years and probably much more, there occurs an irregular process of growth and perfection of the central nervous system, beginning with the crustacea (whose study Dana used to establish his principle), the molluscs (cephalopoda), and ending with man. It is this phenomenon that he called cephalisation. The brain, which has once achieved a certain level in the process of evolution, is not subject to retrogression but can only progress further.

Proceeding from the notion of the geological role of man, the geologist A.P.Pavlov (1854–1929) in the last years of his life used to speak of the anthropogenic era in which we now live. While he did not take into the account the possibility of the destruction of spiritual and material values we now witness in the barbaric invasion of the Germans and their allies slightly more than ten years after his death, he rightly emphasised that man, under our very eyes, is becoming a mighty and ever-growing geological force. This geological force was formed quite imperceptibly over a long period of time. A change in man's position on our planet (his material position first of all) coincided with it. In the twentieth century, man, for the first time in the history of the Earth, knew and embraced the whole biosphere, completed the geographic map of the planet Earth, and colonised its whole surface. Mankind became a single totality in the life of the Earth. There is no spot on Earth where man cannot live if he so desires. Our people's sojourn on the floating ice of the North Pole in 1937–38 has proved this clearly. At the same time, owing to the mighty techniques and successes of scientific thought, radio and television, man is able to speak instantly to anyone he wishes at any point on our planet. Transportation by air has reached a speed of several hundred kilometres per hour, and has not reached its maximum. All this is the result of 'cephalisation,' the growth of man's brain and the work directed by his brain.

The economist L.Brentano illuminated the planetary significance of this phenomenon with the following striking computation: if a square metre was assigned to each man, and if all men were put close to one another, they would not occupy the area of even the small Lake of Constance between the borders of Bavaria and Switzerland. The remainder of the Earth's surface would remain empty of man. Thus the whole of mankind put together represents an insignificant mass of the planet's matter. Its strength is derived not from its matter, but from its brain. If man understands this, and does not use his brain and his work for self-destruction, an immense future is open before him in the geological history of the biosphere.

The geological evolutionary process shows the biological unity and equality of all men, *Homo sapiens* and his ancestors, *Sinanthropus* and others; their progeny in the mixed white, red, yellow and black races evolves ceaselessly in innumerable generations. This is a law of nature. In a historical contest, as for instance in a war of such magnitude as the present one, he finally wins who follows that law. One cannot oppose with impunity the principle of the unity of all men as a law of nature. I use here the phrase 'law of nature' because this term is used more and more in the physical and chemical sciences, in the sense of an empirical generalisation established with precision.

The historical process is being radically changed under our very eyes. For the first time in the history of mankind the interests of the masses on the one hand, and the free thought of individuals on the other, determine the course of life of mankind and provide standards for men's ideas of justice. Mankind taken as a whole is becoming a mighty geological force. There arises the problem of the reconstruction of the biosphere in the interests of freely thinking humanity as a single totality. This new state of the biosphere, which we approach without our noticing it, is the noosphere.

In my lecture at the Sorbonne in Paris in 1922–23, I accepted biogeochemical phenomena as the basis of the biosphere. The contents of part of these lectures were published in my book *Studies in Geochemistry,* which appeared first in French, in 1924, and then in a Russian translation, in 1927. The French mathematician Le Roy, a Bergsonian philosopher, accepted the biogeochemical foundation of the biosphere as a starting point, and in his lectures at the Collège de France in Paris, introduced in 1927 the concept of the noosphere as the stage through which the biosphere is now passing geologically (Le Roy 1927:196). He emphasised that he arrived at such a notion in collaboration with his friend Teilhard de Chardin, a great geologist and palaeontologist, now working in China.

The noosphere is a new geological phenomenon on our planet. In it for the first time man becomes a large-scale geological force. He can and must rebuild the province of his life by his world and thought, rebuild it radically in comparison with the past. Wider and wider creative possibilities open before him. It may be that the generation of our grandchildren will approach their blossoming.

Here a new riddle has arisen before us. Thought is not a form of energy. How then can it change material processes? That question has not as yet been solved. As far as I know, it was first posed by an American scientist born in Lvov, the mathematician and biophysicist Alfred Lotka (1925:405). But he was unable to solve it. As Goethe (1740–1832), not only a great poet but a great scientist as well, once rightly remarked, in science we can know only how something occurred, but we cannot know why it occurred.

As for the coming of the noosphere, we see around us at every step the empirical results of that 'incomprehensible' process. That mineralogical rarity, native iron, is now being produced by the billions of tons. Native aluminium, which never before existed on our planet, is now produced in any quantity. The same is true with regard to the countless number of artificial chemical combinations (biogenic 'cultural' minerals) newly created on our planet. The number of such artificial minerals is constantly increasing. All of the strategic raw materials belong here. Chemically, the face of our planet, the biosphere, is being sharply changed by man, consciously, and even more so, unconsciously. The aerial envelope of the land as well as all its natural waters are changed both physically and chemically by man. In the twentieth century, as a result of the growth of human civilisation, the seas and the parts of the oceans closest to shore become changed more and more markedly. Man now must take more and more measures to preserve for future generations the wealth of the seas, which so far have belonged to nobody. Besides this, new species and races of animals and plants are being created by man. Fairy-tale dreams appear possible in the future: man is striving to emerge beyond the boundaries of his planet into cosmic space. And he probably will do so.

At present we cannot afford not to realise that, in the great historical tragedy through which we live, we have elementally chosen the right path leading into the noosphere. I say elementally, as the whole history of mankind is proceeding in this direction. The historians and political leaders only begin to approach a comprehension of the phenomena of nature from this point of view. The approach of Winston Churchill (1932:274) to the problem, from the angle of a historian and political leader, is very interesting.

The noosphere is the last of many stages in the evolution of the biosphere in geological history. The course of this evolution only begins to become clear to us through a study of some of the aspects of the biosphere's geological past. Let me cite a few examples. Five hundred million years ago, in the Cambrian geological era, skeletal formations of animals, rich in calcium, appeared for the first time in the biosphere: those of plants appeared over two billion years ago. That calcium function of living matter, now powerfully developed, was one of the most important evolutionary factors in the geological change of the biosphere. A no less important change in the biosphere occurred from 70 to 110 million years ago, at the time of the Cretaceous system, and especially during the Tertiary. It was in this epoch that our green forests, which we cherish so much, were formed for the first time. This is another great evolutionary stadium, analogous to the noosphere. It was probably in these forests that man appeared, around fifteen or twenty million years ago.

Now we live in the period of a new geological evolutionary change in the biosphere. We are entering the noosphere. This new elemental geological process is taking place at a stormy time, in the epoch of a destructive world war. But the important fact is that our democratic ideals are in tune with the elemental geological processes, with the laws of nature, and with the noosphere. Therefore we may face the future with confidence. It is in our hands. We will not let it go.

4

PARALLELS: GAIA AND GLOBAL CHANGE

Some parallels between the ideas of the noosphere and biosphere and current environmental themes and issues (e.g. global ecology) have been touched upon above. While other parallels could fruitfully be sought out, this chapter selects two of the most widely, and often hotly, debated: Gaia and global change. As the paragraphs below describe, Gaia shares much in common with the concept of the biosphere, and the concept of global change shares much with the concept of the noosphere. There are some striking parallels with current thought, especially to the use given to these concepts by Vernadsky.

Gaia can be seen as representing an extended view of the biosphere—a sort of ultimate global ecological perspective that stresses the interwoven and inseparable character of living and non-living matter across the planet. Importantly, this perspective suggests that humans are very much part of these global processes, but also that we are neither central nor indispensable to their continuation. In other words, humans do not really make much of a difference to the larger Gaian process; we could pollute ourselves to the point of extinction and Gaia would continue happily without us (although debate continues over whether or not Gaia itself could potentially be fatally disrupted by human pollution). The Gaian perspective is decidedly ecocentric, but the degree to which this is so varies across groups. In many respects, global change is the opposite of Gaia: it is a human-centric view that sees humans as central and even as obliged protectors of the planet. It holds a similar view of biospheric processes and global ecology—in so far as it is not reductionist—but it sees the fate of the planet (for better or for worse) very much in human hands. In other words, the choices that society makes will have an enormous impact on the future development, even survival, of life on Earth. In this sense, the global change school more faithfully reflects the noosphere ideas, where there is an emphasis on human responsibilities, actions and choices.

THE GAIA HYPOTHESIS

James Lovelock, a respected British scientist, along with American microbiologist Lynn Margulis, launched the 'Gaia hypothesis' in the early 1970s (Lovelock 1972; Margulis and Lovelock 1976). The hypothesis, partially resulting from Lovelock's assertion that Mars' atmosphere proved it was a dead planet, proposes that the Earth—taken as whole—functions in a way akin to a living organism. Each part of the Earth is interdependently linked in the task of keeping natural systems relatively stable in the hydrosphere, the lithosphere, the biosphere and so on. The evolution of living and non-living matter is part of a global,

Box 4.1 The Gaia hypothesis

Developed by James Lovelock and Lynn Margulis, Gaia is named after the Greek Earth goddess. Gaia is a metaphor for the proposition that the Earth is a single, self-sustaining and regulating entity—a super-organism—in which biota, rocks and air and oceans are tightly coupled. Over billion of years, plant and animal life has acted as a carbon sink to create a balanced environment suited for life (e.g. the level of oxygen in the atmosphere), which would not otherwise exist. Although Gaia is seen as teleological or untestable by its critics, it offers an altenative vision of the world that has found enormous resonance among the general public as well as with many Earth systems scientists.

holistic and co-evolutionary process in which the quantity and diversity of life are sufficient to regulate the total system. In other words, the whole planet operates in a manner that maintains stable conditions for the continuation of life over hundreds of millions of years. Lovelock (1979:11) has defined Gaia 'as a complex entity involving the Earth's biosphere, atmosphere, oceans, and soil; the totality constituting a feedback or cybernetic system which seeks an optimal physical and chemical environment for life on this planet.' This environment is maintained through 'the maintenance of relatively constant conditions by active control', known as 'homeostasis'. Homeostasis is the Earth's capacity to control its chemical composition and maintain a balanced temperature even as its environment changes dynamically. Lovelock (1988) provided a simple yet powerful 'Daisy world' model to explain this dynamic. Such a system is sometimes described as 'autopoietic': A unity and a network of processes of production, transformation and destruction that through their interactions and transformations are self-reproducing and internally complete (Maturana and Varela 1980).

The ecological principle that 'the interplay of material cycles and energy flows in large ecosystems generates a self-correcting homeostasis with no outside control or set point required' (Odum 1959:35) is long-established, as is the physiological idea of 'homeostasis'—a balance of nature—at the organism level (Cannon 1932). However, many scientists are uncomfortable with the idea that the entire planet is capable of some form of 'directed control' beyond these mechanisms. Others are concerned that Gaia cannot be tested as a scientific hypothesis because there are no other such planets to compare with (see Schneider and Boston 1991). The issue of how such a 'control' system could operate is the main issue of debate. Lovelock denies that there is any mystical element to his hypothesis, despite his use of the metaphor Gaia (the Greek goddess of the Earth). For this reason, he also refers to the same processes as 'geophysiology', using strictly scientific terms (Lovelock 1991).

The idea that the Earth is a living organism—at least in a limited sense—is ancient, and one only needs to look at the history of various indigenous peoples around the world to find such models. Within the context of modern science the idea is much more recent, and it is probably reasonable to trace its origins to the period, if not the work, of the Scottish physician James Hutton. As early as 1795, Hutton (1972:286, 573) discussed his ideas about the 'physiology of this globe'. However, the general notions behind geophysiology and its similarity with the human system are older, as evidenced by von Lewenhiemb's drawing (Figure 4.1).

In the twentieth century, Lawrence J.Henderson (1913) made a determinist argument for geophysiology in which Lovelock surely would have recognised his work, had he known

Figure 4.1 Frontispiece to Sachs von Lewenheimb's *Oceanus Macro-Microcosmicus* (1664). The upper figure shows the circulation of water between Heaven and Earth and the lower the circulation of blood in humans. A parallel is drawn between the two systems

it. Indeed, before Lovelock presented his complete version of the Gaia hypothesis in 1979, many roads were headed in the same direction. Since first independently developing their ideas, both Lovelock and Margulis diligently recognised their debts to past thinkers. Lovelock credits Hutton as being the founder of the geophysiology idea, and both he and Margulis recognise Vernadsky as their 'most illustrious predecessor' (Lovelock 1986:51; Margulis *et al.* 1998:5), although in their earlier work the debt had not been acknowledged. Nonetheless, the number and depth of the parallels to Gaia has been a surprise. For example, Le Roy wrote the following in 1927:

> Almost 40 years ago, the Russian biologist Winogradsky discovered and made known a new factor in the structure of the biosphere, analogous, it seems, to an organ, an apparatus, to which corresponds— we can no longer doubt—a function of wholeness, of which the major role of importance must be linked with that which keeps the planet green. We are talking about autotrophic life, devoid of chlorophyll: bacteria

> (nitrifants and the like), who pollute the soil—in the superficial or even semi-profound parts of the surface and which also penetrate to significant depths of the ocean. These are micro-organisms. Nonetheless, despite their extremely small size, and due to their prodigious power of multiplication, they accomplish incredible geochemical work. Their activity is one of the principal factors in the terrestrial histories of carbon, sulphur, nitrogen, iron, magnesium and probably lots of other elements of our globe.
>
> (p. 170)

Not only does Le Roy's passage provide insight on the interconnectivity of life, he also draws attention to the primordial importance of micro-organisms in the global, geochemical processes. This foreshadows some of Lovelock's ideas, but equal in significance, it provides a precedent to the ideas of Lynn Margulis, who has emphasised the fundamental contributions of micro-organisms in Gaia (Margulis 1981).

David Abram (1985:96) offers the following: The Gaia hypothesis, if taken seriously, has logical implications that call into question the mechanical model of perception upon which most contemporary scientific discourse is based. These implications reach beyond the separate sciences and begin to influence our ordinary perceptual experience.' For Lovelock (1979:10), Gaia stresses a different sense of the Earth being alive—more like 'a biological construction: not living, but like a cat's fur, a bird's feathers, or the paper of a wasp's nest, an extension of a living system designed to maintain a chosen environment.' From a different angle, Margulis and Sagan (1997:18) articulate the notion of interconnectedness with their emphasis on the key role of microbes (namely bacteria) in the evolution of life, asserting that such a perspective 'is a highly useful, even essential compensation required to balance the traditional anthropocentric view which flatters humanity in an unthinking, inappropriate way.' This suggests that by seeing our human reflection in nature's mirror, we may better realise our own place in the world.

The Gaia hypothesis has made inroads towards scientific acceptability. It has become part of the wider scientific debate on global environmental change and related issues (as discussed below). Steven Schneider was instrumental in pursuing the idea seriously, which eventually led to the organisation of the 1988 Chapman Conference of the American Geophysical Union that debated the issue and published the arguments, for and against, in *Scientists on Gaia* (Schneider and Boston 1991). Following this meeting, Gaia received more serious consideration from the scientific community, such as biologists who investigate Gaia as an example of 'self-organised criticality' (e.g. Bak 1993). The number of books on Gaia by scientists continues to grow (e.g. Volk 1997).

In his careful tracing of the Gaia debate, Lawrence Joseph (1990:14) notes that 'regardless of its technical accuracy, many people find the idea of the living Earth spiritually compelling.' Indeed, often to the chagrin of Lovelock (who is generally a hard-nosed scientist), 'Gaia' has become one of the leading symbols of new age philosophy (e.g. Kelly 1994) and spirituality (Berry 1988), just as it has become a vehicle for a 'why worry?' argument about threats to the environment. Lovelock insists that he never intended to present anything other than science, simply choosing the name 'Gaia' as a shorthand description for a complex scientific idea. More reluctantly, partly because of his own direct involvement in the stratospheric ozone controversy, Lovelock (1988:212) has admitted that Gaia's ability to repair itself is not limitless and could potentially suffer as a result of human impacts. However, stated differently, the implications of Lovelock's concession points to the potential risk for humanity to destroy itself by temporarily damaging Gaia just enough to cause its own extinction. This ecocentric perspective contrasts sharply with the concept of noosphere as developed by Le Roy, Teilhard de Chardin and Vernadsky, which places humanity at the centre of both perspective and importance. This same view, treating *Homo sapiens* as no different from any other species, has endeared Gaia to the deep ecologists, who are strongly ecocentric and often see human society as a form of planetary cancer, and the eco-feminists, who see a female Gaia threatened by male values. There is an interesting parallel here to Shiva, the Hindu god of destruction and recreation. As Michael Rampino (1993) put it at the 1988 American Geophysical Union meeting: 'Do Shiva and Gaia represent a coupled and co-evolved system—the stability of one somehow dependent on disturbances caused by the other?'

Different uses of the concept of the noosphere provide disparate implications, even definitions, of Gaia. The underlying notion of 'irreversibility' found in Teilhard de Chardin's and Le Roy's writings would suggest that humanity's path has been predestined to escape any Earthly threat. In Teilhard de Chardin's view, this is because the path to the 'Omega point' (a universal convergence point of spirituality, beyond the noosphere) is predestined by the Creator. By contrast, Vernadsky's view of the noosphere would appear to be compatible with both the eventuality of unforeseen events (e.g. a comet impact) and the potential ability of *Homo sapiens* to soil its own nest. Such ideas were probably apparent to Vernadsky, who chaired the Soviet Meteorite Committee and was very interested in the Tunguska impact of 1908, which flattened 2,000 square kilometres of forest in Siberia with a bang that was heard as far away as London. Nonetheless, Vernadsky was an optimist and confident that humanity was on the right track, as indicated in his later writings, particularly the last one (1945). The idea of the noosphere as a global manifestation of mind may be combined with technological optimism, leading to the belief that in the long run, humanity can defend itself from any external threats posed by space debris or ecological damage. Moreover, libraries—real or virtual—are depositories of accumulated knowledge that potentially could out-survive the human species.

GLOBAL CHANGE

Parallels between the noosphere concept and the science/management of global change (also known as global environmental change) are more evident because an anthropocentric perspective —albeit of varying degrees—is taken as given. As noted above, Gaia makes no such claims. Nevertheless, despite its solid human base, global change writ large offers a range of perspectives on humanity's role in the biosphere. The science of global change offers insight into the natural interactions of the biosphere and, of equal importance, into society's impacts in that environment. Since uncertainty is inherent in such complex, non-linear systems, and even more tricky at such large scales, various scientific scenarios are available for 'management'. Responses to global change are therefore faced with the challenge of employing responses based on competing scientific claims coupled with social constructions on how best to manage. The result offers a spread of options, ranging from management science, to coping, to muddling through. As James Rosenau (1990:324) suggests, in the computer age, 'the science of muddling through may well give way to the science of *modeling* through.' In this way, global change may be viewed as a current form of the debate over what the noosphere *could* become as well as what it *should* become. Given uncertainty, the question may in fact be more normative than scientific. Finally, global change carries implications for the processes through which we identify problems, choose methodologies and extrapolate response strategies—suggesting a transdisciplinary approach. As Rau (1994:167) notes: 'To bring about such a basic transformation, the traditional dividing lines between politics, economics and social values need to be blurred and new paradigms of deliberation, participation and decision-making should be evolved.'

Box 4.2 Global change

Global change, or global environmental change, concerns alterations in environmental systems (e.g. the atmosphere) whose impacts cannot be localised. Such changes occur naturally, but the focus here is on anthropogenic (human-induced) change. Global change includes a whole host of issues, including global climate change, stratospheric ozone depletion, acidification of terrestrial and aquatic ecosystems, land degradation (including deforestation and desertification), and the pollution and toxification of air, water and soil. These categories include two types of change: globally systemic change, which occurs within a fluid worldwide physical system, and globally cumulative change, which reaches the global scale through the worldwide aggregation of more localised changes (Turner *et al.* 1990b: 16). Given their central human element, such environmental changes are tightly coupled with social systems and their manifestations such as population and economic growth, as well as beliefs and values.

The broad precedents of global change research and action are linked to early work on biogeochemical systems, as discussed in Chapter 1. A more specific starting point is in the origin of climate change research. In the 1890s, the Swedish scientist Svante Arrhenius, who later won a Nobel Prize for his work in chemistry, was an early scientist to popularise the greenhouse effect. Not only did he foresee potential warming at the global scale as a result of human activity, namely through carbon dioxide emissions, but he also made surprisingly accurate measurements. Although the basic science relating to climate change has been known since Arrhenius, this issue did not become salient, at least politically, until the late 1980s. Moreover, as Figure 4.2 shows, global climate change is a natural phenomenon that has been traced in some detail over periods going back several hundred thousand years—largely from ice-core samples. Such a long-term global perspective highlights the ubiquitous nature of change, but it also highlights the uniqueness of the industrialised era—a mere instant in geological time—in which we are transforming the atmosphere through human activity (e.g. Imbrie and Imbrie 1986). Could we be entering the 'greenhouse' era, a super-interglacial period with unprecedented (in 800,000 years) average global temperatures?

However, the large-scale chronology shown here masks many changes on a smaller time scale. Ice-core analysis in Greenland and Antarctica has revealed the occurrence of sudden changes in temperature even over a few years. The causes for this flipping of the climatic regime are not well-known, but they may include rapid changes in major ocean currents, stimulated by fluctuations in the oceanic conveyor belt, whereby water is circulated around the globe from the poles, changes in cloud cover, the El Niño phenomenon, changes in the planetary axis or orbit, solar activity, cometary impacts and other natural events, all of which are unpredictable. For a recent review of these issues see Calvin (1997).

Scientific networks such as the International Council of Scientific Unions (ICSU) began to establish the groundwork for global change through efforts after the 1968 Biosphere Conference (UNESCO 1970) with its Scientific Committee on Problems of the Environment (1969). But the term 'global change', closely linked to climate change, was not used until the early 1980s (Goody 1982) and did not emerge as a significant research programme until at least the end of the 1980s. Thomas Malone (Malone and Correll 1989:7), a leading scientist behind early global change initiatives, suggested five principal reasons for the emergence of this research agenda:

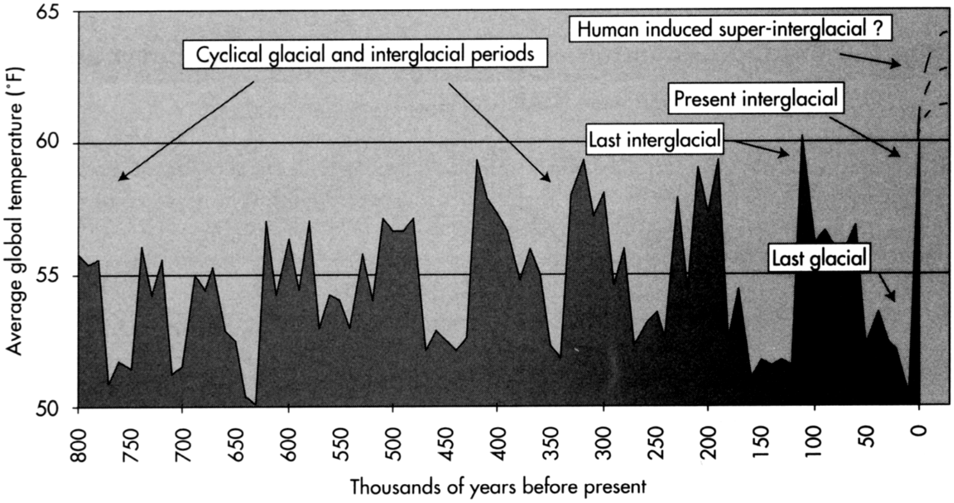

Figure 4.2 Global climate trends during the past 800,000 years (figure based on estimates)

1 The sciences are increasingly treating the physical and biogeochemical processes of the Earth as an integrated and responsive whole;
2 Scientific understanding of each component and their interaction is reaching a sufficient level of quantification;
3 Scientific technology (computers, space-based measurements and communications) is providing the tools necessary for a holistic understanding of the planet's systems, enhancing the ability for prediction;
4 Exponential growth in human population, agriculture and industry is becoming a powerful factor in global environmental change; and
5 An exponentially expanding civilisation is likely to surpass the capacity of the global life-support system and lead to collapse.

By the late 1980s, 'global environmental change' had emerged as an umbrella term. The science of global change continues to grow through a plethora of scientific programmes. Through the International Geosphere-Biosphere Programme (see Box 4.3) and other research efforts, the network of scientists has expanded to become broadly international in scope. Following on the heels of the programmes in the natural sciences, several initiatives were launched at the international and national levels to examine the 'human dimensions' of global environmental change. A clear illustration of the speed of this emergence is demonstrated by the level of funding for global environmental change research in the United States. Little over a decade ago, very few people had ever heard of global environmental change except for a small, dedicated group of Earth systems scientists. In 1995, for example, the United States had an annual research budget of approximately $1.8 billion for its global environmental change research programme. Teilhard de Chardin was optimistic at the very beginnings of these programmes. Just prior to his death in 1955, he believed that the International Geophysical Year (1957–58) would mark 'year one of the noosphere' (1962:355). Efforts by the World Meteorological Organization (WMO) together with the United Nations Environment Programme (UNEP) and countless non-governmental organisations (NGOs) reflect similar trends in the same direction.

***Box 4.3* Examples of international programmes for global change**

Man and the Biosphere Programme (MAB, UNESCO)
Launched in 1971 to promote the rational use and conservation of the resources of the biosphere, for the improvement of the global relationship between people and the environment. Activities are in more than 100 countries, including a network of more than 330 'biosphere reserves' in 85 countries.

International Geosphere-Biosphere Programme (IGBP, ICSU)
Launched in 1986 to create an international, holistic and interdisciplinary framework for the conduct of global change science. In 1997, 76 national science programmes cooperated to set priorities, to establish consistency in methodology, and to achieve compatibility of the resulting data.

Introducing the 1989 special issue of *Scientific American* entitled 'Managing Planet Earth', William C.Clark framed the issue of human development in terms of 'opportunities and constraints'. As he noted, 'the same wellsprings of human inventiveness and energy that are so transforming the Earth have also given us an unprecedented understanding of how the planet works, how our present activities threaten its workings and how we can intervene to improve the prospects for its sustainable development.' This implies the need for a 'self-conscious, intelligent management of the Earth' but poses two deeply intertwined questions: 'What kind of planet do we want?' and 'What kind of planet can we get?' (Clark 1990:1–2). This second question is directly related to human understanding of the science of the biosphere and the first to a choice of values.

One way of addressing this value issue has emerged under the rubric of 'sustainable development'. While sustainable development is tied to physical aspects (presumably drawing from the science of the biosphere), it is also a key vehicle for determining value choices related to issues of security, equity and fairness for present and future generations. As the World Commission on Environment and Development (1987:43) defines it, sustainable development consists of practices designed 'to meet the needs of the present without compromising the ability of future generations to meet their own needs.' Of course, if the 'needs of the present' cannot be met, another set of issues arises. Global change and sustainable development can be viewed as important components of the noosphere. For example, taken together, Clark's two questions become a single noospheric one: how do we employ this combined set of knowledge?

GLOBALISATION

Parallel to the global conceptions of the physical and natural scientists has been the emergence of the discipline of 'globalisation' among social scientists. Martin Albrow (1996) has referred to globalisation as a process whereby everyone on the planet is involved in a single system (Beck 1997). Anthony Giddens (1990:64) views globalisation as 'the intensification of worldwide social relationships which link distant localities in such a way that local happenings are shaped by events occurring many miles away *and* vice versa.' A similar trend can be noted in physical relationships. Immanuel Wallerstein has long traced the evolution of the world system based on trade and capitalism (1974), in which globalisation has led to the embracing of a form of 'geoculture' (1991), as well as a compression of time and space (Allen and Hamnett 1995). The emergence of common values relating to such issues as politics and human rights, as well as an all-embracing information and communications network, can be seen to take us far beyond McLuhan's notion of the global village.

In a globalised world, tourism and travel (as forms of 'transaction') become the biggest industry and the Internet as ubiquitous as the telephone was to previous generations. Yet increasing contact creates a host of new problems—such as the spread of AIDS—without necessarily solving old ones such as war and conflict, which may instead escalate. Studies of globalisation have become a growth industry in the social sciences, and some two hundred books on the subject have been written in the last ten years. Globalisation concepts have many parallels to the ideas of the noosphere. First, both represent artefacts of the mind essentially involving a massive and emergent network of contacts. Both involve central—indeed simplified concepts—conspicuous Veblenian-like consumption of latter-day capitalism on the one hand and processes moving towards the 'Omega point' (at least for the Teilhardian school) on the other. Beyond these, the similarities disappear, especially as noosphere thinkers seek spiritual or moral solutions while the forces of globalisation are seen to be blind.

Neither the noosphere nor globalisation address the essential tasks of policing the global environment in the face of *laissez-faire,* even egotistical, elements, which have run amok in the economy (Aga Khan 1998) and ignored the grassroots (Pitt 1976). The fundamental point remains, whatever global change there is, that the primary social processes take place at the grassroots (or 'local' level), where humans are involved in the daily activities of providing food and shelter and bringing up families. Noospheric ideas have striking parallels with the many indigenous philosophical beliefs of the 6,000 or more tribal subcultures—survivors from the estimated half million cultures of the Palaeolithic—which often have a world view deeply imbued with spirituality and balance with nature. In the modern world, the number of subcultures has proliferated despite—perhaps because of—global communications networks. These subcultures, more than the tribal world, have distinctive mentalities that have had major influences on global thinking—for example, introducing gender perspectives (Massey 1994).

Returning to the discussion about Gaia, we find a similar range of interpretations and consequences. Gaia, as a homeostatic or self-sustaining system, contrasts with the idea of the noosphere as a form of control system where human knowledge and technology are controlled by the human mind and the conscious direction of events. O'Riordan's study of environmentalism (1981) identifies a similar contrast in what he calls 'ecocentric' and 'technocentric'. Similarly, Cotgrove (1982) identifies 'cornucopians' and 'catastrophists'. Lovelock (1979:12) sees Gaia as 'an alternative to that pessimistic view which sees nature as a primitive force to be subdued and conquered.' Vernadsky acknowledged the limits to the optimist's view, if less clearly, in a similar way to that in which Clark (1990:1–2) described 'managing' the planet: 'It is as a global species that we are transforming the planet. It is only as a global species — pooling our knowledge, coordinating our actions and sharing what the planet has to offer — that we have any chance of managing the planet's transformation along pathways of sustainable development.' This offers the potential for management, but management as much in the sense of an art as a science. Contrasting Lovelock and Vernadsky, Rafal Serafin (1988:137) proposes that: 'Taken together as parts of a larger whole, Gaia and noosphere can help distinguish what we do understand from what we do not about humanity's ability to conduct its activities on our planet so as to ensure the survival of our own species, as well as that of the biosphere.' Such a frame is likely to be increasingly useful and necessary.

JAMES HUTTON

James Hutton (1726–1797), a Scottish geologist, chemist and natutalist, was the first to develop uniformitarianism, a theory that views the development of the Earth's surface in terms of natural and generally uniform processes over long periods of geological time. Hutton effectively promoted this theory, a minority one at the time, through a series of confidential works and, finally, in his best-known work, *Theory of the Earth* (1795). Hutton's thesis was very significant in the development of modern geology, but it also laid an important foundation for a scientifically based claim that the Earth functions as a living system—the Gaia hypothesis, or geophysiology, as developed by James Lovelock.

THEORY OF THE EARTH

This globe of the Earth is a habitable world; and on its fitness for this purpose, our sense of wisdom in its formation must depend. To judge this point, we must keep in view, not only the end, but also the means by which that end is obtained. These are the form of the whole, the materials of which it is composed, and the several powers which concur, counteract or balance one another in procuring the general result.

We have now considered the globe of this Earth as a machine, constructed upon chemical as well as mechanical principles, by which its different parts are all adapted, in form, in quality and in quantity, to a certain end; an end attained with certainty or success; and an end from which we may perceive wisdom, in contemplating the means employed.

But is this world to be considered thus merely as a machine, to last no longer than its parts retain their perfect position, their proper forms and qualities? Or may it not be also considered as an organised body, such as has a constitution in which the necessary decay of the machine is naturally repaired, in the exertion of those productive powers by which it had been formed?

This is the view in which we are now to examine the globe; to see if there be, in the constitution of this world, a reproductive operation, by which a ruined constitution may be again repaired, and a duration or stability thus procured to the machine, considered as a world sustaining plants and animals.

If no such reproductive power, or reforming operation, after due inquiry, is to be found in the constitution of this world, we would have reason to conclude that the system of this Earth has either been intentionally made imperfect, or has not been the work of infinite power and wisdom.

Here is an important question, therefore, with regard to the constitution of this globe; a question which, perhaps, it is in the power of man's capacity to resolve; and a question which, if satisfactorily resolved, might add some lustre to science and the human intellect.

In what follows, therefore, we are to examine the constitution of the present Earth, in order to understand the natural operations of time past; to acquire principles, by which we may conclude with regard to the future course of things, or judge of those operations, by which a world, so wisely ordered goes into decay; and to learn by what means such a decayed world may be renovated, or the waste of habitable land upon the globe repaired.

We live in a world where order everywhere prevails; and where final causes are as well known, at least, as those which are efficient. The muscles, for example, in my fingers when I write are no more the efficient cause of that motion than this motion is the final cause for which the muscles had been made. Thus, the circulation of the blood is the efficient cause of life; but, life is the final cause not only for the circulation of the blood, but for the revolution of the globe: without a central luminary, and a revolution of the planetary body, there could not have been a living creature upon the face of this Earth; and, while we see a living system on this Earth, we must acknowledge that in the Solar System we see a final cause.

SVANTE ARRHENIUS

Svante Arrhenius (1859–1927), a Swedish physical chemist best-known for his work on electrolytes, was awarded the Nobel Prize in chemistry in 1903. He was interested in a wide variety of scientific questions, including the influence of varying levels of carbonic acid (carbon dioxide or CO2) in the atmosphere caused by factors including human activities. The paper presented below, written in 1896, was the first to calculate the potential effects of this gas and suggest that their growing influence could lead to human-induced global warming. Almost a century later, as climate change arrived on the political agenda, many scientists and others were amazed to discover the relative accuracy and relevance of Arrhenius' findings.

ON THE INFLUENCE OF CARBONIC ACID

A great deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, which has long attracted the attention of physicists, is this: is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier maintained that the atmosphere acts like the glass of a hothouse because it lets through the light rays of the Sun but retains the dark rays from the ground. This idea was elaborated by Pouillet; and Langley was by some of his researches led to the view that 'the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200 °C, if that atmosphere did not possess the quality of selective absorption.' This view, which was founded on too wide a use of Newton's law of cooling, must be abandoned, as Langley showed himself in a later memoir.

The air retains heat (light or dark) in two different ways. On the one hand, the heat suffers a selective diffusion on its passage through the air; on the other hand, some of the atmospheric gases absorb considerable quantities of heat. These two actions are very different. The selective diffusion is extraordinarily great for the ultraviolet rays, and diminishes continuously with increasing wavelength of the light, so that it is insensible to the rays that form the chief part of the radiation from a body of the mean temperature of the Earth.

The selective absorption of the atmosphere is, according to the researches of Tyndall, Lecher and Pernter, Röntgen, Heine, Langley, Ångström, Paschen, and others, of a wholly different kind. It is not exerted by the chief mass of the air, but in a high degree by aqueous vapour and carbonic acid, which are present in the air in small quantities. Further, this absorption is not continuous over the whole spectrum but nearly insensible in the light part of it, and chiefly limited to the longwave part, where it manifests itself in very well-defined absorption bands, which fall off rapidly on both sides. The influence of this absorption is comparatively small on the heat from the Sun but must be of great importance in the transmission of rays from the Earth. Tyndall held the opinion that the water vapour has the greatest influence, while other authors, for instance Lecher and Pernter, are inclined to think that the carbonic acid plays the more important part. The researches of Paschen show that these traces are both very effective, so that probably sometimes the one, sometimes the other, may have the greater effect according to the circumstances.

Thus if the quantity of carbonic acid increases in geometric progression, the augmentation of the temperature will increase nearly in arithmetic progression. This rule — which naturally holds good only in the part investigated—will be useful for the following summary estimations.

I should certainly not have undertaken these tedious calculations if an extraordinary interest had not been connected with them. In the Physical Society of Stockholm there have been occasionally very lively discussions on the probable causes of the Ice Age; and these discussions have, in my opinion, led to the conclusion that there exists as yet no satisfactory hypothesis that could explain how the climatic conditions for an ice age could be realised in so short a time as that which has elapsed from the days of the glacial epoch. The common view hitherto has been that the Earth has cooled in the lapse of time; and if one did not know that the reverse has been the case, one would certainly assert that this cooling must go on continuously. Conversations with my friend and colleague Professor Högbom, together with the discussions above referred to, led me to make a preliminary estimate of the probable effect of a variation of the atmospheric carbonic acid on the temperature of the Earth. As this estimation led to the belief that one might in this way probably find an explanation for temperature variations of 5–10 °C, I worked out the calculation in more detail, and lay it now before the public and the critics.

From geological researches the fact is well-established that in Tertiary times there existed a vegetation and an animal life in the temperate and arctic zones that must have been conditioned by a much higher temperature than the present in the same regions. The temperature in the arctic zones appears to have exceeded the present temperature by about 8 or 9 °C. To this genial time the Ice Age succeeded, and this was one or more times interrupted by interglacial periods with a climate of about the same character as the present, sometimes even milder. When the Ice Age had its greatest extent, the countries that now enjoy the highest civilisation were covered with ice.

A simple calculation shows that the temperature in the arctic regions would rise by about 8–10°C if the carbonic acid increased to two or three times its present value. There is now an important question that should be answered, namely: is it probable that such great variations in the quantity of carbonic acid as our theory requires have occurred in relatively short geological times?

LAWRENCE J.HENDERSON

Lawrence J.Henderson (1878–1942), a US biochemist who spent most of his career at the Harvard Medical School, discovered the chemical means by which acid-base equilibria are maintained in nature. He was also interested in the broader, philosophical, implications of his ideas and he wrote two books: *The Fitness of the Environment* (1913) and *The Order of Nature* (1917), in which he argued that the planet's natural environment is perfectly suited for the development of life. Similar to Vernadsky's, Henderson's work emphasises the importance of geochemical systems and 'unique physical properties of matter' in the creation of life, and suggests that biological evolution proceeds by design and not accidentally. For this reason, Henderson viewed Bergson's notion of an *élan vital* (of unknown origin) as unnecessary, and his views are closer to the currently popular idea of the emergent self-organising systems of complexity.

FITNESS OF THE ENVIRONMENT

THE PROBLEM

We may now return to the problem of the fitness of the environment. So long as ideas of the nature of living things remain vague and ill-defined, it is clearly impossible, as a rule, to distinguish between an adaptation of the organism to the environment and a case of fitness of the environment for life, in the most general sense. No doubt there are clear instances of both phenomena which require no close analysis for their interpretation. Thus the hand is surely an instance of adaptation, and the anomalous expansion of water on cooling near its freezing point an instance of environmental fitness. But how much weight is to be assigned to adaptation and how much to fitness in discussing the relations between marine organisms and the ocean? Evidently to answer such questions we must possess clear and precise ideas and definitions of living things. Life must by arbitrary process of logic be changed from the varying thing which it is into an independent variable or an invariant, shorn of many of its most interesting qualities to be sure, but no longer inviting fallacy through our inability to perceive clearly the questions involved.

Such is the purpose, and the justification, for setting up the postulates of complexity, regulation and metabolism as inherent in that mechanism which is called the living organism. With them, at length, we face the problem which awaits us. To what extent do the characteristics of matter and energy and the cosmic processes favour the existence of mechanisms which must be complex, highly regulated and provided with suitable matter and energy as food? If it shall appear that the fitness of the environment to fulfil these demands of life is great, we may then ask whether it is so great that we cannot reasonably assume it to be accidental, and finally we may inquire what manner of law is capable of explaining such fitness of the very nature of things.

THE ULTIMATE PROBLEM

Such is the outcome of a preliminary glance at the many departments of science which are necessarily involved in the question of fitness of the environment. Living things permit themselves to be simplified into mechanisms which are complex, regulated, provided with a metabolism; the environment, by a series of eliminations, is reduced to water and carbonic acid. These are simplifications counselled solely by expediency.

Neither logical process is necessary; each involves a disregard for many circumstances which might be of weight in the present inquiry. But in the end there stands out a perfectly simple problem which is undoubtedly soluble. That problem may be stated as follows: in what degree are the physical, chemical and general meteorological characteristics of water and carbon dioxide and of the compounds of carbon, hydrogen and oxygen favourable to a mechanism which must be physically, chemically and physiologically complex, which must be itself well-regulated in a well-regulated environment, and which must carry on an active exchange of matter and energy with that environment?

The fitness of the environment is one part of a reciprocal relationship of which the fitness of the organism is the other. This relationship is completely and perfectly reciprocal;[1] the one fitness is not less important than the other, or less invariably a constituent of a particular case of biological fitness; it is not less frequently evident in the characteristics of water, carbonic acid, and the compounds of carbon, hydrogen and oxygen than is fitness from adaptation in the characteristics of the organism.

The fitness of the environment results from characteristics which constitute a series of maxima—unique or nearly unique properties of water, carbonic acid, the compounds of carbon, hydrogen and oxygen, and the ocean —so numerous, so varied, so nearly complete among all things which are concerned in the problem that together they form certainly the greatest possible fitness. No other environment consisting of primary constituents made up of other known elements, or lacking water and carbonic acid, could possess a like number of fit characteristics or such highly fit characteristics, or in any manner; such great fitness to promote complexity, durability and active metabolism in the organic mechanism which we call life.

It must not be forgotten that the possibility of such conclusions depends upon the universal character of physics and chemistry. Out of the properties of universal matter and the characteristics of universal energy has arisen a mechanism as an expression of physico-chemical activity and the instrument of physico-chemical performance. Given matter, energy and the resulting necessity that life shall be a mechanism, the conclusion follows that the atmosphere of solid bodies does actually provide the best of all possible environments for life.

Half a century has passed since Darwin wrote *The Origin of Species,* and once again, but with a new aspect, the relation between life and the environment presents itself as an unexplained phenomenon. The problem is now far different from what it was before, for adaptation has won a secure position among the greatest of natural processes, a position from which we may suppose it is certainly never to be dislodged; and natural selection is its instrument, even if, as many think, not the only one. Yet natural selection does but age the organism; the environment it changes only secondarily, without truly altering the primary quality of environmental fitness.

There is, in truth, not one chance in countless millions of millions that the many unique properties of carbon, hydrogen and oxygen, and especially of their stable compounds, water and carbonic acid, which chiefly make up the atmosphere of a new planet, should simultaneously occur in the three elements otherwise than through the operation of a natural law which somehow connects them together. There is no greater probability that these unique properties should be without due cause uniquely favourable to an organic mechanism. These are no mere accidents; an explanation is to seek. It must be admitted, however, that no explanation is at hand.

Thus regarded, our new form of the riddle appears twofold, and, on that account for the present the more unanswerable is but one immediate compensation for complexity; a proof that somehow, beneath adaptations, peculiar and unsuspected relationships exist between the properties of matter and the phenomena of life; that the process of cosmic evolution is indissolubly linked with the fundamental characteristics of organisms; that logically, in some obscure manner, cosmic and biological evolution are one.

There is, however, one scientific conclusion which I wish to put forward as a positive and, I trust, fruitful outcome of the present investigation. The properties of matter and the course of cosmic evolution are now seen to be intimately related to the structure of the living being and to its activities; they become, therefore, far more important in biology than has been previously suspected. For the whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric.

Note

1 This is not to be understood as an assertion that the relationship is symmetrical. The fact is that each organism fits its particular environment, while the environment in its most general and universal characteristics fits the most general and universal characteristics of the organic mechanism.

JAMES E.LOVELOCK

James E.Lovelock (b. 1919) is an independent scientist working from his home in Cornwall, England. He began to develop his ideas of the 'Earth as a living planet' during his work on the search for life on Mars with NASA during the 1960s. Lovelock asserted that the state of Mars' atmosphere alone was enough proof that no life was currently present on that planet. As he applied similar observations to Earth, he (in close collaboration with scientist Lynn Margulis and others) developed a more comprehensive set of propositions to explain the entire functioning of the planet (including life) in terms of a single system. These ideas developed into the Gaia hypothesis—or, more technically, geophysiology—and became widely known to the public through Lovelock's two most popular books, *Gaia: A New Look at Life on Earth* (1979) and *The Ages of Gaia* (1988). Since this time, Gaia (often removed from Lovelock's own meaning) has become a major symbol for virtually all facets of the environmental debate. It has encouraged broad (and deeply divided) debate amongst and between scientists, environmentalists and even industrialists, and is used as an image by countless groups. The following extract, a letter to the editor of the scientific journal *Atmospheric Environment,* is Lovelock's first published statement on Gaia.

GAIA AS SEEN THROUGH THE ATMOSPHERE

The climate and the chemical composition of the Earth is usually said to be uniquely favourable for life; indeed, it is not commonly known how small are the changes which might render the planet unsuited for the contemporary biota. An increase in oxygen concentration to 25 percent would so increase the probability of fires that even tropical rain forests might be in hazard. A change in atmospheric pressure of 10 percent, assuming that the composition remained unchanged, would cause a change of 4 °C in the mean surface temperature, enough to set the world on an unfavourable climatic course. These are but two examples chosen from many which might show just how well suited is the environment of Earth for life. Or, is it more probable that the biosphere interacts actively with the environment so as to hold it at an optimum of its choosing?

The purpose of this letter is to suggest that life at an early stage of its evolution acquired the capacity to control the global environment to suit its needs and that this capacity has persisted and is still in active use. In this view the sum total of species is more than just a catalogue, 'The Biosphere', and like other associations in biology is an entity with properties greater than the simple sum of its parts. Such a large creature, even if only hypothetical, with the powerful capacity to homeostat the planetary environment, needs a name; I am indebted to Mr William Golding for suggesting the use of the Greek personification of Mother Earth, 'Gaia'.

As yet there exists no formal physical statement of life from which an exclusive test could be designed to prove the presence of 'Gaia' as a living entity. Fortunately such rigour is not usually expected in biology, and it may be that the statistical nature of life processes would render such an approach a sterile one. At present most biologists can be convinced that a creature is alive by arguments drawn from phenomenological evidence. The persistent ability to maintain a constant temperature and a compatible chemical composition in an environment which is changing or is perturbed if shown by a biological system would usually be accepted as evidence that it was alive. Let us consider the evidence of this nature which would point to the existence of Gaia.

During the period that life has existed on Earth, at least three giga-years, there have been profound changes in the chemical and physical environment. The pH has gone from less than 5 to +13, and the output of radiant energy from the Sun will have increased by approximately one astronomical order, if it is a typical star moving along the main sequence. The change from reducing to oxidising conditions carried the atmosphere through a sequence of quite different chemical compositions and at the same time the solar output was steadily increasing; yet the geological record and the fact of the persistence of life shows that the surface temperature did not vary by more than a few degrees from its current levels. These changes in the Earth's environment probably, although not certainly, occurred slowly enough for life to adapt. Even so, it would have been a remarkable coincidence for these environmental changes always to have followed that narrow path whose bounds are the conditions permitting the continued existence of life. It is even more improbable that this could have happened in a system where the energy received from the Sun was also changing by a substantial amount. In the face of these improbabilities the presence of a biological cybernetic system able to homeostat the planet for an optimum physical and chemical state appropriate to its current biosphere becomes a possibility.

Another body of evidence which favours the existence of Gaia comes from a consideration of the contemporary atmospheres of the Earth and of Mars. It has frequently been stated that the presence of nitrogen in the present atmosphere is a chemical anomaly, for the stable form of the element nitrogen at the present state of oxidation of the Earth is the nitrate ion in solution in the oceans. An even greater chemical disparity is the simultaneous presence of oxygen and of methane in the air. In fact a close examination of the composition of the atmosphere reveals that it has departed so far from any conceivable abiological steady-state equilibrium that it is more consistent in composition with a mixture of gases contrived for some specific purpose. Such an examination was used to prove that the presence of life on Earth could be inferred simply from a knowledge of the chemical composition of the atmosphere. The cratered, moonlike appearance of Mars revealed by the television experiment aboard the 1965 Mariner space craft suggested that Mars was unlikely to bear life. This evidence together with the arguments above were used to predict that Mars would have little or no nitrogen in its atmosphere.

Finally, it can be shown that if life on Earth were to cease, the oxygen and the nitrogen would decline in concentration until they were both trace components in an atmosphere of water vapour, carbon dioxide and noble gases. Earth without life would have an atmosphere whose chemical composition was a reasonable interpolation between those of Mars and Venus and appropriate to its station in the solar system. Life is abundant on Earth, and the chemically reactive gases almost all have their principal sources and sinks in the biosphere. This taken with the evidence above is sufficient to justify the probability that the atmosphere is a biological contrivance, a part and a property of Gaia. If this is assumed to be true then it follows that she who controls the atmospheric composition must also be able to control the climate. In this hypothesis, the air is not to be thought of as a living part of Gaia but rather as an essential but non-living component which can be changed or adapted as the needs require, like the fur of a mink or the shell of a snail.

The concept of Gaia has been intuitively familiar throughout history and perhaps only recently has it been distorted by anthropocentric rationalisations. One of these, fashionable in discourse upon the 'Environment' is that we are travellers within the 'Spaceship Earth' and that the biosphere is there as a 'life-support system', presumably for our special benefit. Analogies of this form are used in considerations of the possible consequences of species deletions, destructive changes of the land surfaces by farming and pollution. They are both misleading and unnecessary as a replacement for the older concept of the Earth as a very large living creature, Gaia, several giga-years old, who has moulded the surface, the oceans and the air to suit her and for the very brief time we have been part of her, our needs.

THE EARTH AS A LIVING ORGANISM

The idea that the Earth is alive may be as old as humankind. The ancient Greeks gave her the powerful name Gaia and looked on her as a goddess. Before the nineteenth century even scientists were comfortable with the notion of a living Earth. According to the historian D.B.McIntyre, James Hutton, often known as the father of geology, said in a lecture before the Royal Society of Edinburgh in the 1790s that he thought of the Earth as a super-organism and that its proper study would be by physiology. Hutton went on to make the analogy between the circulation of the blood, discovered by Harvey, and the circulation of the nutrient elements of the Earth and of the way that sunlight distils water from the oceans so that it may later fall as rain and so refresh the Earth.

This wholesome view of our planet did not persist into the next century. Science was developing rapidly and soon fragmented into a collection of nearly independent professions. It became the province of the expert, and there was little good to be said about interdisciplinary thinking. Such introspection was inescapable. There was so much information to be gathered and sorted. To understand the world was a task as difficult as that of assembling a planet-size jigsaw puzzle. It was all too easy to lose sight of the picture in the searching and sorting of the pieces.

When we saw a few years ago those first pictures of the Earth from space, we had a glimpse of what it was that we were trying to model. That vision of stunning beauty; that dappled white and blue sphere stirred us all, no matter that by now it is just a visual cliché. The sense of reality comes from matching our personal mental image of the world with that we perceive by our senses. That is why the astronaut's view of the Earth was so disturbing. It showed us just how far from reality we had strayed.

The Earth was also seen from space by the more discerning eye of instruments, and it was this view that confirmed James Hutton's vision of a living planet. When seen in infrared light, the Earth is a strange and wonderful anomaly among the planets of the solar system. Our atmosphere, the air we breathe, was revealed to be outrageously out of equilibrium in a chemical sense. It is like the mixture of gases that enters the intake manifold of an internal combustion engine, i.e. hydrocarbons and oxygen mixed, whereas our dead partners Mars and Venus have atmospheres like gases exhausted by combustion.

The unorthodox composition of the atmosphere radiates so strong a signal in the infrared range that it could be recognised by a spacecraft far outside the Solar System. The information it carries is *prima facie* evidence for the presence of life. But more than this, if the Earth's unstable atmosphere was seen to persist and was not just a chance event, then it meant that the planet was alive—at least to the extent that it shared with other living organisms that wonderful property, homeostasis, the capacity to control its chemical composition and keep cool when the environment outside is changing.

When on the basis of this evidence, I reanimated the view that we were standing on a super-organism rather than just a ball of rock, it was not well-received. Most scientists either ignored it or criticised it on the grounds that it was not needed to explain the facts of the Earth. As geologist H.D. Holland put it, 'We live on an Earth that is the best of all possible worlds only for those who are adapted to its current state.' Biologist Ford Doolittle said that keeping the Earth at a constant state favourable for life would require foresight and planning that no such state could evolve by natural selection. In brief, scientists said, the idea was teleological and untestable. Two scientists, however, thought otherwise; one was the eminent biologist Lynn Margulis and the other the geochemist Lars Sillen. Lynn Margulis was my first collaborator. Lars Sillen died before there was an opportunity. It was the novelist William Golding (personal communication, 1970), who suggested using the powerful name Gaia for the hypothesis that supposed the Earth to be alive.

In the past ten years these criticisms have been answered—partly from new evidence and partly from the insight provided by a simple mathematical model called Daisy world. In this model, the competitive growth of light- and dark-coloured plants on an imaginary planet are shown to keep the planetary climate constant and comfortable in the face of a large change in heat output of the planet's star. This model is powerfully homeostatic and can resist large perturbations not only of solar output but also of plant population. It behaves like a living organism, but no foresight or planning is needed for its operation.

Scientific theories are judged not so much by whether they are right or wrong as by the value of their predictions. Gaia theory has already proved so fruitful in this way that by now it would hardly matter if it were wrong. One example, taken from many such predictions, was the suggestion that the compound dimethyl sulphide would be synthesised by marine organisms on a large scale to serve as the natural carrier of sulphur from the ocean to the land. It was known at the time that some elements essential for life, like sulphur, were abundant in the oceans but depleted on the land surfaces. According to Gaia theory, a natural carrier was needed and dimethyl sulphide was predicted. We now know that this compound is indeed the natural carrier of sulphur, but at the time the prediction was made, it would have been contrary to conventional wisdom to seek so unusual a compound in the air and the sea. It is unlikely that its presence would have been sought but for the stimulus of Gaia theory.

Gaia theory sees the biota and the rocks, the air and the oceans as existing as a tightly coupled entity. Its evolution is a single process and not several separate processes studied in different buildings of universities.

It has a profound significance for biology. It affects even Darwin's great vision, for it may no longer be sufficient to say that organisms that leave the most progeny will succeed. It will be necessary to add the proviso that they can do so only so long as they do not adversely affect the environment.

Gaia theory also enlarges theoretical ecology. By taking the species and the environment together, something no theoretical ecologist has done, the classic mathematical instability of population biology models is cured.

For the first time, we have from these new geophysiological models a theoretical justification for diversity, for the Rousseau richness of a humid tropical forest, for Darwin's tangled bank. These new ecological models demonstrate that as diversity increases so does stability and resilience. We can now rationalise the disgust we feel about the excesses of agribusiness. We have at last a reason for our anger over the heedless deletion of species and an answer to those who say it is mere sentimentality.

No longer do we have to justify the existence of the humid tropical forests on the feeble grounds that they might carry plants with drugs that could cure human disease. Gaia theory forces us to see that they offer much more than this. Through their capacity to evapotranspire vast volumes of water vapour, they serve to keep the planet cool by wearing a sunshade of white reflecting clouds. Their replacement by cropland could precipitate a disaster that is global in scale.

A geophysiological system always begins with the action of an individual organism. If this action happens to be locally beneficial to the environment, then it can spread until eventually a global altruism results. Gaia always operates like this to achieve her altruism. There is no foresight or planning involved. The reverse is also true, and any species that affects the environment unfavourably is doomed, but life goes on.

Does this apply to humans now? Are we doomed to precipitate a change from the present comfortable state of the Earth to one almost certainly unfavourable for us but comfortable to the new biosphere of our successors? Because we are sentient there are alternatives, both good and bad. In some ways the worse fate in store for us is that of becoming conscripted as the physicians and nurses of a geriatric planet with the unending and unseemly task of for ever seeking technologies to keep it fit for our kind of life—something that until recently we were freely given as a part of Gaia.

Gaia philosophy is not humanist. But being a grandfather with eight grandchildren I need to be optimistic. I see the world as a living organism of which we are a part; not the owner, nor the tenant, not even a passenger. To exploit such a world on the scale we do is as foolish as it would be to consider our brains supreme and the cells of other organs expendable. Would we mine our livers for nutrients for some short-term benefit?

Because we are city dwellers, we are obsessed with human problems. Even environmentalists seem more concerned about the loss of a year or so of life expectation through cancer than they are about the degradation of the natural world by deforestation or greenhouse gases—something that could cause the death of our grandchildren. We are so alienated from the world of nature that few of us can name the wild flowers and insects of our locality or notice the rapidity of their extinction.

Gaia works from an act of an individual organism that develops into global altruism. It involves action at a personal level. You well may ask: so what can I do? When seeking to act personally in favour of Gaia through moderation, I find it helpful to think of the three deadly Cs: combustion, cattle and chain saws. There must be many others.

One thing you could do, and it is no more than an example, is to eat less beef. If you do this, and if the clinicians are right, then it could be for the personal benefit of your health; at the same time, it might reduce the pressures on the forests of the humid tropics.

To be selfish is human and natural. But if we choose to be selfish in the right way, then life can be rich yet still consistent with a world fit for our grandchildren as well as those of our partners in Gaia.

LYNN MARGULIS

Lynn Margulis (b. 1938), is a US professor at the University of Massachusetts at Amherst, a microbiologist and author of the basis for a novel theory of co-evolution, well captured in her book *Symbiosis in Cell Evolution* (1981), which deals with the symbiotic relationship of early prokaryotes and their development into the ancestors of modern eukaryotic cells. Along with Lovelock, Margulis' work on the role of micro-organisms (especially bacteria) in the biosphere has been key to the promotion of the ideas behind the Gaia hypothesis, and the two have co-authored a number of papers on the subject. Margulis remains one of the most eloquent and respected advocates of these ideas, and the book *Microcosmos* (1991) has greatly promoted acceptance of an evolving Gaia. She (with her son, Dorion Sagan) has recently published *What is Life?* (1995) and *Slanted Truths* (1997), relating a number of other issues to Gaia, the biosphere and symbiosis.

JIM LOVELOCK'S GAIA

My plan is to state 'Gaia' as a scientific hypothesis. Having recognised the Gaian phenomenon I would like to explain where I think Gaia comes from and ask for how long this Gaia phenomenon has persisted on the surface of the Earth. And then I would like to raise some of the objections to the Gaia hypothesis.

The Gaia hypothesis is the offspring of Jim Lovelock's fertile imagination and the US space programme. The hypothesis is concerned primarily with the lower atmosphere, that is, the troposphere. With respect to the chemical composition of the reactive gases of the lower atmosphere, the oxidation/reduction state and the pH (i.e. acidity and alkalinity), the Gaia hypothesis states that these attributes of the atmosphere are actively maintained by the activities of the biota. The biota' refers to the sum of all living organisms: flora, fauna and especially micro-biota. At current estimates we are talking about thirty million or so species.

I reject Jim's statement: 'The Earth is alive'; this metaphor, stated in this way, alienates precisely those scientists who should be working in a Gaian context. I do not agree with the formulation that says 'Gaia is an organism'. First of all, in this context no one has defined 'organism'. Furthermore, I do not think that Gaia is a singularity. Rather Gaia is an extremely complex system with identifiable regulatory properties which are very specific to the lower atmosphere.

Equally, I think there are no fundamental inconsistencies between the Gaia hypothesis and the basic tenets of Darwinian evolution, despite some neo-Darwinian latter-day saints. Yet Gaia is a hypothesis that can be tested just as Darwinian evolution is a testable scientific hypothesis. Gaia definitely falls within the realm of science, even though scientists themselves may be ignorant or small-minded in denying that the hypothesis is testable. Like evolution as a hypothesis, it is testable but complex and requires many observations.

Why do so many people disagree? Why do they tend to reject the Gaia hypothesis? My reading of the reasons are as follows: they ask how can the mere biota possibly regulate the planet Earth? How on this gigantic scale, can the temperature and the reactive gases of the planet be maintained? How does some little organism that is just trying to 'maximise its fitness', or increase its rate of reproduction in a thoroughly selfish way, possibly contribute to global regulation in a Panglossian way? Since no mechanism for regulation appears to exist, these investigators deny the existence of the Gaian phenomenon. Lack of evidence of control mechanisms is the usual kind of complaint. Thus our critics argue first that Gaia has not been stated properly as a scientific hypothesis and second that we lack a tangible mechanism of control.

Both these objections can be countered. As scientists, we cannot deny the existence of phenomena simply because we have failed to see mechanisms. The response that the Gaia hypothesis is encountering is very much like the reception, in the 1920s, of the ideas of Swiss meteorologist Alfred Wegener. He saw a phenomenon, 'continental drift' as he called it, but it was not until the early sixties that many scientists—those dragging magnetometers behind ships, those studying deep earthquakes, those recovering deep sea drilling cores—discovered a mechanism that brought about the acceptance of Wegener's phenomenon. Together, through the impetus of great minds such as Donald Mackenzie and Fred Vines, the concept emerged of plate tectonics as the mechanism of continental drift. Today, the phenomenon of 'drift' is generally believed because the mechanism, 'plate tectonics', has been revealed.

The other serious objection to the Gaia hypothesis has to do with time scale, argue the neo-Darwinists of this world. The question is posed more or less like this: since living organisms are interested only in their immediate survival and the leaving of more offspring, how can the Earth have been regulated for more than 3,000 million years? How indeed can fast-acting organisms contribute to millions of years of regulation and stability?

In Box 4.4, we compare the atmosphere of Venus with those of the other planets.

Box 4.4 Planetary atmospheres

	Venus	*Earth*	*Mars*
Carbon dioxide %	98	0.03	95
Nitrogen %	1.7	79	2.7
Oxygen %	trace	21	<0.13
Methane %	none	0.0000015	none
Water (m)*	0.0003	3000	0.00001
Pressure (atm.)	90	1	0.0064
Temperature (K)	750	290	220

* Depth of water over the planet if all water vapour precipitated out of the atmosphere. (Table derived from *GSA Today*, 1993: 3, 11)

Note that it is composed of 98 percent carbon dioxide. Mars' atmosphere at 95 percent has roughly the same composition as Venus, while each of these planets has about 2 percent nitrogen. Regarding gases such as argon, which are inert and 'noble', they behave more or less as expected for unreactive substances and the concentrations are similar in all three instances. Thus, the planetary reactive gas behaviour is best understood by the Gaia hypothesis.

In 1664, Sachs von Lewenheimb wrote a book entitled *Oceanus Macro-Microcosmicus*. He was a champion, as I understand it, of William Harvey's physiological view of the cycling of the blood. He said that when the blood cycles it does not mean that it makes a 'perfect circle', rather it is part of a closed system phenomenon. He rejected the idea of open systems in which the blood just seeped out of the heart, as previously thought. Von Lewenheimb used 'meteoric' (rain, fog, snow) water taken from a weather example to defend blood physiology [see Figure 4.1]. He pointed out that when the water runs off it does not just vanish but it forms a circle, not in a geometric sense but in a figurative sense. Thus it evaporates and then precipitates over the mountains, collecting into rivers and then into lakes and lakes into more rivers and ponds and so on until it collects in the ocean.

Now Lovelock has the Harvey-von Lewenheimb problem in reverse. Today we all accept that our blood circulates in our bodies. Everybody realises that we are not 'being teleological' when we say that bicarbonate has a function in the blood, that mechanisms exist which keep our blood temperature constant, that mechanisms maintain sodium, chloride and potassium ion concentrations within physiologically appropriate bounds. These are not teleological matters but scientific ones. What are the mechanisms that maintain the properties of circulation, of physiology of the blood? Here Jim and I are in the reverse of the situation in which Harvey and von Lewenheimb found themselves. We ask what mechanisms are there for maintaining the methane in the atmosphere, or dimethyl sulphide; indeed what physiological mechanisms maintain these and so many other phenomena of Gaia planetary control? Like those enlightened scientists of three hundred years ago we find we are being criticised by the geophysical scientists for our inability to produce precise mechanisms. We are accused of teleology. But like the modern physiologists and plate tectonics geologists we shall overcome. That the air is regulated by life will soon seem obvious to biologists and climatologists. Scientists will feel compelled to read Lovelock's works. Jim Lovelock will be recognised as the latter-day William Harvey, and the science of planetary biology will begin.

STEPHEN H.SCHNEIDER

Stephen H.Schneider (b. 1945) is a professor at Stanford University, California, where he holds a joint appointment in environmental biology and international studies. He was also a senior scientist at the National Center for Atmospheric Research at Boulder, Colorado. He is an interdisciplinary pioneer in the climate change debate, still editing the journal *Climatic Change,* which he founded in 1975. He has written and edited a number of works on climate change and has vigorously promoted serious discussion about Gaia, of which the article below is a good example. Among his books are *Global Warming, Are We Entering the Greenhouse Century?* (1990) and *Laboratory Earth; The Planetary Gamble We Can't Afford to Lose* (1996).

DEBATING GAIA

The Gaia hypothesis, as defined by its prime advocates, states that Earth's lower atmosphere is an integral, regulated and necessary part of life itself and that, for hundreds of millions of years, life has controlled the temperature, chemical composition, oxidising ability and acidity of the Earth's atmosphere. As the 1990s dawn, the Gaia hypothesis is finally out of the shadows of fringe science. The notion that life wields active control over the planet's physical and chemical environment has become the subject of critical scientific debate twenty years after British scientist and inventor James E.Lovelock and US microbiologist Lynn Margulis first described the Gaia hypothesis.

One point in the debate—whether a biotic control mechanism somehow maintains the Earth's climate at a temperature suitable for life—has attracted the interest of those who discount the forecasts of a depleted ozone layer and an enhanced greenhouse effect. Indeed, the Gaia hypothesis won some of its earliest support from polluting industries, which interpreted Gaia to mean that nature could counter the effects of pollution and keep the planet inhabitable. (The other major supporters were environmental spiritualists looking for oneness in nature—an idea for which Gaia is a marvellous symbol.) But, until recently, the Gaia hypothesis was virtually ignored by most of the scientific community.

Lovelock was aware in the 1970s that Earth scientists would be sceptical of a Gaian perspective. The predominant view in the natural sciences was that life on Earth is primarily passive, responding to non-living forces like volcanic eruptions, severe storms, droughts and even drifting continents. In return, life can modify the local environment and, to some extent, the chemical environment—through the exchange of gases in photosynthesis, for example.

But the Gaia hypothesis goes further and holds that the biota can effectively and directly manipulate the environment for its own purposes, or that life optimises its environment to suit itself. This is the most radical idea to grow out of the Gaia hypothesis and the one whose criticisms are most difficult to answer. Nevertheless, by promoting the profound realisation that climate and life mutually influence each other, the Gaia hypothesis provides an important counterpoint to the predominant view that environment dominates life.

The Gaia hypothesis evolved from Lovelock's work as a consultant for the US National Aeronautics and Space Administration (NASA) in the 1960s. NASA scientists were preparing to launch the Viking spacecraft for a mission to examine the possibility of life on Mars. Lovelock, working with philosopher Dian Hitchcock, argued that there was a simpler way of detecting whether life existed on Mars. Telescopic observations from Earth had already revealed that the Martian atmosphere is predominantly composed of carbon dioxide (CO_2), with relatively little oxygen, methane and other reactive gases that, on Earth, are the product of photosynthesis and other biological processes. Thus, Lovelock deduced that the probability of life existing on Mars was extremely small. He postulated that, on a lifeless planet, one might expect such gases to be rare because, without constant replenishment by plants and bacteria, these gases would react with other gases and with minerals on the planet surface and disappear, except in minute amounts. Lovelock argued that the inorganic and organic processes of a planet are not independent and that the absence of these gases in the Martian atmosphere indicated the absence of life (assuming that life on Mars would biochemically resemble life on Earth). Nevertheless, the Viking mission went on, analysed Martian soils, and found no evidence of life.

Lovelock's work at NASA eventually led him to his important association with microbiologist Lynn Margulis, who, at that time, also worked at NASA. They postulated the Earth—its biota and environment—to be a self-regulating system able to maintain both the climate and chemical composition of the planet in a state favourable to life. The idea that life shapes the physical environment is an old one, articulated at least since Victorian times. For example, in 1877, T.H.Huxley wrote: 'Since the atmosphere is constantly receiving vast volumes of carbonic acid from various sources, it might not unnaturally be assumed that this gas would unduly accumulate, and at length vitiate the entire bulk of the atmosphere. Such accumulation is, however, prevented by the action of living plants.'

The innovative and controversial part of the Gaia hypothesis is that life somehow maintains control mechanisms for its own good— that is, that life achieves a sort of homeostasis through negative feedback, or cybernetic control. The name Gaia, after the classical Greek word for Mother Earth, was the suggestion of Lovelock's neighbour, the Nobel Prize-winning novelist William Golding. Said Lovelock, 'It is a more convenient term than biological cybernetic system with homeostatic tendencies.'

Lovelock and Margulis suggested that the Earth as a whole be viewed as a physiological system—the study of which Lovelock has recently called the new science of geophysiology—wherein complex but not yet well-understood mechanisms maintain a stable environment beneficial for life on the planet. Just as a person's body maintains its temperature or the thermostat in a home turns on a furnace or an air conditioner to maintain a set temperature range, the Earth may have its own internal feedback control system. The Gaia hypothesis simply states that such mechanisms of physical and chemical control are embedded in the totality of life on Earth.

CLIMATE CONTROL

Consider the Gaian argument for planetary-scale control of the climate. It is widely believed that the Sun has been heating up since its formation many billions of years ago. This belief is based on known principles of nuclear physics, which indicate that the hydrogen in the Sun fuses into helium. This process probably requires the Sun to emit more radiative heat energy over time. Calculations suggest that, four billion years ago when primitive life first appeared on Earth, the Sun was perhaps 25 percent less luminous than it is today. Modern climatic theory suggests that, given such low solar energy, the Earth should have been a frozen ball. Yet sedimentary rocks that could have been formed only by water flowing on the planet's surface have been dated as having been formed as long ago as 3.8 billion years. Fossil evidence of bacteria has also been dated as more than three billion years old. Therefore, at least some part of Earth supported both life and liquid water when the Sun was perhaps 25 percent less luminous than at present.

One plausible explanation of this 'faint early Sun paradox' was offered in 1971 by astronomer Carl Sagan of Cornell University and George H.Mullen of Mansfield University. They suggested that the gases methane and ammonia, which are efficient absorbers of infrared radiation, could have been present in the Earth's atmosphere in concentrations sufficient to trap radiative heat and, through the greenhouse effect, prevent the loss of energy from Earth to space. In other words, these gases could have created a super-greenhouse effect that kept the Earth's temperatures equable while the Sun was still relatively faint. However, methane and ammonia are removed so quickly from the atmosphere that they probably could not have reached the levels that Sagan and Mullen suggested. Scientists have since proposed that CO_2 would have been the best candidate to create a super-greenhouse effect, but the basic idea is still attractive.

Indeed, Lovelock and Margulis have argued that both the emission and removal of greenhouse gases, such as ammonia, CO_2 and water vapour, by various organisms are part of the Gaian planetary temperature control mechanism.

But why has the planet not subsequently overheated, since the sun presumably has increased its luminosity by 25 percent over the past four billion years? Lovelock and Margulis find a Gaian explanation in the tiny ocean phytoplankton that incorporate CO_2 from the atmosphere into their calcium carbonate shells. As the Earth warmed up, the plankton should have taken up CO_2 more efficiently. When the plankton died and sank to the ocean bottom, their carbonate shells would have become sediment, thus removing CO_2 from the system. Moreover, increased rain from warmer conditions would have created more run-off from the land. Run-off provides nutrients to feed plankton and removes CO_2 from the air through the weathering process. Lovelock and Margulis suggest that the net loss of CO_2 would have been enough to compensate for the warming Sun. Thus, they argue, Gaia is actively maintaining a fairly constant climate temperature as the Sun heats up.

Several possible problems with this scenario have emerged, however. First, phytoplankton, although biologically primitive relative to organisms like trees, are still much more sophisticated than the simple bacteria that were the only living things for the first two thirds of the past four billion years. Indeed, eukaryotes such as phytoplankton, which contain distinct nuclei, evolved only about a billion years ago. Thus, phytoplankton could not have been the primary CO_2 sink during the two to three billion years in which simpler life forms were dominant and the Sun continued to heat up. Perhaps certain photosynthesising bacteria were involved in removing CO_2, but the mechanisms and any quantitative assessment of the magnitude of the removal are yet to be shown.

A more serious criticism, however, is the assertion by inorganic geochemists that temperature control through CO_2 removal could be accomplished inorganically, without any biological mechanism. In 1981, University of Michigan geochemists James C.G.Walker, Paul B.Hays and James Kasting developed an elaborate model for feedback control of climate temperature but with a different mechanism for CO_2 removal. Instead of plankton removing CO_2 by depositing calcium carbonate, the geochemists postulated an inorganic competitor for this process involving the weathering of silicate minerals on land. In this model it is assumed that, as the Sun heats up, the climate and oceans become warmer. More water would evaporate from the warmer oceans and eventually rain back down on Earth. Carbon dioxide in the air dissolves in water droplets and forms weak carbonic acid, which reacts with calcium silicate in rocks to form carbon-containing sediments. The geochemists hypothesised that, as the sun heated up, this weathering could have effectively removed enough CO_2 from the air to maintain climatic stability.

The Lovelock and Margulis scenario acknowledges the role of weathering. As Lovelock has commented, The Gaian variant of Walker's model assumes that the biota are actively engaged in the process of weathering and the rate of this process is directly related to the biomass of the planet. If conditions are too cold the rate of weathering declines, and as a consequence of the constant input of CO_2 by degassing from the Earth's interior the CO_2 partial pressure rises' (Lovelock 1987:11).

Kasting, now at Pennsylvania State University, and NASA planetary scientists Owen Toon and James Pollack have argued that, even without life, inorganic oceanic chemical reactions would produce carbonate sediments, but this feedback control system would result in global temperatures about 10 °C warmer than would result if life were the significant CO_2-removing agent. More recently, Tyler Volk at New York University and David Schwartzman at Howard University argued that soil biota facilitates the rate of weathering reaction to such an extent that a lifeless Earth would be as much as 45 °C warmer than it is today. This hypothesis, however, has been challenged by Harvard University geochemist Heinrich Holland. Clearly, the scientific debate over Gaia is in full bloom.

Unfortunately, there is as yet no sufficient evidence, empirical or theoretical, to resolve the question of whether organic or inorganic CO_2 removal would have dominated in this potential mechanism of climate control. One of the most tenuous aspects of the argument for Gaian climate control has to do with the Earth's temperature at the time that life got a toehold on the planet 3.5 to four billion years ago. That the Earth's temperature has been reasonably constant since its inception, as Gaian supporters have stated, is not well supported by the palaeoclimatic evidence. Direct temperature measurements, upon which quantitative knowledge of Earth's climate history is based, exist for only the past few hundred years. Nevertheless, physical evidence of the many life forms that have existed provides a proxy thermometer from which past temperature conditions can be estimated. For example, fossiliferous sediments may indicate the distribution of warm- and cold-loving species. Also, the ratio of various isotopes of oxygen in the fossilised shells of clams and plankton may indicate something about temperature conditions at the time the animals secreted their shells. Thus, about a half a billion years worth of evidence is available from which to draw crude but reasonable conclusions about the mean temperature of Earth.

It is quite possible that the planet was very cold by present Earth standards and that life existed only in limited domains in warm, tropical regions or in areas heated by upwelling lava or other flows from the interior. On the other hand, it is also plausible that the average global temperature was exceedingly hot and that the fossiliferous sedimentary rocks dated to 3.8 billion years ago were deposited in what were temperate or polar regions at the time. Palaeoclimatologists have not yet resolved to better than ±25 °C the Earth's mean temperature three to four billion years ago. For more recent geological history, the evidence is more abundant, and for the past billion years the record of life is sufficient to suggest that Earth's mean temperature has probably not been more than 10 to 15 °C warmer or about 5 °C cooler than it is today. This range at least suggests the existence of partial climate control, whether through organic processes, inorganic processes or, more likely, both.

PLANKTON AND CLOUD ALBEDO

Another Gaian mechanism of potential climate control was debated in March 1988 at the American Geophysical Union Chapman Conference in San Diego, California, the first major scientific meeting on the Gaia hypothesis. Certain marine phytoplankton reduce dimethyl sulphide (perhaps as part of a process to help to maintain their internal osmotic pressure), which is subsequently emitted as a waste product and—the relevant hypothesis—may somehow influence the climate. This seemingly fantastic scenario was proposed when Lovelock visited atmospheric chemist Robert Charlson at the university of Washington. Also involved were oceanic chemist Meinrat Andreae of Florida State University and climate theorist Stephen Warren of the University of Washington. Their hypothesis evolved from a synthesis of Lovelock's interdisciplinary ideas, Charlson's knowledge of the effect of atmospheric particles on cloud formation, Andreae's understanding of sulphur-cycle chemistry and Warren's knowledge of climate modelling. They proposed that, after the dimethyl sulphide (DMS) released into the ocean by phytoplankton is outgassed into the air, it is converted chemically to sulphur dioxide and then to sulphuric acid particles. These particles are incorporated into low-altitude clouds, which are made up of relatively few large water drops because of the lack of dust particles (which serve as cloud condensation nuclei) over oceans. The extra sulphur particles substantially increase the number of water droplets, which, in turn, scatter more sunlight. Thus, the albedo, or sunlight reflectivity, of clouds increases, and this process, other things being constant, would cool the climate. (Indeed, when James Coakley, then working at the National Center for Atmospheric Research in Boulder, Colorado, saw bright streaks in clouds over the oceans in satellite pictures, he attributed them to the extra droplets condensed around smoke particles from ships criss-crossing the ocean.)

Unfortunately, although the Charlson group could show that relatively small changes in the concentration of sulphuric acid in the atmosphere could cause substantial changes in cloud albedo—enough to vary temperature by a few degrees Celsius perhaps —the group could not show that this process was necessarily negative feedback. That is, they could not demonstrate how a cooling of the climate, for example, would reduce the plankton's DMS production and thus decrease cloud albedo, thereby opposing the cooling. In fact, recent studies (as yet unpublished) have found more sulphate in Antarctic ice cores at the height of glacial cooling, which suggests a positive feedback—namely, that more DMS is produced in cold times, causing more cloud seeding and greater cloud albedo. The increased reflection of solar radiation would have produced lower temperatures. However, as Warren has pointed out, it is also possible that the increased sulphate in Antarctic ice is not a result of globally increased DMS emissions but simply that of a local, cold-water species of phytoplankton that expanded its numbers near the Antarctic continent, thereby inducing the enhanced cold-era Antarctic sulphur deposition.

In short, while the DMS climate change hypothesis has not yet been demonstrated to include positive or negative feedback, without Lovelock or the Gaia hypothesis it probably would not have been investigated for quite a while. The same seems true for the hypothesis of Schwartzman and Volk mentioned earlier about the effect of soil biota on Earth's temperature, which was also presented at the 1988 conference. The San Diego meeting signalled that, after 20 years, the Gaia hypothesis has moved from non-scientific forums to where it fundamentally belongs—in the turbulent flow of mainstream science. The most serious critique of the Gaia hypothesis to date was presented at the conference in a session on the philosophy of science and is summarised in Box 4.5.

Presenting the critique was James Kirchner, a physicist, philosopher and—at that time—graduate student of the Energy and Resources Group at the University of California at Berkeley. The essence of his criticism was that there are many Gaia hypotheses rather than a single one. Kirchner described five hypotheses, each supported by a quote from Lovelock, Margulis or one of their close colleagues.

Kirchner differentiated between the relatively weak-acting hypotheses, such as influential or co-evolutionary Gaia, which seem to state only that the biota and the physical environment have something to do with one another, and those that imply a stronger connection. 'If we all talk about "the Gaia hypothesis" without specifying which Gaia hypothesis, we can create a lot of confusion,' he said. This confusion can appear in different guises. One of the most serious lies in claiming that evidence for one of the weaker versions of the hypothesis somehow proves the much stronger versions of the hypothesis as well. Said Kirchner:

> You may believe, as I do, that the biota affect the physical environment. You may also think, as I do, that the physical environment shapes biotic evolution. You are in good company, because scientists have thought these things for over a hun-

Box 4.5 The many faces of Gaia

Influential Gaia

This simply asserts that the biota has a substantial influence over certain aspects of the abiotic world, such as the temperature and composition of the atmosphere. According to Lynn Margulis and science writer Dorion Sagan, 'The Gaia hypothesis states that the temperature and composition of the Earth's atmosphere are actively regulated by the sum of life on the planet.'

Co-evolutionary Gaia

This asserts that the biota influences its abiotic environment and that the environment in turn influences the evolution of biota by Darwinian processes. In the words of Andrew Watson and James Lovelock, 'The biota have effected profound changes on the environment of the surface of the Earth. At the same time, that environment has imposed constraints on the biota, so that life and the environment may be considered as two parts of a coupled system.'

Homeostatic Gaia

This asserts that the biota influences the abiotic world and that it does so in a way that is stabilising. In the language of systems analysis, the major linkages between the biota and the abiota world are negative feedback loops. Lovelock and Margulis have called the Gaia hypothesis 'the notion of the biosphere as an active adaptive control system able to maintain the Earth in homeostasis'.

Teleological Gaia

This holds that the atmosphere is kept in homeostasis, not just by the biosphere, but by and for (in some sense) the biosphere. According to Lovelock and Margulis, 'The Earth's atmosphere is more than merely anomalous; it appears to be a contrivance specifically constituted for a set of purposes.'

Optimising Gaia

This holds that the biota manipulates its physical environment for the purpose of creating biologically favourable, or even optimal, conditions for itself. 'We argue that it is unlikely that chance alone accounts for the fact that temperature, pH and the presence of compounds of nutrient elements have been, for immense periods just those optimal for surface life. Rather we present the "Gaia hypothesis", the idea that energy is expanded by the biota to actively maintain these optima,' wrote Lovelock and Margulis.

> dred years. So if you ask me whether I believe in the Gaia hypothesis, and you mean that Gaia hypothesis I would say that I do. But if you then say that I must believe that the biota are part of a global cybernetic control system, the purpose of which is to create biologically optimal conditions… well, that's another matter entirely.

Kirchner argued that the weak forms of Gaia are not new and that the strong forms are either incorrect or untestable. Ultimately, he classified the strong forms of Gaia as a metaphor, not a testable hypothesis. In concluding, he commented that 'the common perception is that Gaia means "the Earth is alive" or the biota are trying to make themselves a nice home here. Given that the public doesn't understand the risks of treating poetic statements as scientific propositions, the common perception is that a bunch of scientists are busy trying to figure out whether the Earth really is "alive" and I don't think that perception helps any of us.'

Two years later, Kirchner's critique remains a stunning challenge to the Gaia hypothesis. Lovelock recently responded to Kirchner's 'spirited attempt to demolish all notions of Gaia. Like some figure of the

Inquisition, he publicly burned several imaginary Gaias, and his pyrotechnic demolition of the strong Gaia stole the show. But when the sparks faded, the real system Gaia was still there hidden only by the smoke. The flux of papers inspired by Gaia, and now appearing in the journals, are the real proof of the value of the conference. It has not stopped peer review from censoring any mention of Gaia by name.' Of course, Kirchner never intended to demolish the Gaia hypothesis but, rather, to sharpen the debate. In that quest, he clearly succeeded.

THE QUESTION OF OPTIMISATION

The realisation that climate and life mutually influence each other is profound and provides an important counterpoint to the parochial view of the world as a physical environment dominating life. Nonetheless, to say that climate and life 'grew up together', or coevolved, is not the same as to say that life somehow optimises its own environment to suit itself.' It is the latter idea, the most radical proposed by Lovelock and Margulis, that is most open to criticism.

The early physical environment largely determined the ecological niches in which early life forms had to live. Life altered the physical environmental constraints on itself by changing the composition of the atmosphere. To be sure, this modification changed the competitive balance of species and forced evolutionary change—indeed, co-evolutionary change—between the organic and inorganic parts of the environment. Change, yes; but to say 'optimisation' is problematic. If one simply asserts 'optimum' in terms of the current biota, then life is at its optimum by definition. But what about the losers? Extinct life forms probably would not view the current environment as having been optimised.

One of the principal confusions with the whole idea of life's self-regulation, or optimisation, is what is 'life? Is life's self-regulation a matter of maintaining for the longest period of time the stability (that is, the survival) of extant species? Does optimisation entail the maintenance of maximum biomass or the maintenance of maximum diversity of species? All of these goals seem to be legitimate definitions of optimisation of life, yet to optimise each one is probably inconsistent —the three goals are not necessarily compatible.

Consider a specific example. Orbital variations of the Earth are thought to drive the ice age cycles, but changes in CO_2 and methane concentrations may amplify the cycles substantially. Near the end of the Pleistocene, 15,000 years ago, when the last ice age receded rapidly, the CO_2 content of the atmosphere was about one-third less than it was just before the Industrial Revolution. This difference suggests that a weakened greenhouse effect made the ice age colder than it otherwise would have been. A principal explanation for the decrease in CO_2 during the height of the last ice age has to do with a change in the biochemistry of the oceans, perhaps from a planktonic response to altered nutrient availability. In other words, ocean life probably helped to alter the chemical composition of the atmosphere, the climate and its own environment. (Another possible contributing factor to the decrease in atmospheric CO_2 is the storage of carbon in bogs.)

But it is hard to imagine how making an ice age even colder could increase the total biomass, let alone be any general statement of homeostasis, or self-regulation of life. If the atmospheric CO_2 content was diminished by life during an ice age, a monkey wrench is thrown into any hypothesis that environmental conditions were somehow being altered by life for self-optimisation; the preponderance of evidence suggests that, relative to today, terrestrial biomass was at least 10 to 20 percent less at the last glacial maximum, 15,000 to 20,000 years ago. Because the vast bulk of biomass is on land, even if oceanic organisms thrived during the ice age by sequestering more carbon for themselves, their proliferation most probably replaced only a small portion of the land biomass lost to the cold that was enhanced by a decrease in CO_2 for which the oceanic organisms were at least partially responsible. But, that the plankton take care of themselves without regard for the wider consequences for life on land sounds very Darwinian rather than Gaian. Indeed, Lovelock recently reformulated the question of optimisation:

> In the early days when it was a bit poetic one thought of life as optimising conditions on Earth for its survival. Now that I understand the theory behind Gaia very much more than I did then, I recognise that this is not so, that it's nothing as highly contrived or as complicated as that. There is no foresight or planning involved in the part of life in regulating the planet. It's just a kind of automatic process.

GAIA AND GLOBAL CHANGE

Lovelock, Margulis and their collaborators have illuminated the very important role of feedback mechanisms between the organic and inorganic components of planet Earth. In particular, they have challenged scientists to view the Earth from a new perspective, one that Lovelock calls geophysiology. Gaian supporters believe that such a whole-system view should be as legitimate a scientific pursuit as the more traditional reductionist views. Yet the level of aggregation at which complex systems can be most profitably viewed cannot be determined without detailed empirical investigation. Both 'bottom-up' and 'top-down' approaches are valuable, especially for a science that is developing. Unless one has strong ideological views about how the physical and biological worlds are organised, it seems that the most practical way to study complex systems is to try to analyse them at those levels that provide the greatest explanation of system behaviour for the least expenditure of effort. In this context, the Gaian scientists' call for a geophysiological approach to the interaction between organic and inorganic components of Earth is both welcome and overdue. But this does not mean that scientists should accept the proposition that such feedbacks are always negative —that is, self-regulatory for life, once life has been defined.

Feedback processes are not just interactions that tend to stabilise a system; they can also be interactions that tend to destabilise—like those that appear to have operated between biomass and CO_2 during the last ice age. Life and the environment have coevolved, but their interactions have not always been optimal for all forms of life or even for the overall biomass. Such interactions simply lead to mutual changes—some beneficial and some detrimental for some forms of life at some times. The importance of whole-system studies alone is sufficient to justify looking beyond the narrow disciplines of biology, climatology, geophysics, chemistry and so forth, in what has come to be called the 'global change' movement. Clearly, more scientists should insist that the organic and inorganic parts of the planet be viewed as coupled systems that can be studied at various levels of aggregation.

At a 1975 meeting organised by anthropologist Margaret Mead on threats to the atmosphere, Lovelock applied Gaian ideas in a controversial statement: 'Our capacity to pollute on a planetary scale seems rather trivial by comparison and the system does seem to be robust and capable of withstanding major perturbations' (Lovelock 1987). Subsequently, a large debate broke out in which the author and energy analyst John Holdren from the University of California at Berkeley countered that, although no human intervention, probably not even nuclear war, could be powerful enough to threaten all of life on Earth, when dealing with human beings, a billion or so of whom are already suffering from severe malnutrition, even slight disturbances in the environmental systems that produce food and recycle wastes can be catastrophic to some humans and many other species. 'Though we probably are not threatening the survivability of the entire biosphere, changes of 5 or 10 percent in the carrying capacity of the Earth for human beings must be viewed as having enormous social and political consequences on a global scale.' From the human point of view, prevention of such consequences is essential.

Lovelock responded that, indeed, pollution could be an enormous problem, but that, if scientists approached environmental problems from the perspective that nature has feedback on the system, they might very well propose different solutions than would otherwise be offered. Nevertheless, it is speculation at best and environmental brinkmanship at worst to believe that Gaia, through self-regulation, will somehow protect the planet from the negative consequences of all human intervention. Neither Jim Lovelock nor Lynn Margulis believes in this mystical protection.

Today, the unknown extent of negative and positive feedback poses a dilemma that applies to many environmental questions, including the greenhouse effect, ozone depletion, acid rain and toxic waste disposal. It is extremely unlikely that scientific assessment can answer all of the questions relevant to enlightened policy making before human-induced experiments unfold on 'laboratory Earth,' with humanity and every other living thing as passengers along for the ride.

THOMAS F.MALONE

Thomas F.Malone (b. 1916) is Sigma Xi chief scientist and director of the Sustainable Human Development Program. He is a distinguished university scholar in marine, Earth and atmospheric sciences at North Carolina State University, USA, and former foreign secretary of the American National Academy of Sciences. He was the first secretary general of the International Council of Scientific Unions' Scientific Committee on Problems of the Environment and has long been a leader in the promotion of international scientific co-operation and programmes. The following extract is from Malone's introduction to the proceeding of the First International Symposium on Global Change held in Ottawa, Canada, in September 1984, where he outlines a historical context of the issues.

GLOBAL CHANGE

For millennia, humankind has sought to understand the nature of the world we inhabit and the processes which determine its state at any given time. This inquiry began long before we realised that the world was a planet, and that we were tenants and caretakers.

Centuries ago, Aristotle began to set down some thoughts on the physical system which sustains life in his treatise on the philosophy of science and nature. Somewhat between ancient Platonism and modern idealism, Aristotelianism maintained that all things are substances (natural, supernatural and human) and all are related in one way or another to each other. Of more immediate concern to this symposium was the suggestion early in the seventeenth century by Francis Bacon that co-operative efforts were the best way to obtain information about the nature of the world we occupy. European nations did, in fact, mount a co-operative programme to observe the transit of Venus in 1751. A subsequent transit of Venus in 1769 afforded an opportunity to link observations in the New World with those in the Old. Within a few decades, a meteorological network was established from Gotthaab in Greenland to Pyshminish in Russia. Observations were taken three times daily at as many as thirty-nine stations and were published in *Ephemerides Societatis Meteorological Palatinae*.

International collaboration proceeded slowly during the nineteenth century, initiated for the most part by an emerging set of international scientific organisations. The so-called First International Polar Year (FPY) in 1882–83, involving scientists from two dozen nations, is generally recognised as the forerunner of international, collaborative efforts to lay the observational basis for an understanding of the Earth and its environs. A network of fourteen circumpolar stations provided simultaneous observations during thirteen months over a number of disciplines, including geophysics and biology. The Second Polar Year (SPY), fifty years later, involved scientists from forty countries and led to the publication of observations and analyses in the fields of meteorology, radiation, ozone, aerology, geomagnetism, Earth currents, atmospheric electricity, ionospheric physics, auroral physics, cosmic rays, hydrography, glaciology, noctilucent clouds, astronomy and some elements of biology. A by-product of these scientific studies that is of contemporary significance was increased knowledge of the ionosphere, which greatly enhanced the technology of radio communications.

During the next two decades, the pace of scientific and technological progress was so rapid that the need and opportunity for synoptic, global observational data and analysis became urgent. The prediction of a period of unusual solar activity in 1957–58, and the imminent possibility of an Earth satellite programme, prompted the scientific community to propose an 'International Geophysical Year' to cover the eighteen-month period from 1 July 1957 to 31 December 1958. The importance of continuing the traditional attention to polar regions that had characterised the FPY and SPY was preserved by special plans to explore the Arctic and Antarctica.

Tens of thousands of scientists from seventy nations participated in this endeavour. The IGY was so successful that it led to the International Year of the Quiet Sun (IQSY), the Upper Mantle Programme (UMP), the International Magnetospheric Study (IMS), the Global Atmospheric Research Programme (GARP), the International Biological Programme (IBP), the Man and the Biosphere Programme (MAB), the International Hydrological Decade (IHD) and the International Decade of Ocean Exploration (IDOE).

The rapid growth in the study of Earth, its environs and life in the biosphere has progressed to a point where it is now possible to think seriously of fashioning a bold, holistic approach that will deepen and strengthen our understanding of the planet's subtle and often synergistic physical, chemical and biological processes. Such a framework would examine the oceans, atmosphere, lithosphere, hydrosphere, biota and the solar-terrestrial domain as a single system.

Three characteristics of the International Council of Scientific Unions (ICSU) proposal under consideration are unique. The first is the integration of biological processes in the biosphere with the geophysics of the much larger domains of the atmosphere, oceans, lithosphere and solar-terrestrial interval. The second is much greater attention to chemical processes, in particular to the biogeochemical cycles of both major and minor nutrients and contaminants. The third is the holistic framework within which the processes in the domains will be examined and their interactions assessed. All three are formidable tasks, not to be undertaken lightly. No amount of exhortation or erudite exposition of a rationale will be decisive. It is the judgement of active researchers, particularly young scientists, that will be the determining factor.

The proposal to unite geophysics and biology is the culmination of conceptual thinking that began in 1875 with the identification of the 'biosphere'—described by the Austrian geologist Edward Suess—as the concentric, life-supporting layer of the primordial Earth. It was developed as a concept in modern scientific thought largely through the work of the Russian mineralogist V.I.Vernadsky during the 1920s. He characterised the biosphere as the terrestrial envelope embracing the troposphere, the hydrosphere or oceans, and the continental layer extending several kilometres below the surface of the Earth. Its unique properties were prevailing conditions that enabled incoming solar radiation to produce the geochemical changes essential for the genesis and continued existence of life forms. He stressed the inextricable linkage between life and its surrounding energetic and material structure through photosynthesis, transpiration and nutrition.

We are apparently on the threshold of developing a new paradigm by which the processes governing the behaviour of this system are defined and identified. For example, Lovelock has postulated the existence of an encompassing living feedback system through which the biosphere regulates the physical environment by and for itself as external stimuli change— the Gaia hypothesis.

Four reasons suggest that 'the time is ripe to set up and expand current efforts to understand the great interlocking systems of air, water and minerals nourishing the Earth.' The first is the growing realisation—from the more or less independent studies of the atmosphere, oceans, crustal dynamics, life-supporting ecosystems and solar—terrestrial relations—that the biotic and non-biotic components of the biosphere are inextricably intertwined. For example, the global issue of climate is now correctly perceived to be as much an oceanographic problem as a meteorological one. Moreover, the illuminating studies of the ICSU's Scientific Committee on Problems of the Environment (SCOPE) on biogeochemical cycles have clearly demonstrated the 'far-reaching consequences at all ecosystem levels, both in marine and terrestrial systems,' of these processes.

Improved understanding of the pathways and rates of exchange for the primary constituents of living organisms (carbon, nitrogen, phosphorus, sulphur, hydrogen and oxygen) and their relation to the other great domains of Planet Earth have taken on a 'special urgency'. Only as recently as 1981 W.S. Fyfe, professor of geology at the University of Western Ontario, was able to make the unchallenged statement that 'the significance of the exchange processes of the outer systems of the Earth, oceans, atmosphere, biomass, sediments and rock is obvious.'

A second reason for creating an international collaborative effort is that human impacts have grown to approximate those of the natural processes that control the global life-support system. The sagacious words of Harvard professor Richard Goody and his colleagues at a workshop of scientists who met in Woods Hole, Massachusetts, in July 1982 set forth the case eloquently:

> The human race lives on a planet characterised by change. This is a unique time, when one species, humanity, has developed the ability to alter its environment on the largest (i.e. global) scale and to do so within the life-time of a single species member.
>
> Climatic change resulting from increased anthropogenic carbon dioxide in the atmosphere, acid deposition, deforestation and desertification are all examples of this phenomenon.

A third reason for the necessity of studying the link between biological and geophysical processes rests with the inexorably growing demand in developing nations for sharply enhanced biological productivity. In the coming years, humanity will have to respond to the imperative to increase access to the food, fibre, energy and shelter required by the rapidly growing global population. For example, it is estimated that the population of the Third World will increase by two billion people between 1975 and 2000.

Finally, a rapidly advancing technological base has brought within reach the capacity to complete the triad of theory, observation and data management that must underlie an international collaborative effort—one that will extend the imagination and capacity of the world's scientific community to its limits. An incredible array of observational tools is now within reach, from the numerous different satellites that provide global surveillance to chemical techniques that measure substances in parts per trillion. The sophistication of communications technologies, the capacity of computers and the methodology of systems analysis have literally exploded in recent years. Such advances have brought within real time the analytical, data-handling and data-management techniques required to respond to a sharply focused set of questions concerning the interaction of the Earth's life-sustaining physical, chemical and biological processes.

The century since the First Polar Year has seen a phenomenal increase in our knowledge of Planet Earth and its environs. We now stand—on the shoulders of our predecessors —on the threshold of a revolution of historic proportions in human understanding. The vantage point from space provides a leverage that makes possible a quantum leap. The intellectual challenge of acquiring deeper understanding is equalled by the promise of utilising that understanding in shaping human destiny over the critical next millennium. The prospects for a new and better kind of human future, both on and off Planet Earth, have never been brighter.

WILLIAM C.CLARK

William C.Clark (b. 1946), professor of public policy at the Kennedy School of Government, Harvard University, USA, is an environmental scientist by training who studied with the noted ecologists G.E.Hutchinson and C.S.Holling. He is a co-executive editor of the journal *Environment.* Clark has been at the forefront of research on both global change and sustainable development issues, where he has drawn attention to the interplay of physical and social systems as a necessary frame for developing workable strategies for understanding the modern aspects of these problems, including recognition of the role of thinkers such as Vernadsky, Teilhard de Chardin and Lovelock. He was director of the Ecologically Sustainable Development of Biosphere Project at the International Institute for Applied Systems Analysis (IIASA) at Laxemberg, Austria, which produced ground-breaking interdisciplinary work and helped to set a theoretical base for further research on global environmental change. This short extract is from the important volume of this work *Sustainable Development of the Biosphere* (Clark and Munn 1986).

SUSTAINABLE DEVELOPMENT OF THE BIOSPHERE

THE EARTH AS GARDEN

What images are appropriate for thinking about an Earth transformed by human action? As emphasised by Holling, Timmerman, and Thompson, the choice of the images or myths that we use to structure our accounts of the world is a fundamental one, which radically constrains the questions we ask and answers we get. Much of what Burton and Kates characterised as conservationist thinking seems to be based on an image of nature in its 'original state', perturbed by sporadic human blundering. The concerned possibilists, in contrast, have embraced the image of 'spaceship Earth' as a creation of and responsibility for enlightened engineering.

Neither image, however, will quite do. On the one hand, the Earth *has* been transformed by human activity, with hardly a corner that is not now being managed, at least in some limited sense. On the other hand, we have learned just enough about the planet and its workings to see how far we are from having either the blueprints or the operator's manual that would let us turn that diffuse and stumbling management into the confident captaincy implied by the 'spaceship' school of thought.

Reflecting on these inadequacies, Harvey Brooks has argued that today's Earth 'is more like a garden than a primeval forest. Even if the garden is ill-kept.' I like the 'garden' image, not the least because it emphasises the human use of Earth for productive purposes. I should add, however, that my personal gardening experience is not of trim English hedges but rather of the tense encounter in the foothills of the Appalachian Mountains between, vines, bugs, beasts, tornadoes and the would-be gardener. If we accept the garden image as a useful one, two questions arise: What kind of garden do we want? What kind of garden can we get?

The first of the questions—'What kind of garden do we want?'—ultimately calls for an expression of values. The values on which we have based this study—the kinds of garden we want—are suggested in our choice of title: *The Sustainable Development of the Biosphere*. The common-sense meaning of 'sustainable' is a good first approximation of our intended meaning. We seek to distinguish gardening strategies that can be sustained into the indefinite future from those that, how ever successful in the short run, are likely to leave our children bereft of nature's support.

There is a strong anthropomorphic bias in these 'sustainability' values—people worry about nature primarily in terms of what nature means for people's own welfare. If environmental degradation occurs, perhaps it can be traced to people's failure to define their welfare in sufficiently long-run terms to include their descendants. Other less anthropomorphic biases are possible, but I suspect that most of us eventually return to our essential humanness.

The second question raised above is one of feasibility: 'What kind of garden can we get?' While not divorced from value judgements, this latter question is fundamentally one of knowledge and know-how. Environmental degradation results not only from insufficient value placed on the long run, but also from sheer ignorance of how environment and development interact. What kinds of long-term development pressures are likely to be the sources of the next century's environmental transformations? What are the implications of these transformations for the biosphere's productive capacity? How can the transformations be managed to shape a garden more to our liking, yet still enhance our children's options?

RAFAL SERAFIN

Rafal Serafin (b. 1959), a Polish citizen, completed graduate studies in environmental science at the University of Waterloo, Canada, and is currently Director of the Polish Environmental Partnership Foundation in Krakow. He worked on the staff of the Ecologically Sustainable Development of Biosphere Project at the IIASA, where he undertook a comparative study of Vernadsky's biosphere, Teilhard de Chardin's noosphere and Lovelock's Gaia, forming the basis for this extract. Serafin's work is one of the only comparative analyses that looks at all three of these perspectives, and it has frequently been cited as an important contribution to the intellectual history on the origins of global change.

NOOSPHERE, GAIA AND THE SCIENCE OF THE BIOSPHERE

INTERPRETATIONS OF NOOSPHERE

There are two possible interpretations of the noosphere as described by Teilhard de Chardin and Vernadsky. The first is that the noosphere represents the total pattern of thinking organisms and their activity, including the patterns of their interrelations. The other is that of a special environment or medium for humanity, consisting of the systems of organised thought and its artefacts among which humans move and have their being—as fish swim and reproduce in rivers and the sea. Huxley has referred to the former as the noosphere and the latter as the noosystem in an attempt to draw attention to this ambiguity.

For Teilhard de Chardin, the noosphere was the planetary layer of consciousness and spirituality that was emerging from a biospheric mass of vitalised substance. For Vernadsky, the noosphere was above all the medium within which humanity could find fulfilment. He believed that humanity could achieve this through exercising deliberate and conscious control over its milieu.

Vernadsky referred to himself as a 'cosmic realist'. By this he meant that he accepted the reality of a physical universe outside himself and believed that the only valid knowledge that could be obtained came from a scientific study of that universe. Thus, despite his close association with Teilhard de Chardin, Vernadsky appears to have remained materialistic rather than spiritual in his own ideas. Teilhard de Chardin's conception of the noosphere tried to draw together material and spiritual interpretations of the development of the universe. In contrast, Vernadsky saw the noosphere in primarily materialistic terms as a historically inevitable stage in the evolutionary development of the biosphere.

This materialism did not stop many at the Soviet Academy from accusing Vernadsky of mysticism. The often venomous criticism, however, seems to have been motivated by Vernadsky's stubborn refusal to condemn idealistic philosophies, such as those of Teilhard de Chardin, and to adopt dialectical Marxism. Vernadsky steadfastly refused to recognise dialectical Marxism as an objective and universal philosophy that created conditions for a flowering of science, holding instead that this doctrine had no more monopoly on the truth than Teilhard de Chardin's teleological speculations or Indian philosophies. Each was distinct and separate from the objective study of the functioning of the biosphere. Each one was useful as each increased the pressure on science to sharpen its methods, logic and verification.

Thus, in spite of the philosophical differences between Teilhard de Chardin and Vernadsky, or perhaps because of them, both men came to share a deep-rooted conviction that the destiny of humanity lay within its own grasp. The belief that humans have a duty to modify the biosphere through science and technology lay at the heart of the notion of the noosphere.

GAIA AND THE NOOSPHERE AS COMPLEMENTARY SYMBOLS

Followers of Vernadsky in the Soviet Union have continued the detailed and quantitative study of biogeochemical cycles, especially through the construction of numerical computer models. Attempts have been made to investigate the carrying capacity of a biosphere that is evolving mainly through processes beyond human influence and partly as a result of human intervention. The important outcome of such research has been increased attention to thresholds of biospheral carrying capacity and the implications of not respecting them. Large models of biospheral processes have been used, how ever crudely, to ask analytical questions about how and to what degree human activities may be responsible for large-scale changes in biogeochemical cycles. For example, what would be the implications for the carbon cycle if a quarter of the existing forests were removed? If the loss of a quarter of our planet's forests does not lead to a radical transformation of biogeochemical processes, would the loss of a third make a difference? What might be the implications of the deforestation of a quarter of existing resources over a period of thirty years? What if such deforestation happened over sixty years?

Meanwhile, Lovelock's geophysiology aims to tackle such questions as how stable is the planetary operating system? What will perturb it? Can the effects of perturbation be reversed? And can our planet maintain its present climate and composition without the humid tropics in their current form'?

In his analysis of modern environmentalism, Timothy O'Riordan (1981) has identified ecocentric and technocentric ideals as opposite ends of a continuum governing human relations with nature. The continuum illustrates important patterns of thinking. Ecocentrism is a nature-centred view of the Earth, grounded in a belief that humankind and its activities are subject to a natural order according to which the universe operates. In contrast, technocentrism is a human-centred view of the Earth, based on the belief that humanity can manage and control nature. In considering the future of environmentalism, O'Riordan has suggested that Gaia has emerged as a popular symbol of ecocentrism primarily because it has come to be associated with the belief that humankind is not a dominant species and human consciousness is not the only means through which nature should be judged and interpreted.

Quite apart from the scientific community, Gaia has captured the imagination of a wider public through popular scientific publications, such as *The Gaia Atlas of Planetary Management* (Myers 1985), numerous articles in *The Ecologist* that have explored the notion of Gaia, and Lovelock's beautifully written book, *Gaia: A New Look at Life on Earth* (1979). Recently, Gaia provided the backdrop to a British made-for-television thriller, *Edge of Darkness*. It has given a new focus to writings on 'alternative living', and has even inspired a mass in New York and a (bad) disco record.

If Gaia represents an ecocentric guiding concept of the universe, then the noosphere represents a technocentric one. Vernadsky, like Teilhard de Chardin, believed that human beings are the planet's consciousness with the right, responsibility and now ability, in the words of George Sessions, to 'seize the tiller of the aimlessly drifting planet' and direct evolutionary forces. This approach is rejected by the ecocentrists, or 'nature-centrists', who reject such a notion of ecological anthropocentrism and call for an ecological egalitarianism to end all forms of human domination. According to those inspired by Saint Francis, 'Man' should be deposed from his monarchy over creation and a democracy of all God's creation should prevail. According to the ecologist Aldo Leopold, 'Man' should cease to try to manage the biosphere and should instead become a 'plain biotic citizen'. Gaia encapsulates a concept of an evolving planetary entity which is fundamentally ecologically egalitarian, with 'man at the periphery', because humanity may not be a necessary ingredient in the future of the biosphere. In contrast, Vernadsky's noosphere is not only ecologically anthropocentric, 'man-centred', but also 'man in charge'.

Thus, Gaia and the noosphere appear to represent contradictory informing concepts about humanity's relationship with nature, and as such can be interpreted as the latest in the dialectic of technocentrism versus ecocentrism that has coloured so much of the thinking on environmentalism. For example, the question 'is humankind at the centre or at the periphery of ecological processes?' has consistently been a prominent one in environmental literature. I contend, nevertheless, that because Gaia and the noosphere share a common analytical basis, a science of the biosphere, they are unlike previous adversaries in the technocentrism versus ecocentrism debate.

In the conceptions of both Gaia and the noosphere, the biosphere represents human understanding of the biogeochemical cycles taking place on our planet. Thus, the contradictions of technocentrism and ecocentrism become irrelevant with the asking of common analytical questions about the functioning of the biosphere. On the basis of current answers to such questions, proponents of Gaia might concede that some portions of the biosphere and biogeochemical processes, such as the hydrological cycle or the stratospheric ozone budget, are within the partial control of humankind, while others, such as international control of industrial sulphur emissions, may well become subject to human regulation in the near future. On the other hand, modern proponents of the noosphere might concede that some portions of the biosphere and biogeochemical processes, such as large-scale control of climate, will remain for ever beyond the reach of human science and technology.

This convergence represents more than a mere sharing of methodological and quantitative understanding of the biosphere. Seen in this way, Gaia and the noosphere no longer appear as proponents of contradictory informing concepts of human obligations toward nature. As a result, I see no contradiction between Lovelock's speculations about exporting Gaia to Mars and Soviet endeavours to design deliberate strategies for reshaping the hydrological cycle to benefit economic development. Although each one is influenced by an apparently different informing paradigm, each is increasingly held back by a sense of humility and caution. Schemes for large-scale river diversions in the Soviet Union, once so popular among central planners, have come in recent years to be regarded with scepticism, and some have even been abandoned altogether.

Increasingly, public as well as scientific debate has come to take the form of asking empirically oriented questions about humanity's socio-economic and technological influence on the biosphere and its biogeochemical processes: 'Which processes?' 'Where?' 'How?' 'When?' 'To what extent?' Thus, the informing concepts of Gaia and the noosphere can be viewed as complementary to each other since each has been erected on an analytic interpretation of the biosphere. The concept of noosphere focuses on what we do know and understand about the workings and management of biogeochemical cycles, while the notion of Gaia emphasises what we do not know and understand. Taken together as parts of a larger whole, Gaia and the noosphere can help to distinguish what we do understand from what we do not about humanity's ability to conduct its activities on our planet so as to ensure the survival of our own species, as well as that of the biosphere. Such a perspective offers the opportunity for a shared ethical perspective on global ecology which could not occur merely in terms of the methodological common ground between East and West or scientists and policy-makers.

As long as proponents of both Gaia and the noosphere continue to reinterpret their paradigms in the light of scientific advances in our understanding of biogeochemical cycles, these concepts are likely to continue as useful guides for avoiding potential malfunctions of our biosphere. It is the combined philosophical perspective of Gaia and the noosphere, firmly rooted in analytical understanding of the biosphere, that is embodied in the emerging notion of a transnational 'sustainable development of the biosphere'.

5

POTENTIAL: THE FUTURE OF THE NOOSPHERE

Recent profound technological changes have enormous potential to alter the fundamentals of the biosphere adversely as well as offering greater promise for the noosphere. In the same way as we might imagine the risks of climate change, we can also conceive of the replication of our own biosphere and noosphere in the creation of new worlds through the colonisation of the oceans or space. Perhaps most striking is the information and communications technology revolution, and the growing power of the global network to shrink our world and generate a sort of 'planetary consciousness'— albeit still highly inchoate and riven with inequities and divisions. As a result of this technical progress, the notion of 'global learning' is revived as both a desirable and feasible means of building a new society on a higher plane—in some sort of balance or symbiosis with nature and the universe.

This chapter is concerned with those applications and practices that derive—whether explicitly or not—from noosphere-related concepts, and that in turn might enhance the broader noosphere idea and its relevance to current agendas and contribute to a vision of the future. Each of the themes above presents itself as a potential means not only to perpetuate but also to evolve or progress humankind as a species. The relevant ideas may be divided into three categories: global learning (memetics), the emergence of a new form of *Homo*/cyber intelligence (planetary brain) and the creation of new biospheres and noospheres outside the Earth (space colonisation). Each of these views represents a generally positive and optimistic perspective on human evolution, and they differ principally on the means by which the noosphere is to be created. A vague notion of destiny or irreversibility, if not Teilhardian inevitability, is often detectable.

GLOBAL LEARNING AND MEMETICS

The notion of 'global learning' has long fascinated a variety of thinkers espousing a diversity of world views. The twentieth century has witnessed the widest expression of such sentiment, largely as the result of two devastating world wars, massive increases in general literacy, and improvements in the techniques of information generation and dissemination. The League of Nations Covenant (1919) sought to create a type of global learning which would preserve world peace. Despite the League's failure in meeting its objectives, many continued to hold out hope for the idea. For example, in the 1930s, H.G.Wells (1938: xiii–xiv) called for the 'unifying of the general intelligence services of the world' in a 'gigantic and many-sided educational renascence', which he described as a 'world brain'.

Following the collapse of international co-operation, in 1945 the United Nations again took up this agenda with no less optimism and with additional ideas for peace-promoting activities as well as promoting health, economic development and human rights while monitoring meteorology and the environment. The best example of efforts towards global learning is UNESCO, created in 1948. As previously mentioned, this organisation's first director general was the evolutionary biologist Julian Huxley. In his extensive report submitted to the Preparatory Commission of UNESCO, Huxley clearly expressed his views suggesting that the new organisation be based on a general philosophy of 'evolutionary humanism' in order to ensure continued progress. Huxley (1946:9) believed that the rate of evolution would be enormously speeded up through such institutional means and that 'the struggle for existence that underlines natural selection is increasingly replaced by conscious selection, a struggle between ideas and values in consciousness.'

In subsequent years, UNESCO's development was influenced by the noosphere idea introduced by Teilhard de Chardin and supported by Huxley, Joseph Needham (Head of the Science Division) and others. A UNESCO International Symposium entitled 'Science and Synthesis of Knowledge on Man and the Universe' was convened in Paris in 1965 to mark the fiftieth anniversary of the formulation of the general theory of relativity and the tenth anniversary of the deaths of Albert Einstein and Teilhard de Chardin. Recalling the latter's views, Julian Huxley suggested the following:

> In the evolutionary process man has at last become conscious of itself and his destiny is to be the sole agent for future evolution of this planet. Evolution is directional. And man is the latest product of a continuous process of such improvement punctuated by critical steps from one dominant type of organisation to a new and higher one. Our present psycho-social system has reached the limit of its usefulness. We need a new synthesis of ideas and beliefs to act as a supporting and directive matrix for the new psycho-social system waiting to be born…a new, an integrated and compelling vision of human destiny.
>
> (quoted in the *Teilhard Review* 1966:22–23)

Later still, the notion of biosphere, loosely coupled with notions of global learning, emerged in the Man and the Biosphere Programme (MAB) as outlined in Chapter 4. MAB divided the world not into states but into ecosystems (and 'biosphere reserves') and assembled leading scientists to prepare plans for their best management—an early application of the sustainability idea. However, although this exercise yielded promising early results it was soon riven with academic and political considerations, ultimately leading to the withdrawal of the United States and (temporarily) the United Kingdom.

Kenneth Boulding (1978) proposed an 'evolutionary vision' that connects evolution at all levels of reality, including the physical, biological and sociocultural. For Boulding, however, culture is as crucial as it is tenuous (*ibid.:* 14): 'If nobody spoke to children, if all schools and universities were shut down for as little as one or two generations, the human race would be virtually identical biologically to what we are now, but its culture would, if it survived at all, revert to the Stone Age.' If we believe such a statement—which is by no means uncontroversial—then there is also the implication of a positive flip-side to it: we can change virtually the entire world culture or mentality in just one or two generations for the benefit of all. If this is true, could the perception of worldwide risks or threats such as global environmental change spur new forms of global social movements of this scale and type in response?

New social movements have formed as a response to the forces of globalisation, but not only along the lines suggested by optimists. As we have seen above, those who see the Gaia hypothesis in a deep spiritual manner in which humans are not a special species and caretaker of the planet, but more like a cancer, are an example of such a group response. The

Box 5.1 **Deep ecology**

Deep ecology was coined by the Norwegian philosopher Arne Naess in 1973 and was later developed and popularised in California by Bill Devall and George Sessions (1985), and others. It is a fundamentally ecocentric (as opposed to anthropocentric) world view that is seen to provide a basis for the relationship between humankind and its surrounding environment. Humans are seen to be one species among others, not above others, suggesting a form of biospheric egalitarianism. The term has become a significant symbol for the more radical branches of the environmental movement. Gaia, in its stronger form, is often used as a justification for or symbol of deep ecology.

Teilhardian view of the irresistible progression of the noosphere, and ultimately the 'Omega point', can be seen as an opposite view, with humans at the centre, but still in the form of an all-encompassing theory. More broadly, the 'deep ecology' movement may be seen as a direct response to the challenges of globalisation and an increased perception of risk. A good example of this view is expressed by Edward Goldsmith (1996), himself inspired by the original ideas of deep ecology (see Box 5.1) as well as Gaia and the biosphere. While Goldsmith sees a necessary return to a simpler way of life, deep ecology is more broadly defined. According to Fridtjof Capra (1996: 7–8), such a way of thinking 'is nothing short of spiritual or religious awareness,' which questions 'the perspective of our relationships to one another, to future generations, and to the web of life of which we are part.' Deep ecology offers a perspective allowing a way out (if only temporarily) of the current crisis, but it does not provide a sense of inevitable escape— instead stressing the rather temporary nature of human ideas and species.

Evolutionary biologists and others have long grappled with the issue of change in cultural behaviour in relation to natural selection and evolution (e.g. Waddington 1959). However, it was the Oxford biologist Richard Dawkins (1976) who coined and popularised the notion of the 'meme' as a replicator or unit of cultural transmission—a cultural analogue for gene. The term is used in an evolutionary sense and focuses on replicative cultural artefacts such as ideas, behaviour norms, etc. Memes are seen to compete and influence each others' chance of being replicated. This process allows for innovation (similar to mutation), but the result is largely a copy of the original. Memes have been used in a variety of ways, including Daniel Dennett's (1991) view of the human mind as being composed of memes in a fashion similar to the programming of a computer. Dawkins has suggested that memes are similar to biological and computer viruses and describes them as 'viruses of the mind', which act in the same way that genes do. Moreover, evolution of cultural forms does not necessarily enhance the biological fitness of the producing units (Csikszentmihalyi 1988:107). However, despite some caution, the idea is that the coming of human intelligence has a revolutionary impact on the course and form of evolution. More significantly perhaps, Dawkins (1976) has built his meme model on an analogy with the so-called 'selfish gene'. Memes, no less than genes, reflect individual competition, not holistic, noospheric co-operation.

Memetics may offer a good starting point for an explanation of the mechanism of the transmission of knowledge, but it provides no guidance as to which direction society should choose, beyond mere survival. If we presume that there are several paths in the direction of survival—not all of them equally sustainable—memetics is a useful mechanism, but it is an insufficient guide for the future. A vision of the future—providing both physically sustainable and ethically satisfying goals—would be necessary to provide a positive direction for memetics. In fact, perhaps genes and memes will remain equally important. U.Savchenko

(1997) has identified the 'genosphere' as the total combination of genetic systems that ensures the existence, regeneration and reproduction of the biosphere as a whole living complex. According to this view, the only hope for a durable noosphere will be found in 'a system of global genetic monitoring' (*ibid.:* 97).

Allerd Stikker (1992:128) draws attention to the parallels between Taoism and the noosphere to suggest that 'everything should be done to ensure that humanity becomes intensely conscious of its vital position and role in the evolutionary process of the Earth and the universe. Then and only then will the decision-making process in human society change.' Lynton Caldwell (1990: xiii) asserts that we need 'a new and higher level of behavior in relation to the biosphere.' Dennis Pirages (1977) proposes a 'sustainable society'. But what do these ideas mean in concrete terms? How can such a vision be deployed? The Russian scientist Nikita Moiseev (1989) is more concrete and captures a very powerful strand of this idea in suggesting the need for a form of 'global teacher' to promote understanding of the co-evolution of the biosphere and the noosphere. Moiseev outlines a path that captures many of the ideas presented in these pages—a rather balanced view of the physical and mental worlds and the ecocentric and human-centric perspectives. On the question of feasibility, Moiseev seems to have in mind a new organisation—perhaps some type of revamped UNESCO—that would be the basis for such a vision to grow from. But such organisations have significant shortcomings and failures, not least because of bureaucracy and politicisation. Nonetheless, there have been accomplishments, such as the lowering of infant mortality rates and increases in literacy and educational opportunities, in which UNESCO has played an important role. Are such organisations really the key to a sustainable and desirable future? In a recent article, Fuchs-Kittowski and Kruger suggest that such a hypothesis is possible:

> On the basis of an intensive networking of interactions of human beings among one another and supported by world-wide socio-technological information and communications systems, a communication society can emerge whose way of value creation is based on deploying the creativity of human beings, on the evolution of their intelligence and on a deeper understanding of their condition as human beings.
> (1997:772)

Technological change may have altered the potential for such traditionally structured organisations in the sense of both making more of the vision partly possible (today, knowledge is more easily exchanged in networks) and making the organisational structure itself less relevant (centralised offices are less and less important). Could some of the old ideas and hopes become reality as a result of new technology? Information technology does provide some new opportunities, but the need for some form of social structure—albeit an altered one—remains.

AN EMERGING PLANETARY BRAIN

The economic, political and cultural forces of globalisation have created a semblance of what the Canadian Marshall McLuhan has called the 'global village'—or 'a single constricted space resonant with tribal drums.' Citing Teilhard de Chardin, McLuhan saw the characteristics of the global village ultimately leading to the development of the '"noosphere" or a technological brain for the world' (1962:31). McLuhan's notion of the global 'electric culture' builds on Teilhard de Chardin's idea of tangential energy (energy of consciousness) as a primary factor in evolution. Numerous thinkers, many with a new age perspective, adopt this view in the context of an ever-expanding, decentralised, interactive global web—the Internet. The virtual office and town hall at least are now a technological reality. But much of this remains mythical. In practical terms, superior technology is not enough to create profound change by itself; it must also be culturally integrated.

Central to this idea is notion that information, or at least ever-expanding knowledge, can somehow escape the laws of thermodynamics. Under the second law, the entropy law, the total amount of free energy available for increased complexity through evolution is decreasing. Teilhard de Chardin, for one, did not deny this law but suggested that tangential (spiritual) energy was not subject to it forces. Instead he shifted the emphasis of evolution away from evolution as a means of diminishing the total amount of energy in the universe (which is fixed under the first law of thermodynamics) to the process of concentrating psychic energy and the development of meta-consciousness, first through the noosphere and later through the 'Omega point' (O'Manique 1967). These ideas would appear to have increasing support as the theory of an ever-expanding universe continues to attract more supporters (e.g. Watson 1997).

We are told by such thinkers that this is 'the noosphere, towards which we are moving even now, via our cybernetic interconnections, know it or not, like it or not, want it or not' (Mabry 1994). As Kevin Kelly (1994) notes, the new network is a revolutionary type of 'thinking space' that 'is far different from a printed book, or even a chat around a table. The text is a sane conversation with millions of participants. The type of thought encouraged by the Internet hyperspace tends toward nurturing the nondogmatic, the experimental idea, the quip, the global perspective, the interdisciplinary synthesis, and the uninhibited, often emotional, response.' Mizrach (1997) goes further, presenting a new age perspective based on the idea of the noosphere:

> Following Teilhard de Chardin, a number of non-idealist 'info-mystics' suggest that, while the universe is made of matter, it is evolving into pure information or pure mind (the noosphere). While the matter in the universe is falling into entropy, ultimately life and consciousness may be able to escape this fate by becoming forms of information which are material-independent, i.e. patterns of organization, and enter into hyperspace or other dimensions. I suggest that these mystics are non-idealist in that they subscribe to emergence—they don't see mind as prior to matter, but rather something which emerged out of matter and may eventually be able to leave its material substrate. It may be the escape route from entropy.

Perception of global aspects of mind preceded technological change. In *Darwin Among the Machines: The Evolution of Global Intelligence* (1997), George Dyson traces the long history behind the idea of the 'artificial mind' within the context of debate over evolution and reminds us of its longstanding (through largely forgotten) history. We are reminded (*ibid*.: 26) of one of Darwin's most outspoken critics, Samuel Butler, who in 1872 asked: 'Why may not there arise some new phase of mind which shall be as different from all present known phases as the mind of animals is from that of vegetables?' Dyson concludes that society is well on the way down this evolutionary path, asserting that: 'We have mapped, tamed, and dismembered the physical wilderness of our earth. But, at the same time, we have created a digital wilderness whose evolution may embody a collective wisdom greater than our own' (*ibid*.: 228). However, if the idea is not a new one, why should a global mind actually come into being now? An increasingly common answer to this question is the Internet. For example, the Frenchman Joel de Rosnay (1995:128) sees the noosphere as expanding through the intermediary of computers and large communications networks, but he also sees this as part of a much broader planetary process, which he describes as follows:

> the issue is about a new form of life; a level of organization never before reached by evolution: *macro-life* at the global level in symbiosis with the human species. This hybrid life form, which is at the same time biological, mechanical and electronic, is in the process of unfolding before our eyes. We are the 'cells' in this process. In a manner which is still unconscious, we are contributing to the invention of its metabolism and its circulatory and nervous systems. We call them economies, markets, highways, communication

> networks and information superhighways, but they are really the organs and vital system of an emerging super-organism. These upheavals will change the future course of humanity and condition its development over the next millennium.
>
> (*ibid*.: 16–17)

The fact that such ideas have been part of our acknowledged 'science fiction' culture for so long does not help in establishing credibility. One is reminded of Arthur C.Clarke's fusion of the mind of humanity with the universal mind in the novel *Childhood End* (1953) and a whole host of other stories. This is fiction, not science, although many of Clark's ideas, including satellites, were once dismissed in the same manner.

Of course, space flight started its life as fiction in books like Jules Verne's *From the Earth to the Moon* (1870) and is now very much reality. Today, a growing number of thinkers (e.g. de Rosnay and Dyson), many with excellent reputations in their field, have reached similar conclusions, if by different means. The MIT scientist Marvin Minsky believes that it is incorrect to see ourselves as a final product of evolution and that humankind is now evolving more rapidly, and hand in hand with our own creations. When answering the question: 'Will robots inherit the earth?' Minsky responds: 'Yes, but they will be our children' (1994).

In *The Awakening Earth* (1982), Russell sees the noosphere, 'the cumulative effect of human minds over the entire planet', as part of a new evolutionary phase towards 'collective consciousness'. His idea is not only based on perception but also on the observation that major qualitative transitions take place throughout the course of evolution and the historical record proves this in several systems where the units become tightly but flexibly coupled at a density of roughly 10^{10} (10 billion), as the number of atoms in a bio-molecule and number of molecules in a cell. Russell argues that the human population (now at roughly six billion) is approaching this threshold. Through the use of computers, satellites, fibre optics, video recorders and other technology, Russell (1995) sees catalysts that are linking the planet into a single community—a 'global brain'. However, in a manner similar to the Gaia hypothesis, Russell sees humankind as potentially acting as a planetary cancer if it is not able to come together. Moreover, he suggests that if we do wipe ourselves out, and even if intelligent life fails to re-emerge on the Earth, the process is somehow irreversible and inevitable: 'The Universe will carry on evolving towards higher levels of integration and complexity whether we do or not' (1982:206).

Gregory Stock (1993) proposes another form of emergence from the intensification of human activities—primarily in transportation and communications—across the globe, which he calls 'metaman'. Stock asserts that this new form has appendages (markets, politics, etc.), arteries (cables, pipes, waterways, roads, etc.), a nervous system (mail and electronic communications) and a collective memory (libraries, electronic data banks, etc.). As a result, metaman is seen to be not only increasing in size but also in robustness. Stikker (1992:127) suggests that much of our world's infrastructure—communities, associations, institutions, corporations and nation-states—is near a saturation point in the evolutionary planetary process in which 'a transformation to a new consciousness, a new orientation and configuration will occur.' Abraham (1992) sees a similar trend, in which a vast 'concordance' of unprecedented scale emerges in the noosphere and allows society to guide evolution—through the extra 'nourish-ment' of computer networks, interdisciplinary conferences and feminist thinking.

MAKING BIOSPHERES

Another important noospheric idea is tied to the notion that, at least in theory, life could possibly exist—and perhaps more importantly, be created by humans—outside and independent from our own biosphere. Thus far in history, *Homo sapiens* has tended towards material expansion, and presuming the species survives long enough—a big assumption—we will ultimately be forced to continue this process, as well as mere existence, beyond the existing biosphere first into, and then beyond, the Solar System. According to well-established scientific theories, ultimate escape from the Earth is necessary to avoid the occasion when, in about five billion years, the Sun grows into a red giant and engulfs the Earth. Along with many more immediate and concrete reasons such as human population growth, natural resource depletion and the pursuit of science, this vague feeling of distant insecurity has prompted reflection in this area.

The best-known experiment so far—with strictly limited success—has been Biosphere 2, which has attempted to perpetuate a mini biosphere (complete with a few humans) in a totally closed system (see Figure 5.1 and Box 5.2). Two of the scientists in the project, John Allen and Mark Nelson (1987:50–1) see this experiment as 'the central issue facing the noosphere: whether humankind can take the unprecedented step of intelligence regulating the technosphere and their own species expansion, harmonizing it within the biospheric totality rather than having the biosphere control this species.' Sagan sees such experiments as the first 'buds and blossoms of a cosmic springtime in which the Earth itself will bloom into the space between the stars,' representing nothing less than the rebirth of the Earth itself, or

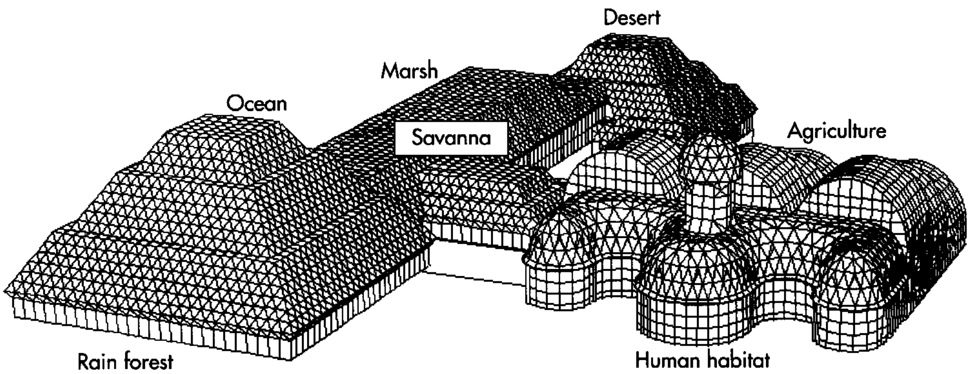

Figure 5.1 Biosphere 2

Box 5.2 Biosphere 2

Biosphere 2 is a self-contained structure, originally designed to model the workings of Biosphere 1 (the Earth). It covers 1.275 hectares, measures 28 m at its highest point and contains five self-sustaining communities of living organisms (biomes): rain forest, desert, savanna, marsh and ocean (7.5 m deep), and a human habitat. It is located in the desert in Arizona, USA.

In 1991, an eight-person crew started a two-year mission, which failed due to problems related to food and oxygen production, species loss, pests and other problems. A second crew of six in 1994 fared little better. Columbia University took over project management in 1996 and uses the facility to accommodate visitor programmes, scientific research, conferences and educational programmes. It draws 200,000 tourists a year.

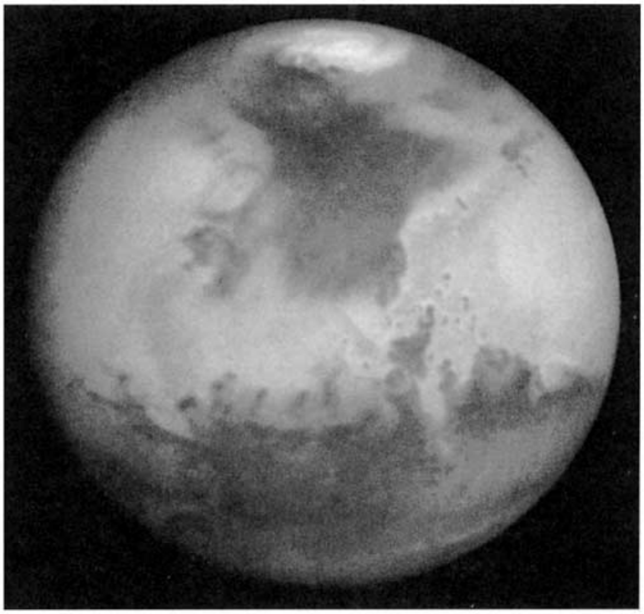

Figure 5.2 Springtime on Mars. The Hubble Space Telescope provides a clear view of the permanent water-ice cap—several hundred kilometres across—in Mars' northern hemisphere. Dark areas, once believed by some earlier observers to be vegetation, are really areas of coarse sand, which are less reflective to sunlight. Did life ever exist on Mars? Scientists continue to debate the issue. Irrespective of the answer to this question, an equally interesting one might be raised: could humans launch the creation of a self-sustaining biosphere on Mars, the Moon or another celestial body?

the 'breaking up of the Earth into earths' or 'miniaturized offspring' (1990:178). Sagan is quick to point out, however, that such developments are hardly inevitable. Even if the idea of evolutionary convergence suggests that various kinds of being will seek to expand into space for the same reasons that life moved from the seas to land, there can be no guarantee that humans, or any other species, will inevitably succeed in this quest. As Margulis and Sagan note, given time to evolve (and probably necessarily in the absence of people), the future descendants of some other species could potentially start their own space programmes (1997: 236). According to Lovelock's Gaia hypothesis, life cannot exists in sparse distribution and there can be 'no partial occupation of a planet by living organisms' (Hansson 1997:109).

Freeman Dyson, professor emeritus at the Institute of Advanced Studies (and father of George), has convincingly argued that human colonisation of space is bound to happen for reasons of curiosity, economics and necessity—essentially because the Earth is growing crowded and resources may become scarce and because of fear of future asteroid impacts (1997). Dyson suggests that colonisation may result as a sort of spin-off from research and planning to intercept such bodies. The recent discovery of ice on the Moon by the Lunar Prospector may well encourage colonisation. In his book *The Physics of Immortality* (1994), Frank Tipler claims that 'Science can now offer *precisely* the consolations in facing death that religion once offered. Religion is now part of science.' He goes on to state that 'Gaia, like all mothers, is not immortal. She is going to die. But her line of descent might be immortal. Indeed, every being now alive on the Earth is the direct lineal descendant of one-cell organisms that lived 3.5 billion years ago. So Gaia's children might never die out— provided they move into space. The Earth should be regarded as the womb of life—but one cannot remain in the womb forever.' Tipler's theory of an 'Omega point' (borrowing Teilhard de Chardin's term but not his reasoning) combines the ideas of both a meta-thought network and expanding biospheres. For Tipler, an ultimate sense of mind comes together from all points of the universe in a final convergence as the result of ever-expanding intelligent life in all directions. But he does not see this expansion as necessarily human: 'The heirs of our civilization must be another species, and their heirs yet another, ad infinitum into the Omega Point. We must die as individuals, as a species—in order that our civilization might live. At the present rate, computers will reach the human level in information processing and integration ability probably within a century, certainly within a thousand years.' Although Tipler goes to considerable pains to support his argument with physics, he has been criticised that his theory cannot be tested and is not even believed by himself (Ellis 1994). Nonetheless, the scientific investigation of such ideas does fit with an optimistic view of the potential of the noosphere.

As evolutionary biologists often remind us, ultimately every species has a beginning and an end. According to Margulis and Sagan: 'Beyond short-term technological fads are the long-term trends of life—extinction, expansion, symbiosis—which seem universal. We the species *Homo sapiens,* will reach extinction, with or without a nuclear war' (1997:240). Much closer to us is the phenomenon of global environmental change and the very real threats it carries for even the current generation. As the ethologist E.O.Wilson has noted, within the context of this anthropogenically driven change, the 'Earth has at last acquired a force that can break the crucible of biodiversity' (Wilson 1992:343). We are reminded that knowledge can destroy as easily—perhaps more easily—than it creates.

For some, the concept of the noosphere stems from a yearning for the comfort of a world that entails a predetermined escape from the biosphere. Teilhard de Chardin's notion of noogenesis and link to the 'Omega point' points in this way. On the other hand, the idea of the noosphere, as founded upon and integral to the science of the biosphere, has been employed by scientists like Vernadsky to offer hope for the success of our species—not as an escape from natural laws but as an adaptation to them. In both senses, the noosphere can be seen as offering a way to extend our tenure on this planet or beyond.

THOMAS A.GOUDGE

T.A.Goudge (b. 1910) a Canadian, was professor of philosophy at the University of Toronto. He wrote extensively on the philosophy of biology and evolution, and was an expert on, among others, the work of Henri Bergson and Teilhard de Chardin. Goudge played a significant role in the development of the noosphere concept. Following P.Medawar's famous critique of Teilhard de Chardin's work in the journal *Mind* (1961), he responded with a plea entitled 'Salvaging the Noosphere' (1962), in which he suggested that the concept of the noosphere was promising 'for use in connection with evolutionary theory' and should therefore be salvaged. Goudge often used this concept in his work, but its most developed usage appeared in the following extract from his principal work, *The Ascent of Life* (1961).

THE ASCENT OF LIFE

At least two different interpretations of the concept of the noosphere have been given. Teilhard de Chardin uses the concept to refer to the *ensemble* composed of man and his various cultures. The 'marvellous sheet of humanised and socialised matter' includes *Homo sapiens* as its central constituent. It has come into being because man has produced culture and by producing it has transformed himself. Another way of interpreting the concept is due to J.S.Huxley, who limits its reference to the psychic dimension of culture. This dimension is affirmed to be man's distinctive environment, the milieu in which he characteristically lives. 'As fish swim in the sea and birds fly through the air, so we think and feel our way through this collective mental world…the noosphere or world of mind.' Here *Homo sapiens* is not a constituent part of the noosphere but an occupant of it. Both interpretations are defensible as models, although Teilhard de Chardin's may have certain advantages from a comprehensive point of view.

Within the noosphere the unique process of human evolution has taken place. Strictly speaking, 'human evolution is a singular product of interaction between biology and culture' (Dobzhansky 1956:28). For modern man has not ceased to be subject to the biological factors which were responsible for his emergence. These factors are still at work. But they are now less influential in determining his history than are cultural factors. Hence it is customary to refer to what *Homo sapiens* has initiated as cultural evolution. This has not replaced but includes biological evolution in a more complex process with various novel features.

There are countless cases in evolutionary history where members of a population have responded to the exigencies of a changing environment by developing organs needed to effect a new adaptation. Often these organs are extremely elaborate. While not extra-somatic, they are comparable with the tools invented by man to solve various practical problems. Cuénot has argued forcibly that this comparison is not just a vague analogy. There is a close empirical similarity, according to him, between many adaptive organs at the pre-human level and the 'inventions' which have characterised the technological dimension of human culture. If so, it seems appropriate to say that a remarkable degree of 'inventiveness' has been shown by organisms since the beginning of life. They have solved numerous problems of adaptation successfully. Yet, as far as we can tell, this inventiveness was, prior to the emergence of man, entirely unpremeditated. Organisms simply improvised with whatever materials happened to be available at the time.

Cultural evolution, on the other hand, has brought into existence a new form of inventiveness. This is the result of man's ability to devise and execute plans for the realisation of his purposes. These purposes are consciously entertained, often, as long-range objectives. The devising of plans calls upon the power of rational thought and constructive imagination. Their execution calls upon theoretical knowledge and technology. Moreover, this new form of inventiveness is far more efficient than the old. It has made possible large-scale control of the physical environment with a minimum of wastage. It works at a speed incomparably faster than anything found in purely biological evolution. During the last century, socially organised programmes of research have been responsible for accelerating the production of inventions at a staggering rate. 'The greatest invention of the nineteenth century was the invention of the method of invention' (Whitehead 1929: 141). The consequences of all this have not been uniformly advantageous to man, at least on a short-range estimate. There are some who argue that the disadvantages so out-weigh the benefits as to constitute another sign that man is approaching the end of his evolutionary trail. Even if those who argue in this way are right, it is still true that the new form of inventiveness resulting from the injection of conscious purposes and plans into evolution has opened a new (though perhaps short-lived) era in the history of terrestrial life.

There has appeared within the noosphere a new kind of heredity freed from the above physica limitations. Thanks to man's psychic capacities—particularly to his high learning ability and his power of using languages—a complex cultural legacy has grown up. This legacy is transmitted in some degree to each individual from his birth onwards. Because of the long pre-adult period through which he passes, be is able to learn at least the rudiments of the legacy, and he will normally be involved later in teaching them to other individuals. He will also, very probably, make some contributions of his own to the way of life of his community. Here, then, is a new kind of heredity which is cultural or, in the broadest sense, educational.

Unlike physical heredity, this new kind is not restricted to a single channel but is conveyed to individuals in myriad ways. 'Transmission and acquisition of culture occurs by conditioning, teaching, guidance, precept, indoctrination, learning, imitation, and finally by conscious choice. Cultural traits can be transmitted potentially to any number of persons regardless of descent relationships' (Dobzhansky 1956:33). New elements arise not 'blindly', as do genetic mutations, but consciously, as thoughts or ideas in individual minds. These ideas often reflect personal or social needs; and once in existence, they are continuously subject to human direction and control. The process of cultural change can therefore be far less 'tedious, difficult and wasteful' than the process of genetic change.

Language is the chief vehicle by which cultural heredity is disseminated. It is so different from the vehicle of physical heredity that any comparison of the two is likely to seem far-fetched. Nevertheless, there is perhaps some point in saying that with regard to flexibility, responsiveness to environmental nuances and the power to convey an immense range of items, language is immeasurably superior to genes and chromosomes. When used in a responsible way, it is admirably adapted, as they are not, to the storing of knowledge, which can become available to peoples remote from one another in space or time. The transmission of all phases of culture is more rapid than anything which can be achieved by genetic factors. In short, 'an incomparably more sensitive and receptive educational heredity is now at work in the noosphere. This is precisely the power needed to collect the over-abundant products and to feed the constantly accelerated progress of a self-evolving process' (Teilhard de Chardin).

Although it is essential to underline the differences between physical and cultural heredity, we should not forget that the two inevitably interact. Examples of this interaction are easy to adduce. Thus, the human sexual instinct is genetically determined, but its expression is governed by an intricate array of cultural factors. Similarly, the ability to use language has its basis in the human genotype; yet a man's mother tongue depends on the society in which he is reared. The phenomenon of language, indeed, illustrates another point worth remembering, namely that cultural heredity seems to be found in a primitive form among pre-human animals. We know, for instance, that honey bees employ a 'language' involving symbols of considerable complexity. Ants, termites and other insects establish highly organised social communities. There is evidence of the rudiments of reflective thought, including an impulse of 'pure curiosity', among monkeys and apes. Hence, while cultural heredity exists in a fully developed state only at the human level, it did not come into being *ex nihilo*. Moreover, its earliest manifestations must have had some adaptive value, and have been favoured by natural selection.

The third novel feature of cultural evolution relates to the process of speciation. As already indicated, when an animal population endures for a long period (i.e. not less than half a million years), it tends to split into branching systems of subgroups or varieties. Ecological differentiation and reproductive isolation result in some of these varieties becoming new species. This process is normally a gradual one that occurs under the statistical effect of genetic mutations. It leads to a continual increase in the diversity of living things.

The biological history of mankind has not exhibited this pattern. Huxley has expressed the matter by saying that whereas the evolution of most animals has been branching, the evolution of man has been reticulate. In the case of the human family, 'after incipient divergence, the branches have come together again, and have generated new diversity from their Mendelian recombinations, this process being repeated until the course of human descent is like a network' (Huxley 1941:6). Thus despite his geographical distribution over the whole planetary surface, man has continued to be a single species, a population combining an exceptional degree of diversity with a unity of biological structure. Within the noosphere, then, there has been no proper zoological speciation.

At the same time, as Teilhard de Chardin has persuasively argued, there has occurred another sort of branching, which has resulted in the formation of the different human cultures. These cultures may be regarded as constituting for the noosphere the equivalent and the true successors of zoological species in the biosphere. 'Fundamentally culturation is nothing but a "hominised" form of speciation' (Teilhard de Chardin 1956:109). Moreover, this hominised form of speciation opens up possibilities for human evolution which zoological speciation could not provide. At the biological level, a species as it begins to emerge becomes more and more isolated from surrounding species. It shows an increasing impermeability to them, so that it follows its own, quite separate, course of development. Cultures, on the other hand, show a high permeability. They influence, fuse with and even absorb one another. Planned inventions and techniques, scientific and philosophical ideas, moral and religious beliefs, legal and political practices, etc., readily cross cultural boundaries. This is the process known as 'acculturation'. Its occurrence makes possible the achievement in the noosphere of a kind of integration unknown in the biosphere. The limit to which the process can approximate is a single world culture in which man's biological unity would be matched by a spiritual unity, a harmonious integration of diverse elements.

The uniqueness of human evolution, then, consists *inter alia* in the fact that it has been subject to a new life of inventiveness, a new type of heredity and a new type of speciation. These features largely account for man's rise to a position of dominance in the living world, a position so distinctive it is little wonder that pre-evolutionary thinkers regarded him as specially created with all his powers fully developed. The new features of his evolution have given *Homo sapiens* not only an unprecedented control over the physical world but also the capacity (as yet largely inchoate) of controlling in some measure his own further development. Man alone among living things knows that he has evolved. Man alone is able to decide what direction or directions he desires his own future evolution to follow, and can set about acquiring the knowledge he needs to achieve the desired results.

This last consideration points to another facet of the human situation which must be mentioned. Although reflective thought is probably the most potent single factor in the noosphere, another factor has run it a close second, especially during the last five or ten thousand years. This is man's capacity to evaluate his own conduct and to guide it in the light of moral ideals. If we attempt to reconstruct the psychic life of the first representatives of *Homo sapiens,* it is fairly safe to conclude that just as they had only a rudimentary control of their physical surroundings, so they had no more than a rudimentary capacity to make moral judgements about their behaviour. During the millennia between the Pleistocene period and the present, there took place a gradual evolution of the latter capacity, which culminated in what Breasted has called 'the dawn of conscience'. Man's 'moral sense' began to operate more and more in his individual and corporate life. *Homo sapiens* became also *Homo moralis*. If he is ever effectively to control his own evolution, moral ideals or values will have to play a central part in determining its direction.

One other feature of man's evolution is that it is almost certainly incomplete. Several converging lines of thought support this view. For one thing, it is most unlikely that he has arrived at the end of his evolution in the relatively short time he has been on the Earth. Throughout human history, anywhere from half a million to a million years have been needed to produce a true species. But *Homo sapiens* is only about 100,000 years old. Hence, even allowing for the extreme rapidity of his evolution, it is difficult to believe that it has run its course so soon. Furthermore, there is evidence that bodily changes are still occurring in him. He continues to be somatically plastic and subject to the influence of genetic and selectional processes. With regard to his psychic powers, no great effort of thought is required to arrive at the conclusion that they are only partially developed. 'Man of today is probably an extremely primitive and imperfect type of rational being.' He is also a primitive type of moral being. Much of his personal and social behaviour exhibits traces of his animal ancestry, just as his physical body does. Yet occasionally he exhibits the power to make his actions conform to the highest moral ideals. For the most part he is indifferent to beauty. Yet he can catch fleeting glimpses of it and embody them in artistic form. Because of all this, the verdict must surely be that man is still in the making. Biologically, he is an adolescent being and does not yet have a fully developed set of *human* traits.

MARSHALL MCLUHAN

(Herbert) Marshall McLuhan (1911–1980) was a Canadian communications theorist and educator, associated with the University of Toronto from 1946 until his death. One of his best-known aphorisms, 'the global village', summarised his view of the increasing power of information, communications and networks to profoundly influence thought, culture and daily life across the globe and into the smallest community. A firm believer in the positive aspects of technology, McLuhan regarded many institutions—such as the printed book—as outdated and destined to disappear. For these reasons, he was keenly interested in ideas relating to transformation, and integrated the noosphere idea into his widely influential book *The Gutenberg Galaxy* (1962).

THE GUTENBERG GALAXY

Such awareness as this has generated in our time the technique of the suspended judgement by which we can transcend the limitations of our own assumptions by a critique of them. We can now live, not just amphibiously in divided and distinguished worlds, but pluralistically in many worlds and cultures simultaneously. We are no more committed to one culture—to a single ratio among the human senses—any more than to one book or to one language or to one technology. Our need today is, culturally, the same as the scientist's who seeks to become aware of the bias of the instruments of research in order to correct that bias. Com-partmentalising of human potential by single cultures will soon be as absurd as specialism in subject or discipline has become. It is not likely that our age is more obsessional than any other, but it has become sensitively aware of the conditions and fact of obsession beyond any other age. However, our fascination with all phases of the unconscious, personal and collective, as with all modes of primitive awareness, began in the eighteenth century with the first violent revulsion against print culture and mechanical industry. What began as a 'Romantic reaction' towards organic wholeness may or may not have has-tened the discovery of electromagnetic waves. But certainly the electromagnetic discoveries have recreated the simultaneous 'field' in all human affairs so that the human family now exists under conditions of a 'global village'. We live in a single constricted space resonant with tribal drums. So that concern with the 'primitive' today is as banal as nineteenth-century concern with 'progress,' and as irrelevant to our problems.

The new electronic interdependence recreates the world in the image of a global village. It would be surprising, indeed, if Riesman's description of tradition-directed people did not correspond to Carothers' knowledge of African tribal societies. It would be equally startling were the ordinary reader about native societies not able to vibrate with a deep sense of affinity for the same, since our new electric culture provides our lives again with a tribal base. There is available the lyrical testimony of a very Romantic biologist, Pierre Teilhard de Chardin, in his *The Phenomenon of Man:*

> Now, to the degree that, under the effect of this pressure and thanks to their psychic permeability the human elements infiltrated more and more into each other, their minds (mysterious coincidence) were mutually stimulated by proximity. And as though dilated upon themselves, they each extended little by little the radius of their influence upon this earth, which, by the same token, shrank steadily. What, in fact, do we see

> happening in the modern paroxysm? It has been stated over and over again. Through the discovery yester-day of the railway, the motor car and the aero-plane, the physical influence of each man, formerly restricted to a few miles, now extends to hundreds of leagues or more. Better still: thanks to the prodigious biological event represented by the discovery of electromagnetic waves, each individual finds himself henceforth (actively and passively) simultaneously present, over land and sea, in every corner of the earth.

People of literary and critical bias find the shrill vehemence of Teilhard de Chardin as disconcerting as his uncritical enthusiasm for the cosmic membrane that has been snapped around the globe by the electric dilation of our various senses. This externalisation of our senses creates what Teilhard de Chardin calls the 'noosphere' or a technological brain for the world. Instead of tending towards a vast Alexandrian library, the world has become a computer, an electronic brain, exactly as in an infantile piece of science fiction. And as our senses have gone outside us, Big Brother goes inside. So, unless aware of this dynamic, we shall at once move into a phase of panic terrors, exactly befitting a small world of tribal drums, total interdependence and superimposed coexistence. It is easy to perceive signs of such panic in Jacques Barzun, who manifests himself as a fearless and ferocious Luddite in his *The House of the Intellect.* Sensing that all he holds dear stems from the operation of the alphabet on and through our minds, he proposes the abolition of all modern art, science and philanthropy. This trio extirpated, he feels we can slap down the lid on Pandora's box. At least Barzun localises his problem even if he has 'no clue as to the kind of agency exerted by these forms.' Terror is the normal state of any oral society, for in it everything affects everything all the time.

Reverting to the earlier theme of conformity, Carothers continues: 'Thought and behaviour are not seen as separate; they are both seen as behavioural. Evil-willing is, after all the most fearful type of "behaviour" known in many of these societies, and a dormant or awakening fear of it lies ever in the minds of all their members.' In our long striving to recover for the Western world a unity of sensibility and of thought and feeling we have no more been prepared to accept the tribal consequences of such unity than we were ready for the fragmentation of the human psyche by print culture.

THEODOSIUS DOBZHANSKY

Theodosius Dobzhansky (1900–1975) was born in the town of Nemirov, Ukraine (then part of Russia) and trained as biologist. He emigrated to the USA at the age of twenty-seven, working at several research institutions including Columbia University, where he was professor of zoology. Dobzhansky became a leading geneticist and made key contributions in the Modern Synthesis (of evolution). His major book, *Genetics and the Origin of Species* (1937), established evolutionary genetics as an independent discipline. His ideas helped to uproot the generally held view that natural selection produced something close to the best of all possible worlds and that changes would be exceptional and gradual. It is in this light that Dobzhansky was very sympathetic to Teilhard de Chardin's views on the unique evolution of humankind as a species. The following extract from *The Biology of Ultimate Concern* (1967) reflects these views.

THE BIOLOGY OF ULTIMATE CONCERN

Among the two million or more species now living on Earth, man is the only one who experiences the ultimate concern. Man needs a faith, a hope and a purpose to live by and to give meaning and dignity to his existence. He finds himself in this world not by his own choice; he wants at the very least to avoid excessive suffering, and to capture the joys that may be within his reach. He desires to experience beauty and to shun ugliness. Above all, he yearns for love and relatedness to other persons; he wants to gain and to hold his self-respect, and if possible the respect and admiration of others. For this respect and self-respect, he may forgo pleasures and accept pain and ordeal.

This is necessary, but is this sufficient to make life meaningful? To some people this is sufficient, *faute de mieux*. But others, perhaps unreasonably, ask for more. If mankind is meaningless then my personal existence cannot be meaningful. I must discover a hope for mankind in its historical development. The purpose of my life can be only a small part of mankind's larger purpose. It is, furthermore, inconceivable for mankind to have meaning if the universe has none. Man is involved in mankind, mankind in life, life in the planet Earth, and Earth in the universe. The universe of which mankind is a part must be meaningful. Toynbee has expressed this beautifully as follows:

> The Human Spirit that dwells in each of us cannot refrain from seeking for an explanation of the Universe in which we find ourselves, and it insists that our *Weltanschauung* shall give the Universe significance without making the Universe centre round the Self. In logic it may be impossible to reconcile these two requirements. Yet, even in the teeth of logic, the Human Spirit will not consent to abandon its search for explanation of the mystery; and the new gospel revealed by the higher religions does seem to offer a reconciliation in the intuition that the meaning of Life, Existence, and Reality is Love.

Modern man must raise his sights above the simple biological joys of survival and procreation. He needs nothing less than a religious synthesis. This synthesis cannot be simply a revival of any one of the existing religions, and it need not be a new religion. The synthesis may be grounded in one of the world's great religions, or in all of them together. My upbringing and education make me biased in favour of Christianity as the framework of the synthesis. I can, however, understand people who would prefer a different framework. What is important is that the outcome must be truly a *synthesis*. It must include science, but it cannot be science alone, and in this sense it cannot be 'scientific'. It must include art and aesthetics, but it cannot be aesthetics alone. A faith which stands in flagrant contradiction with well-authenticated scientific findings cannot be right, but one in accord with such findings may nevertheless be wrong. Science discovers what exists; man has a longing to discover what ought to exist. The synthesis must be aesthetically satisfying, but it must also be rationally persuasive.

To satisfy man's hunger for meaning, not only man but the whole of nature, living and non-living, must be understood in their relatedness. For man, though he may be nature's spiritual vanguard and spearhead, is nevertheless only a small part of nature. Viewed on a cosmic time scale, he is very much a newcomer in the universe. He appeared probably about two million years ago, and the universe is five to ten billion years old [current estimates are twelve to fifteen billion years]. If man be regarded in some sense as a being above nature, it is certain that he has only recently emerged from nature, on the bosom of which he took shape.

Life is very much older than man, and the universe is much older than life. This points to an indispensable condition which any synthesis must satisfy in order to be acceptable. It must envisage man, life and the universe as changing rather than fixed, as parts of a single ongoing process rather than as three separate static realms. The central postulate of the synthesis must be that the universe and everything in it are evolving products of evolution. The synthesis must be an evolutionary synthesis.

The trend prevailing in the evolution of the noosphere, the noogenesis, is towards 'planetisation' and the 'megasynthesis'. This implies a radical convergence and integration of the physical, cultural and ideological branches of mankind. Branching, cladogenesis, has played a subordinate but important role in human evolution for the last one or two million years. It has created racial, national, social-class and cultural divisions. Like the diversity on the biological level, human diversity served to 'try everything so as to find everything'. The other side of the coin is not pretty; differences between men have often inflamed hatreds, cruelty, strife, war (hot and cold), genocide, concentration camps. Social Darwinists, as un-Darwinian as they are antisocial, contend that strife and all its grim consequences are merely the wages which mankind has to pay for progress. Some biologists still sing paeans 'in praise of waste'.

Teilhard de Chardin rejects social Darwinism. In noogenesis, the most powerful impetus towards progress comes not from strife or waste but from love. Replacement of strife by love already began in biological evolution, biogenesis. The classics of evolutionism described natural selection as a consequence of the struggle for existence. The 'struggle' does not, however, always mean strife. Our modern view of natural selection sees it promoted by co-operation as well as by competition. Moreover, the importance of co-operation relative to competition has been growing as biological evolution has advanced. By and large, it is greater among higher than among lower animals.

The 'planetisation' of mankind is, in Teilhard de Chardin's view, made inevitable by the swiftly increasing facility of communication and by increasing knowledge. Mankind inhabits the surface of only one rather small planet. Unless means are found to emigrate and to colonise other planets, people will finally have to learn to live harmoniously or at least peacefully with more and more numerous neighbours. The main point here is not only that population densities have grown and are growing, but even more that technological inventions facilitate and make possible almost instantaneous transmission of information and ideas to every corner of the world. Knowledge promotes spiritual growth as well as unification—'to be more is in the first place to know more.'

Teilhard de Chardin's prophecies of eventual planetisation and megasynthesis may seem to be daydreams of a visionary, taking no account of the forces of evil and of the darker sides of so many human natures. He realised that his ideas are liable to be misconstrued as advocating a reduction of mankind to a state of vapid uniformity for some benign stereotype. Nothing was more alien to his thought. He faced the formidable problem of how to reconcile unanimity and megasynthesis with individuality, freedom and what Brinton so aptly called 'multanimity'. It is best to quote his own words:

> The Earth not only covering itself with myriads of grains of thought, but enclosing itself in a single thinking envelope, to become functionally a single vast 'grain of thought' on a planetary scale. The multitude of individual reflection, grouped and mutually reinforced in the act of one single unanimous Reflection.

Far from becoming all alike, or undergoing amalgamation or coalescence, as the noogenesis approaches the consummation of megasynthesis the human personalities are expected to grow in depth and to maximise their individual uniqueness. The meaning of an individual life is its inclusion in the evolutionary upswing of noogenesis. Even on the animal level, individuals are not interchangeable, because they are neither genetically nor developmentally identical. Noogenesis leads to affirmation, not to levelling of individuality.

Is there anything more than Teilhard de Chardin's burning faith to bear out the bright hope of the megasynthesis? Can one rule out the polar opposite: disunion, dispersion and arrogant self-assertion of the individual against mankind? The antithesis to megasynthesis is the ideal of the Dostoyevskian Grand Inquisitor and the Nietzschean Superman. Without specifically mentioning Dostoyevsky or Nietzsche, Teilhard recognises the danger. Human freedom also enables man to choose a direction away from megasynthesis. Mankind may become a dust of independent and dissociated sparks of consciousness. Spiritually matured mankind should be able to extricate itself from such a blind alley, because man is the only form of life which need not accept the direction of the evolutionary forces upon him, but can direct his evolution.

It is evidently the inspiration of a mystic, not a process of inference from scientific data, that lifts Teilhard de Chardin to the heights of his eschatological vision. Yet he remains a consistent evolutionist throughout. The point which he stresses again and again is that man is not to be a passive witness but a participant in the evolutionary process.

DORION SAGAN

Dorion Sagan (b. 1959), an American science writer, studied sciences at Boston University. In conjunction with his writing partner (and mother) Lynn Margulis, Sagan (son of the astronomer Carl Sagan) has played a crucial role in spreading awareness and discussion of the biosphere, the noosphere, Gaia and related concepts. His book *Biospheres* (1990) met with success and integrates a number of issues touched upon in this anthology, especially the idea of the potential for creating new biospheres within, or beyond, our own.

BIOSPHERES: METAMORPHOSIS OF PLANET EARTH

How ever unsuccessful the Pharaohs may have been, now the Earth itself seems to be opting for a form of propagate formation. The biosphere is 'adopting' these strategies, not so much out of conscious design as out of the incessant evolution of the beings within it. This fairly hieroglyphic process is latent within the structure of the Earth. Propagate formation, the 'seeding' of the biosphere prior to its dissemination, is as natural as a larval metamorphosis, the shedding of old hard parts in preparation for a new life. Language, technology, humanity, physicality, meaning—all of these are included latently and blatantly in the workings of the Earth, in the global regime. Each successful encapsulation of Earth life in the technological extrastructure of a biosphere represents an Earth 'seed'—part of a podforming or blossoming process that is more central to life than are plants, fungi or animals. By forming biospheres, Earth enters a stage of propagate formation preparatory to dissemination and cosmic metamorphosis. In such a dissemination and metamorphosis it becomes clear that technology was never anything but natural.

This latest exquisite twist in the spiral of being affords us sudden insight into our past. The twist is a turning into the 'technological spring'. Entering this turning we find that 'our' past is not our past so much as a past shared with life as a whole—though civilisation has forgotten this in the continuing isolation of its agricultural, industrial and technological phases.

We find that we belong inside a living world, an incalculable maze of responsive entities, all subtly impinging on us. Biospheric regulation, at a physiochemical level that can never be separated from our emotional and mental lives, represents a new explanatory principle, a new way to understand. Like all great systems of thought, this explanatory principle even hints at why we do not understand—because we are engulfed in a living thing literally outside of and containing our comprehension.

In another sense, the explanatory principle is not really new, for the idea that the Earth is alive belonged among the deepest beliefs of our ancestors. Nor, strictly speaking, is the biosphere a new form of life. Because the biosphere has maintained itself in a dynamic equilibrium for almost one-third the age of the universe, it is difficult to argue that it has just awoken (through the achievement of a critical living mass) from some inanimate slumber. Rather, it has been alive for aeons. The new form of life is not the biosphere but biospheres, its miniaturised offspring. The new form of life represents only secondarily a human renaissance. Primarily it is the rebirth of the Earth itself, the breaking up of the Earth into earths. If the Earth is looked at as a flower, then the formation of ecospheres, biospheres and other self-sustaining communities represents the putting to seed of this flower. The seeds are propagating but have not yet been disseminated. Space still looks too cold to dive into. In the chronically subjective sense of time that waits for us beyond the orbit of this planet it is not even May. What time is it? It is no time. Spring is still coming.

Folsomes' flasks, ecospheres, New Alchemy and Ocean Ark designs, Soviet Bios projects, and Biosphere 2 represent the first buds and blossoms of a cosmic springtime in which the Earth itself will bloom into the space between the stars, copying itself over in miniature, descending through the heavens, as Darwin might put it, with modification. Several points must be made about this process, which seems at first so dependent upon our skills and motivations as technological humans. The first point is that biospherically humanity is not only dispensable to the metabolism of the Earth but to its reproduction as well. Only the timetable of biosphere reproduction would be upset by the absence of humanity. In the absence of humanity other organisms would evolve or re-evolve technological prowess. The fossil record reveals increasing cranial capacity in a wide range of organisms, especially the mammals. The augmentation of neural networks identified as the cause of the increased intelligence is widespread, not solely a human phenomenon. Humanity is thus not the last word but an index of increasing planetary complexity and global intelligence. Evolution-arily, intelligence is expanding. In the absence of people, many species that are ecologically repressed by our activities would be free to expand into new territories. Squirrels, monkeys, racoons all come to mind as animals with the potential over evolutionary time to redevelop technology. Their descendants could even discover in the future fossil record our technological detri-tus, which might allow them to retrace our steps or make short cuts in the task of technological advancement. The idea of a squirrel or a racoon sitting at a computer keyboard sounds absurd; however, we are not talking about these relatively dextrous animals but about their descendants, whom they need resemble only remotely. In retrospect, science fiction writers realise they have often erred in making predictions that were not bold enough. The destiny of technology as a planetary rather than human matter, in the hands (or grippers) of whatever species, may belong to this category, realistic to the extent it sounds absurd. Any brainy technological animal would develop tribes and civilisations and, due to the overcrowding on Earth that would eventually develop, would be forced along the same opening paths that currently are bringing us as humans to the brink of biosphere formation and geogenesis.

Ultimately we are not required to enable the cosmic spread of planetary life. From a biospheric viewpoint, humanity must be considered not transcendent but only transient. We, too, will pass. Into what we do not know. Now we occupy centre stage, the very thick of things. Tomorrow, who knows? We will most likely be gone, or so mutated into remnants, traces of our former selves, that we would not recognise our very progeny. One cannot say that humankind is not a special species. We are. But we are not that special. As in space, the human form, should it endure at all, will evolve, and be pantropically transformed beyond recognition. The whole history of the human race could be erased, appearing only as traces in forms of future life that defy the imagination, except in so far as we may predict the existence of some sort of structural unity on the level not of multicellular organisms but of multiorganism biospheres, recycling biosystems taking after the Earth.

On Earth or in space, communication between and among biospheres would be advantageous and would present biospherians not only with new technological challenges but also with the possibility of achieving major technological breakthroughs. If communication between neurons (nerve cells in the brain) is the physiological basis of mind, what might accrue from the cosmic intermingling of biospheres? In chemical and electromagnetic communication separately performing biospheres might ally to become the basis of still larger and more complex life forms. These, in turn, might provide the basis for a cosmos which is, not only in limited parts, but through and through, alive. Moreover, this very possibility suggests that the principle of a totally living universe is not foreign to the nature of the universe but may, rather, be part of its essence. Man, that is, may represent the groggy arising or coming-to-self of a universe already always, in its slumbering or conscious totality, alive.

On an ecologically ravaged Earth, or in sterile interstellar space, what will it be like outside the protective envelope of biospheres? Will the new outside of life be as important in the intellectual development of future beings as gap junctions and synapses are thought to be in the thinking of the human brain?

EDWARD GOLDSMITH

Edward Goldsmith (b. 1928), a Franco-English writer, activist and publisher, has been an outspoken leader of the environmental movement since the 1960s. He has played an important role in the development of the radical ecology school, notably in the publication of the *Blueprint for Survival* (1972) and in founding the journal *The Ecologist,* of which he is currently editor-in-chief. Goldsmith has been a long-time promoter of discussions relating to the biosphere and Gaia. However, his view of the desirability (at least in terms of sustainability) of vernacular societies most probably makes him a sceptic of an optimistic view of the noosphere's potential—at least in terms of technology. In his most recent work, *The Way: An Ecological World View* (1996), extracted here, he presents a poetic and deep ecologist vision of society's future, inspired from both physical and spiritual sources.

THE WAY: AN ECOLOGICAL WORLD VIEW

Even if it be admitted that all natural systems are intelligent, thus allowing the term to be used in a meaningful way, it will still be maintained by many that man remains unique as he alone displays consciousness — and if other living things are not 'conscious', how can their behaviour be anything but robot-like, and therefore random unless managed by an external agent? If non-human animals are not conscious, then the extraordinary feats of tropical insects described by Major Hingston can clearly only be the work of blind instinct, not of intelligence.

Medawar considers that only human behaviour can be genuinely purposive because only man is conscious. Erich Jantsch argues that evolution is usually seen as the history of the organisation of matter and energy. However, it can also be viewed as 'the organisation of information into complexity of knowledge,' This 'may be understood as the evolution of consciousness,' the highest state of evolution, corresponding to Teilhard de Chardin's noosphere. 'Once this state is achieved,' he writes, 'the whole universe can be identified with consciousness and it is this consciousness that determines the course of further evolutions.' In this way, by identify-ing the universe with human consciousness, Jantsch has reconciled—to his satisfaction at least—the notion that the universe is self-organising with the idea that conscious man can determine his own evolution. The Pro-methean enterprise is thus fully justified and man, the creator of the new world it brings into being, is effectively deified. Indeed 'it is because man possesses consciousness,' Jantsch tells us, 'that mankind is not redeemed by God, but redeems itself.'

Along with Herrick, I think we can best regard consciousness as a state of awareness, associated with enhanced mental activity, which may be required when it is necessary to identify and interpret very carefully an important environmental challenge to which an immediate and often innovative response is required—the unconscious mind being capable of dealing only with routine matters.

Thorpe is perfectly willing to accept that man is not the only living thing to possess this faculty. He sees the same degree of consciousness in the higher animals (chimpanzees, like other higher animals, denoting specific states of mind by different facial expressions) and the possibility of its presence far down the animal scale. Conscious awareness, he feels sure, provides some adaptive advantage over the purely unconscious appre-hension of the environment. Julian Huxley talks of the 'mind-intensifying' organisation of animals' brains. He sees this as providing a fuller awareness of both outer and inner situations and as enabling living things to deal with chaotic and complex situations.

For some authors, all natural systems are endowed with consciousness, or 'bio-conscience'. Teilhard de Chardin goes so far as to attribute a primary consciousness to the atom. This may be going too far. It is probably more realistic to see consciousness as a feature of organisms—embryonic among the simpler organisms, and more highly developed with the evolution of the brain and in particular the neo-cortex. It is also important not to overrate the importance of consciousness. As motivation research has revealed, humans themselves are not conscious of their basic underlying motivations, the reasons they give to explain their actions being largely those that best serve to rationalise them. It is indeed one of the principal failings of modern epistemology that it is concerned only with conscious knowledge, completely ignoring the unconscious or ineffable knowledge that plays an incomparably greater role in shaping our world view and in determining our behaviour pattern and hence our influence on the Gaian hierarchy.

No amount of empirical or theoretical evidence is likely to persuade mainstream scientists or other proponents of the world view of modernism to accept any of the principles set out in this book. If eventually they are to be accepted, it will not be because they will by then have been 'proved' to be true in the scientific sense of the term, but because the reigning paradigm or canonical knowledge will have changed to such an extent that they will have become consistent with it. Until this occurs these principles are, in the words of Gunther Stent, 'premature', in that 'their implications cannot be connected by a series of simple logical steps to "canonical" or "generally accepted knowledge" with the current paradigm.' In this way, Gleason's 'individualistic concept of plant association' was rejected when ecology was still a holistic discipline, only to be adopted once it had been brought into line with the paradigm of science.

At the same time, no amount of empirical or theoretical 'evidence' as to the untenability of a hypothesis can lead scientists to abandon it if it is part of current wisdom, the reigning paradigm, or canonical knowledge. However, once it has ceased to enjoy that status, because it has been transferred to another paradigm, then the hypothesis will simply die a natural death. In this way, hypotheses that have achieved the status of 'scientific facts' have, in the space of a few years, been 'completely discredited and committed to oblivion, without ever having been disproved or even newly tested.' This is, as Polanyi points out, 'simply because the conceptual framework of science had meanwhile so altered that the facts no longer appeared credible.'

Clearly then, so long as we argue within the accepted 'conceptual framework', or the reigning paradigm, or the canonical knowledge of the day, we can never persuade people either to accept a new idea or to abandon an old one. 'Demonstration,' Polanyi insists, 'must be supplemented by forms of persuasion which can induce a conversion.' This is the crux of the matter. It is the conceptual framework itself which must be changed, and this, as Polanyi suggests, means converting people to a new conceptual framework. For people to accept the principles listed in this book, it is the paradigm of science itself that must be abandoned and hence the world view of modernism which it faithfully reflects; and they must be replaced by the world view of ecology. Such a conversion, or generalised paradigm shift, involves a profound rearrangement or recombination of the knowledge that makes up our world view. It must affect its very metaphysical, ethical and aesthetic foundations. It must in fact, involve a change akin to religious conversion to which—as Kuhn, Polanyi and more recently Rupert Sheldrake have noted —a paradigm shift, even one occurring in a purely scientific context, can be realistically compared.

However, one must distinguish between a real religious conversion and a nominal one. All too often a religious conversion is of a superficial nature; it is largely the terminology used in addressing the world of gods and spirits which changes and little else. A real conversion seems to occur in quite specific conditions, which psychologist William Sargant has compared with those who live stressfully, to a nervous breakdown, and also to the brainwashing which prisoners of war are often subjected in order to make them confess to crimes that they have not committed, and it seems probable that the electric shock treatment often given to psychiatric patients fulfils a similar function. This explains why religious conversions are often preceded by physically and mentally exhausting ceremonies, the taking of alcohol and drugs and the achievement of trance-like states, as in the famous Dionysian rites. All this gives rise to a state of mind that may be functionally analogous to a nervous breakdown, one in which people can be inculcated with a new world view.

It may be that the same process occurs — though in a less dramatic way—in new environmental conditions such as those created by economic development, to which a traditional cultural pattern proves to be unadaptive, causing people to question and eventually to abandon the associated world view with which they and their ancestors have been imbued for centuries or even millennia. Such people pass through a highly stressful, indeed, psychically intolerable experience, for the human psyche abhors a cultural vacuum, as it does the terrible social disorder to which it must give rise.

We cannot afford to wait and see whether such movements will develop into revitalist cults that are powerful enough to transform our society. Instead, we should work towards their development by helping to create conditions in which they are likely to emerge…we must do everything to help to recreate the family and the community, and above all a localised and diversified economy based on them, reducing in this way our increasingly universal dependence on a destructive economic system that, in any case, is in decline and may well be close to collapse.

RICHARD DAWKINS

Richard Dawkins (b. 1941) is a British biologist and Professor for the Public Understanding of Science at Oxford University. He is the author of several important books on evolution, including *The Blind Watchmaker* (1986) and *Climbing Mount Improbable* (1996). Dawkins has been one of the most outspoken critics of the Gaia hypothesis, asserting that the idea goes against the principles of neo-Darwanism and is based on mysticism rather than science. On the other hand, in his influential book *The Selfish Gene* (1976), Dawkins launched the theory of 'memes' (cultural transmitters and replicators), which has considerable resonance with some ideas relating to the noosphere and which has attracted significant attention and interest from a wide variety of thinkers. Dawkins' view of a meme framework, as blind agents of cultural transmission, offers an opposite view to Teilhard de Chardin's perspective of predestined evolution through the noosphere. As to the Vernadskian view of a managed planet through the noosphere, memes would appear only to paint an unpredictable picture.

THE SELFISH GENE

MEMES: THE NEW REPLICATORS

Most of what is unusual about man can be summed up in one word, 'culture'. I use the word not in its snobbish sense, but as a scientist uses it. Cultural transmission is analogous to genetic transmission in that, although basically conservative, it can give rise to a form of evolution. Geoffrey Chaucer could not hold a conversation with a modern Englishman, even though they are linked to each other by an unbroken chain of twenty generations of Englishmen, each of whom could speak to his immediate neighbours in the chain as a son speaks to his father. Language seems to evolve by non-genetic means, and at a rate which is orders of magnitude much faster than genetic evolution.

I think that a new kind of replicator has recently emerged on this very planet. It is staring us in the face. It is still in its infancy, still drifting clumsily about in its primeval soup, but already it is achieving evolutionary change at a rate which leaves the old gene panting far behind.

The new soup is the soup of human culture. We need a name for the new replicator, a noun which conveys the idea of a unit of cultural transmission, or a unit of imitation. 'Mimeme' comes from a suitable Greek root, but I want a monosyllable that sounds a bit like 'gene'. I hope my classicist friends will forgive me if I abbreviate mimeme to meme. If it is any consolation, it could alternatively be thought of as being related to 'memory', or to the French word même. It should be pronounced to rhyme with 'cream'.

Examples of memes are tunes, ideas, catch-phrases, clothes, fashions, ways of making pots or of building arches. Just as genes propagate themselves in the gene pool by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation. If a scientist hears or reads about a good idea, he passes it on to his colleagues and students. He mentions it in his articles and his lectures. If the idea catches on, it can be said to propagate itself, spreading from brain to brain. As my colleague N.K.Humphrey neatly summed up an earlier draft of this chapter: 'Memes should be regarded as living structures, not just metaphorically but technically. When you plant a fertile meme in my mind you literally parasitise my brain, turning it into a vehicle for the meme's propagation in just the way that a virus may parasitise the genetic mechanism of a host cell. And this is not just a way of talking—the meme for, say, "belief in life after death" is actually realised physically, millions of times over, as a structure in the nervous systems of individual men the world over.'

For more than three thousand million years, DNA has been the only replicator worth talking about in the world. But it does not necessarily hold these monopoly rights for all time. Whenever conditions arise in which a new kind of replicator can make copies of itself, the new replicators will tend to take over, and start a new kind of evolution of their own. Once this new evolution begins, it will in no necessary sense be sub-servient to the old. The old gene-selected evolution, by making brains, provided the 'soup' in which the first memes arose. Once self-copying memes had arisen, their own, much faster, kind of evolution took off. We biologists have assimilated the idea of genetic evolution so deeply that we tend to forget that it is only one of many possible kinds of evolution.

Some memes, like some genes, achieve brilliant short-term success in spreading rapidly, but do not last long in the meme pool. Popular songs and stiletto heels are examples. Others, such as the Jewish religious laws, may continue to propagate themselves for thousands of years, usually because of the great potential permanence of written records.

Memes and genes may often reinforce each other, but they sometimes come into opposition. For example, the habit of celibacy is presumably not inherited genetically. A gene for celibacy is doomed to failure in the gene pool, except under very special circumstances such as we find in the social insects. But still, a meme for celibacy can be successful in the meme pool. For example, suppose the success of a meme depends critically on how much time people spend in actively transmitting it to other people.

One unique feature of man, which may or may not have evolved memetically, is his capacity for conscious foresight. Selfish genes (and, if you allow the speculation of this chapter, memes too) have no foresight. They are unconscious, blind, replicators.

It is possible that yet another unique feature of man is a capacity for genuine, disinterested, true altruism. The point I am trying to make now is that, even if we look on the dark side and assume that individual man is fundamentally selfish, our conscious foresight—our capacity to simulate the future in imagination—could save us from the worst self excesses of the blind replicators. We have at least the mental equipment to foster our long-term selfish interests rather than merely our short-term selfish interests.

We are built as gene machines and cultured as meme machines, but we have the power to turn against our creators. We, alone on Earth, can rebel against the tyranny of the selfish replicators.

KENNETH BOULDING

Kenneth Boulding (1910–1993), an English-born American economist by training, developed a wide range of interests over a long, immensely prolific and highly interdisciplinary academic career as professor of economics at the University of Colorado. He also served as president of the American Economic Association and American Association for the Advancement of Science. Boulding was an early supporter of 'systems thinking' and the human and social scientific dimensions of environmental issues. Pursuing these and other lines of thought, he made some important departures from mainstream economics. *Ecodynamics* (1981) is based loosely on Teilhard de Chardin's concepts, but Boulding views the noosphere as representing forms of genetic or cultural information—now surpassing the power of DNA information to transform the planet—and ignores the spiritual aspects.

ECODYNAMICS: A NEW THEORY OF SOCIETAL EVOLUTION

As we move into biological evolution, we find two different modes of genetic structure. There is what might be called 'biogenetics', which is the genetic structure of the gene and of DNA, a programme for producing the corresponding organism or phenotype and for producing the nervous system, which impels or at least predisposes towards certain types of behaviour. Once we have reasonably complex nervous systems produced by biogenetics, however, another process emerges, which might be called 'noogenetics'. This is the structure within the nervous system which the individual organism has to learn, often of course from its parents, but also from its other environments. No one really knows when learning began in the biosphere. It is certainly important in all species that have parental care of offspring. The possibility of learning from the general environment, even in quite primitive species, should also not be overlooked. Certainly many species of bird have to learn at least part of their birdsong, kittens learn a good deal about how to be a cat from their mothers, and a kitten raised by a dog can have peculiar behaviour patterns. When we get to the human race, of course, noogenetic patterns predominate. Biogenetics produces an extremely unstructured human nervous system with fantastic potential for learning. We really know very little about the biogenetics of the human nervous system. It certainly can possess biogenetic defects, and biogenetic origins may produce structures that make some learning processes easier than others, but on the whole the noogenetic element is overwhelmingly dominant. If nobody spoke to children, if all schools and universities were shut down for as little as one or two generations, the human race would be virtually identical biologically to what we are now, but its culture would, if it survived at all, revert to the Stone Age.

Once we get to the human race noogenetics dominates biogenetics to a remarkable extent. We know very little about the relation between the human genetic structure and the human phenotype apart from a few abnormalities. We know a little about genetic defects in the human being and practically nothing about genetic excellence, particularly in the brain. Indeed, in the present state of human knowledge eugenics, the theory that better human beings can be bred by careful selection of mates is an illusion, except perhaps at the level of obvious defects such as haemophilia. The processes by which each generation of human beings learns from the last are far more important than the process by which biological genes are inherited.

The genetic structure of an individual human can certainly produce certain limitations in the learning process. For instance, a person who is genetically tone deaf, if there is such a thing, would certainly not be a great musician. For the most part, however, these genetic learning obstacles are probably not large and could be overcome by improvements in human learning techniques. It seems clear that for the most part genetic limits on learning are quite rarely reached. It is the learning patterns themselves that are self-limiting. The human mind is a vast ballroom. Most of us can paint ourselves into a tiny corner of it because we learn not to learn. It is very rare that we press against the genetically imposed walls.

What is puzzling is the dynamics of the system. What are its patterns of change, if any? It is what it is today because of what it had become in the past. Can we look at the whole history of the system, as it spreads from the first human beings over time and space to the present day, and ask ourselves what patterns can be perceived in it? This is a particularly difficult problem because the integrative system for the most part consists of species that inhabit the structural forms of the human nervous system. Material artefacts can be observed and they leave traces and records. Organisational artefacts can also be observed, though less easily, and they also leave very extensive traces and records. Love and hate, dominance and subordination, assent and dedication, legitimacy and illegitimacy, and the whole vast world of symbols that makes up the complex image of human identity is a subterranean ecosystem hidden beneath the hard surface of skulls, apparent only when it results in communications and records of communications, which interacts only through communications. No person has ever been inside another skull. It is not surprising that this is a world of cloudy obscurity, unlike the sharp, clear ecosystems of plants and animals or even of knives and forks, corporations, churches, and states.

Yet the 'integry' is an essential part of the genetic structure of society. It is part of the noosphere. The products of society in terms of material artefacts or social organisations cannot be understood without it. As part of the noosphere, it is parallel in social systems to what the genosphere is in biological systems. Because of the enormous power of communication, however, it is far more complex than the genosphere. The genosphere consists of information shut up in sperm cells and egg cells, mixing occasionally in sexual reproduction, which changes very slowly through mutation or through the crossing over of chromosomes. The noosphere, by contrast, of which the integrative system is a vitally important part, is not shut up in the four billion individual skulls that constitute, as it were, the cells of the system, or even in the seventy or so billion human skulls that have ever been made. It is the great network of interaction and communications between mines the content of each. Human minds, therefore, constitute almost a single social genome extending over the whole surface of the Earth and back into time as far as the these individual minds that largely deter- records permit.

NIKITA N.MOISEEV

Nikita N.Moiseev (b. 1917) is one of Russia's leading environmental scientists. He is a senior academician and member of the Russian Academy of Sciences, Agricultural Academy of Natural Sciences and International Academy of Astronautics. He is also co-chairman of the Supreme Environmental Council of the Russian Federation and president of Green Cross Russia. He is the author of numerous books and articles on the biosphere and noosphere and has played a major role in promoting awareness of these concepts, and particularly their association with Vernadsky. Equally important has been Moiseev's role as leader and collaborator in several international research efforts—at IIASA, UNESCO, etc. —where he has also promoted these concepts. In the piece that follows, written for UNESCO in 1989, Moiseev provides a broad perspective on the noosphere and asserts that an urgent transformation of society through education will be necessary to avoid massive environmental and other looming problems.

REFLECTION ON THE NOOSPHERE—HUMANISM IN OUR TIME

THE STUDY OF THE NOOSPHERE —CONTEMPORARY HUMANISM

The twentieth century will probably go down in history as the century of warning, the one in which the development of the human race took it right up to the brink of possible global disaster.

The human potential—knowledge, will and social structures—that had emerged over thousands of years all took on completely new possibilities at the time of the Industrial Revolution. Having acquired the enormous energy reserves of the fossil fuels, humankind directed all its strength to the applying of them with maximum effect. People's lives began to change, imperceptibly perhaps at first, but the speed of change gradually increased. The nineteenth century bears witness to that. Nevertheless, the beginning and the end of that century were by present-day standards not so very different from each other. Admittedly, steamships and railways had appeared on the scene, but horse-drawn carriages were still in use, and the cavalry still proudly rode on parade. The lavish apparel of the monarchs and the epaulettes of the generals somehow symbolised stability and the time-honoured traditional nature of standards of conduct, thought and ideals. Only the most far-sighted greeted the advent of the twentieth century in the realisation that the old order had gone once and for all.

The twentieth century has been the century of a radical break with all our conventional ideas and, above all has seen the incredible, fantastic (no adjective is too strong here) forward leap of technology — and of the productive forces of society. Every technological innovation, such as radio, television, computers, space flight, the harnessing of atomic energy, genetic engineering, plastics and countless others, has changed our lives out of all recognition and has given us advantages about which people could not have even dreamed even a hundred years ago. Our whole way of life, our thoughts and the way we perceive the world have changed unrecognisably during this century. Completely new horizons have opened up to us. However, with the new opportunities science and technology have given us have come new difficulties and new dangers that we did not even conceive of a few decades back. Chief of these is our newly acquired ability to annihilate the race.

We could do it in no time at all if we were to have a nuclear war. Alternatively, we could do it by a process of slow and agonising degradation if, having avoided a nuclear disaster, we failed to learn to live in harmony with nature and continued to pollute the environment, deplete the gene pool, cut down the tropical rain forests and continue with similar abominations.

The last quarter of a century has seen the emergence of a series of facts to which it is impossible to shut one's eyes. In 1983, scientists demonstrated that the consequence of a nuclear war would be a nuclear winter and a nuclear night. In 1986, the tragedy of Chernobyl occurred, giving us a glimpse of what can happen when an atomic power station suffers even relatively slight damage.

It is not just the atom, however, that is threatening us today. Acid rain, which has killed the fish in the cold lakes of Scandinavia, the pollution of Lake Ladoga, Lake Baikal and the Great Lakes of North America, and the turning of the Rhine into a sewer—these facts surely tell us that we are approaching the limits of what is permissible.

Unlike people living in developed countries at the end of the last century, we know that the approaching twenty-first century is going to hit us with a new flood of extremely difficult problems—for which we must prepare today.

This is why it is now not only futurologists who give serious thought to the future and what lies in store for us in the next few decades: it is also scientists in the most varied disciplines and, quite simply, all people of any intelligence. Human beings possess reason and will. They are not simply spectators of events but active participants in them. Nature has endowed us with power that we can, in general, use at our discretion—and that power is growing all the time. On what we do today, moreover, largely depends what will happen to us tomorrow. To give thought to the coming days and to the choice of a strategy for development is becoming an urgent requirement for society to help to establish the intellectual and moral climate necessary to change the course we are following—for if it does not change it can lead us only to catastrophe.

This circumstance is stimulating intellectual life, the establishment of an array of alternative paths of human development and a new view of the world. Great support has been provided by the ideas of V.I. Vernadsky and Pierre Teilhard de Chardin, which are today not only of general philosophical and methodological interest but of practical significance too.

THE CONCEPT OF THE NOOSPHERE

The concept of the noosphere is also the concept of a new humanism. In addition, if you like, it is a new scientific paradigm requiring the searcher to change from being a spectator on the sidelines into an active constituent of the process he is studying. It is a doctrine that takes us back to the sources of our European civilisation and to the ideas of the ancient Greeks about the unity of the gods, humankind and the cosmos. The ideas about humans forming a community with the gods and the cosmos and of being close to them and the conception of their unity—a human being even being able to become a god—were lost at the time of the Renaissance and in the Age of Reason, when the foundations of the contemporary scientific perception of the world were laid down—those principles of scientific thinking that have led to the successes of modern physics and natural science. Nature is an entity in itself. It exists independently of human beings, following the laws appropriate to an automation that has been set in motion and keeps going for all time. Human beings are just spectators on the sidelines. They also exist as entities, in all their irrationality. A person studying the laws of nature is like an ento-mologist studying the alimentary canal of an insect under a magnifying glass. The basic model of scientific thinking that gradually established itself after the scientific revolution of Copernicus, Galileo and Newton held that only that which did not depend on human beings was objective. The assertion of rationalism, to which contemporary science owes its successes, thus at the same time brought an end to unity and separated men and women from the world around them. Such is the contradiction of development, new achievements being always accompanied by losses of some sort.

Kant was the first to give consideration to this dualism, although it is precisely with his name that one of the first irrational constructions of those times is associated—the Kant-Laplace hypothesis, which explains how the Solar System was formed. The rationalism of the eighteenth century thus began to be criticised from the moment of its birth.

The well-known Russian writer I. Odeovsky wrote in the middle of the nineteenth century that the age of rationalism had brought us to the gates of truth but that it had not been given to it to open them. The return to the lost unity has been long and complicated. It has been achieved chiefly through the development of science itself, which has brought to light all the many facets of the various links. It has also been achieved by the emergence of new philosophical studies and art, which have all contributed to the formation of a new view of the world. In my opinion, in the search for the path to unity a significant contribution has been made by the classical Russian literature of the last century, that of Gogol, Dostoyevsky and Tolstoy. In the study of the noosphere alone there has occurred the necessary synthesis of human beings and the cosmos, and the sciences have begun to merge into a single science, the science of humankind. The establishment of the doctrine of the noosphere is a turning point in the formation of a new philosophy concerning the emergence of a new contemporary humanism.

The cornerstone of the theory of the noosphere is to be found in the idea of the unity of nature, the Earth and the cosmos and in the idea of their deep-seated interdependence. We are no longer spectators on the sidelines but form a constituent part of the universe and are able to influence the whole character of its development. We study nature from within, uninterruptedly, and influence it by our very study. The fate of humankind has merged into the fate of nature and, as an integral part of it, is governed by the fate of nature. The biosphere may indeed perhaps exist without humankind, but humankind outside the biosphere is nonsense, at any rate in present-day circumstances. This means that together with the growth of the might of the human component of the biosphere the need is also growing rapidly for a worldwide (perhaps even universal) strategy for humankind.

For this, however, a new understanding of the place of humankind in the biosphere and of the inevitability of a new way of life are needed: in other words, the new morality of contemporary humanism, the morality of the age that is dawning in the history of humankind. In it the limitation of space and resources and the fragility of the biosphere itself are beginning to oppose the increasingly unlimited might of civilisation.

This new morality must be based on two key ideas concerning the unity of humankind and its responsibility for the fate of the planet and, above all, of the biosphere. Responsibility for the fate of nature is now becoming responsibility for the fate of humankind and of civilisation. These ideas are fundamental to the doctrine of the noosphere.

The ideas put forward by Teilhard de Chardin and Vernadsky about the noosphere were not absolutely identical. Their interests, too, as researchers and thinkers, likewise did not coincide. Teilhard de Chardin proclaimed the principle of the unity of humankind, a principle that called for the overcoming of racial prejudice, individualism and a number of other faults of contemporary society. In affirming these principles, nevertheless, he came closer than Vernadsky to the rationalist view of the world. At times he even took up the position of an observer discussing humankind's movement towards some final omega, at which point there would occur the complete fusion of humankind—reason, will and ego—into a united whole. He regarded that final state as the end of human development, the end of its evolutionary path. And yet a number of features of social dynamics and the development of the biosphere in recent decades are not touched on in his general philosophical analysis. I think his abstraction from contemporary realities and the attempt to see not just over the horizon but to glimpse in the distance 'the end of the worlds' is a consequence of his education as a thinker and of the religious slant of his mind.

Vernadsky had a more constructive temperament, although he was far from attempting to formulate any kind of programme for the study of ways of moving from the biosphere to the noosphere. At the same time, he realised that this change could not occur automatically and many times expressed the idea that the noosphere did not just mean the penetration of or into the biosphere, that its emergence necessarily had to be accompanied by the perfection of the bearer of reason, i.e. the human being and human society, and that it had to point to the new conditions emerging on Earth. His view of the prospect of moving towards the noosphere also seems to me excessively optimistic, however. In December 1944, for example, a month before his death, he wrote that we were already entering the noosphere. He was thinking of the approaching victory over Nazi Germany and, consequently, as he thought, over all the evil that was hindering the application of the principles of humanism on which the idea of the noosphere was based. The post-war period, the advent of which was already seen, seemed to Vernadsky the beginning of a triumph of reason, opening the way to the noosphere for the human race.

As we now know, the reality turned out to be more complex and grim. Before beginning to build the sphere of reason we still have a difficult and painful road to tread, a road that means the reinterpretation of all man's previous experience. We still have to understand the need for it and work to bring it about. This why I prefer to speak not so much about the noosphere as about a new state of the biosphere, and to use the age of the noosphere to describe a time when we shall be able to direct the development of the biosphere, a development that will guarantee the future of the human race, i.e. the co-evolution of nature and society.

Entry into the age of the noosphere will not be automatic; it is a special, lengthy and purposeful process. At the same time, there is no alternative to it: humankind and civilisation cannot have a future outside the noosphere. It is a case of either—or! Either we start along the road leading to the age of the noosphere or there will occur in the shorter or longer run the degradation of human society, even if society manages to exclude war from the means of settling conflicts. There is no third path!

THE ECOLOGICAL IMPERATIVE

We have come to understand a lot in the last few decades. Science has very substantially widened its horizons. Today we are able to discover the properties of the universe and how it came into being and reconstruct the history of our planet, life on it, the emergence of the human species and the establishment of society much more fully than Vernadsky and Teilhard de Chardin were able to do. The word that most of all holds the key to the future, nevertheless, was uttered by them, and that word is 'noosphere'.

In recent years, we have come to understand that entering the age of the noosphere requires the practical reconstruction of the worldwide order and the establishment of a new thinking, a new scale of values and a new morality.

The theory of the noosphere is today taking a new course. From being a theory of a primarily general scientific and philosophical nature, it is gradually becoming 'the theory of the development of the noosphere, which studies possible strategies for the transition of society to the age of the noosphere. Its first stage is to define the permissible limits of human activity. The human species, like every living species, has interfered, is interfering and will interfere in the structure of the biosphere. This process now occurs spontaneously in response to the prompting of human interests, but they are not the interests of humankind as a whole: they are the interests of groups or even individuals. We now know that there is some kind of 'forbidden limit' beyond which people may not go in any circumstances. Beyond it begin irreversible processes that will convert the biosphere to a new state in which there may be no room for people. The risk of forfeiting the future is far too great to allow the human race to cross that boundary. We still know very little, however, about that boundary—far too little to make practical recommendations. We do know something, nevertheless. We know, for example, that nuclear wars are quite inadmissible, as are any large-scale wars in general, since the power of modern weaponry is hundreds and maybe even thousands of times greater than that of the weaponry that ended fifty million lives in the last world war. And as any 'small' war can always easily become a 'big' war, any means of resolving conflicts by force must be excluded from the array of means for their settlement.

There must be other prohibitions too, however. The future of the race is also threatened by the pollution of the atmosphere and the sea, by the overpopulation of Third World countries, by the reduction of genetic variety, and by the raising of the mean temperature of the Earth as a result of higher concentrations of carbon dioxide in the atmosphere and of the production of manufactured energy. There is much, much else besides. This means that people's activity cannot follow the principle of *laissez-faire:* it must be subject to many prohibitions, most of which still have to be established. These prohibitions form the 'ecological imperative', one of the most important phenomena of modern times.

Defining the conditions of the ecological imperative must be one of the main tasks of contemporary science. The limits to what is permissible will, of course, be continually clarified and changed as techniques and technology improve. I am profoundly convinced that, as science develops, people will come to know the limits of 'the fateful boundary' as fully as is necessary.

Nevertheless, gaining knowledge of the ecological imperative is just the first step and the first of the tasks we have to accomplish on our way towards the age of the noosphere. The next and far more difficult task is already facing us, namely where are the guarantees that society, even if it knows where the edge of the abyss is to be found, will never-theless not step into it? This, indeed, is the crucial problem of modern times.

The theory of the transition of our society to the age of the noosphere must thus become a synoptic discipline in which there must be a joint study of the change in natural factors under the influence of human activity (primarily productive activity), the possible ways in which society can be organised so as to ensure the co-evolution of humankind and the biosphere (the chief of the conditions of the ecological imperative), and, finally, the phenomenon of human beings for whom and by whose hands the race must complete the transition to the new age in its history.

WHAT RESEARCH PROGRAMMES?

How should we approach the problem of choosing a strategy or strategies for joint activity by people which will guarantee us both the development of nature and society and the future of the human race? Where should we begin? What research programmes should we set up?

Programmes relating to the natural sciences are more or less obvious. Their task would be to define 'the fateful boundary' and its main parameters. Research of this kind is in fact being conducted in national and international programmes, even if it is not being conducted as intensely as it might be. Where humanitarian problems and the organisational and political problems connected with them are concerned there is still a very long way to go before the need to tackle them is understood.

How should we begin to shape such programmes? I feel that the first and necessary step is to imagine possible scenarios for social development and to try to discuss what society might perhaps be like in the next few decades. In that discussion we can be helped immensely by that common conception of the development of our world and that common picture of the world, to the formation of which Vernadsky and Teilhard de Chardin made such a fundamental contribution.

Wherever it takes place, in inanimate nature, animate nature or society, the process of the development of self-organisation is always marked by divergence. In the process of evolution not only does the complexity of organisations and links constantly increase but the variety of the possible forms that the organisation of the material world might take increases too. This is entirely true of the organisation of society, its productive activity, its social structures and its political and spiritual life.

If we follow the general logic of the development of our world we have to state that the future development of society will be characterised by a further extension of the pluralism of productive, political and organisational structures. Socialism and capitalism will continue to exist together and to develop on Earth, neither of these systems presenting a monolithic front. Socialism in China will not resemble socialism in the USSR very much and still less socialism in Hungary or the German Democratic Republic. The forms of organisation of productive activity in capitalist countries will multiply in exactly the same way. This is reality. I do not believe in convergence: an unnatural movement that contradicts all the experience of the development of life on Earth. Nonetheless, this in a way signifies that individual forms of the organisation of productive activity and social structures in capitalist and socialist countries will be very close to each other. In addition, I admit the possibility of the emergence of organisational structures that it will be extremely difficult to relate to one or other political system. This will in no way be converse, however, but, on the contrary, the growth of pluralism, a pluralism of productive relationships, a pluralism of the political and a pluralism of the social.

Nonetheless, as I see it, a number of important consequences stem from this assertion. First of all, the broadening of the spectrum of social and productive structures will inevitably lessen the polarisation of ideological conflict—not so much conflict within this or that country as conflict in ideology between countries.

There are grounds for thinking that in general the nature of conflict in society will change in a very substantial way. It will, to a greater or lesser degree, lose its antagonistic character whereby everything that is good in one country is bad in another! The reason for this general phenomenon is to be found not in organisational pluralism but in a radical and qualitative change in the general world situation.

In fact, the change of interests and aims of countries (and not just of regions, classes, etc.) is beginning to include an increasing number of common components. These are primarily ideological, and in the forefront, of course, is the inherent desire to preserve peace on Earth. The governments of all states today want to reduce the risk of nuclear war, whether or not they possess nuclear weapons. And so, to an even greater extent, do wide sections of the population. We now know, however, that the safeguarding of civilisation and of our future is not just a matter of banning war. Even exclusion of the use of force to settle conflicts by force could not guarantee the future of either the biological human species or its civilisation. Reducing ideological polarisation also brings to the fore and strengthens the activity in other common interests such as cultural, religious and, of course, economic interests—and studies have shown that common interests often (but, alas, not always!) provide an opportunity for the conclusion of mutually advantageous agreements of a co-operative kind.

Thus an analysis of the possible scenarios for the development of a planetary society, that is an analysis based on the study of the structure of conflicts and their dynamics, makes it possible to outline certain research programmes. First of all, there is more detailed study of the conflicts themselves and trends in their evolution. Second, making use of knowledge of the structure of conflicts, there should be study of the possibility of making an effort to establish a genuine instrument for the settlement of conflicts.

INSTITUTES OF AGREEMENT

My position is thus quite clear. I see as the most important part of humankind's strategy on its path towards the age of the noosphere the gradual establishment of 'institutes of agreement' able not only to study the real conflicts that arise in society but also to work out mutually acceptable compromises in the political, economic, social, cultural and religious spheres. The serene wisdom of institutes of agreement is the sole alternative to opposition and antagonism.

Such institutes can genuinely fulfil their role only if they have all the necessary tools and legal means to settle recurring ecological conflicts like the one centring on acid rain or deciding on the quotas of resources to be furnished by countries and businesses for the cleaning up and restoration of the environment.

The time has now come to raise seriously the question of the establishment of institutes of agreement. There is every reason to think that they could function successfully. This assertion is not a pious hope but a sober assessment of reality based, in fact, on successes in developing a number of natural science disciplines, in particular the theory of compromises.

NEW BEHAVIOURAL NORMS

The conditions enumerated constitute a necessary but of course not sufficient cause to guarantee the ecological imperative, which requires in addition a new morality, a kind of moral imperative. I have already described the basis for this to some extent. It is the acceptance of a feeling of community and of the ideas that Teilhard de Chardin propounded, namely the overcoming of the isolationism of individual and groups of nations, the inculcation of a new attitude towards the noosphere, the overcoming of all forms of racial and religious hostility, etc. Here, the requirements of the moral imperative are probably close to many of Gandhi's ideas.

I think that the present restructuring of morality and the norms of people's behaviour must be no less profound than the one that occurred in the early stages of anthropogenesis and, in the final analysis, led to morality taking the place of those principles of conduct among the hominids that permitted intraspecific selection. As a result of that restructuring, which probably lasted many tens or maybe even hundreds of thousands of years, the process of the individual improvement of the human being as a biological organism came to an end.

Precisely because of that, however, human society emerged from the herd of neo-anthropoids. Working out the principles of morality and overcoming the laws of intraspecific selection was a most pressing need for our ancestors. Tribes that were able to take under their protection all members of the community, and not just females and infants, were able to transmit accumulated knowledge and skills more successfully to succeeding generations, i.e. to transmit information that is not passed on through the genetic code or taught according to the principle of 'do what I do', which is widespread in gregarious communities. Knowledge, working skills and ability, however, had for some time begun to guarantee the homeostasis of a race or tribe far better than powerful biceps or swift feet. The tribes that were able to assimilate the basis of morality ensured their future and became our ancestors.

The situation today is somewhat similar. To guarantee their future people must learn new standards of behaviour and a new scale of values. The similarity of the situation is, however, purely external. Unlike the neo-anthropoids, we do not have those thousands of generations over which the transition took place from the herd and the horde to society through the workings of natural selection. We do not even have tens of generations. The ecological crisis is lapping at our gates. And so what is to be done? How are we to reconstruct the consciousness of thousands of millions of the Earth's inhabitants?

It seems to me that first of all we have to understand the profound sense of the moral imperative and state it briefly in a form everyone can understand. The foundation of the morality that emerged at the time of anthropogenesis amounts primarily to the principle Thou shalt not kill'. This entered the laws of all nations and is an essential attribute of all the world's religions.

Today, the principle 'Thou shalt not kill' is already insufficient. I think that in its most all-embracing, pithy form the basis of the morality needed by society in the age of the noosphere can be expressed in the principle Christianity has actively followed for almost 2,000 years, namely 'Love thy neighbour as thyself. It will become more precise and take on a variety of details, of course, but the core of the moral imperative of our times seems to me to be precisely that.

I should like to point out that Dostoyevsky said very much the same thing and Teilhard de Chardin expressed very similar thoughts, devoting a whole chapter in his book *The Phenomenon of Man* to the question of love and mutual goodwill, since he considered love to be the main component of the 'super-life', the society of the future.

Merely to state the principle is not enough, however. Far from it! We should not forget that that great precept did not prevent 'good' Christians from lighting the bonfires of the Inquisition, from exterminating the Albigenses and Arabs and from committing various other abominations while uttering it. For this reason, understanding the content of the moral imperative as a consequence of the ecological imperative is only a first and necessary step towards its affirmation. All the time, too, one must bear in mind that such understanding must not be the property just of individual scientists, politicians and priests. It must enter the consciousness of thousands of millions of people, become second nature to them and permeate their very being.

Affirmation of the moral imperative will call for all the means at the disposal of society. New legal norms are needed to regulate and preserve people's freedom to produce energy. Legal institutes exist and will exist. We are entering the age of the noosphere with all the burden of positivism possessed by the far from perfect state of *Homo sapiens*. We have to reckon with the fact that development of the human individual may have ended too soon. Aggressiveness towards one's neighbours and attempts to lord over them and to make use of their activities, resources and even their lives for the good of only oneself are still with us today. Human development seems to have ended at the beginning of the Neolithic age, fitting us for the demands made by the conditions of life in the next age and the period preceding it. Our nature is therefore very little suited to the demands of the com-puterised and automated society of the twenty-first century, a society that, in addition, possesses nuclear weapons. These circumstances also form part of the description of the human phenomenon.

Special legal standards are thus required. They must also be worldwide, since people all over the world are the descendants of Cro-Magnon man, who made his appearance about thirty thousand years ago in the last pre-glacial period.

Together with worldwide legal institutes, what is more, worldwide educational programmes must be introduced. Only an intelligent society, educated in a modern way, will be fit to enter the age of the noosphere. Acceptance of the ecological imperative and the new morality can be a conscious act only when the majority of Earth's inhabitants become aware of the approaching crisis and of the need for a new moral imperative.

Teilhard de Chardin spoke about the emerging human community and new means of communication. They can and must be used. He also spoke about a certain natural process for the interpenetration of cultures and knowledge, suggesting that it would bring about the emergence of a worldwide community. He nevertheless wrote this about fifty years ago. Now it is already becoming clear that we cannot pin our hopes on any such natural process. They should be studied but are not to be fully trusted and, in addition, do not occur at anything like the speed necessary. Besides the ecological crises, we must not leave out of account other crises as well. It also has to be borne in mind that civilisation is extremely fragile: the twentieth century has given enough examples of how the primitive being living within us can so easily destroy it.

A PROPOSED GLOBAL INSTITUTION: 'THE TEACHER'

I think that the time has come to establish within the framework of the United Nations a special worldwide system or institute known as 'The Teacher' that would work out principles for people's conduct—and not only as regards things that must unconditionally be placed under supervision or prohibited. The main task of the 'Teacher' system would be to instil in people an awareness of the absolute need, in their relations with nature, to observe the principles that had been worked out. In my opinion, this system should be based on an amalgam of similar national systems teaching national traditions, history, religious views, etc.

In this system should also be included, perhaps, a study of the phenomenon of aggression in young people. The rowdy behaviour of English football supporters and the surfacing of groups of young people in the United States, USSR and other countries who savagely fight each other are examples of that latent primitivism breaking through and causing great harm to society.

This century is by no means like the last one. Then, too, there was talk of the end of the world, but such talk was the appanage of dreamers and poets. How ever great the changes in human life were in the nineteenth century, the beginning and end of that century were very similar. At the end of the present century, we are threatened by enormous ecological difficulties caused by the progress of science and technology. We can overcome these difficulties only with the assistance of the same scientific and technological progress—that is the conflict of modern times. Today there is no talk of the end of the world, but we clearly recognise that it is a possibility. There is, however, talk of something else—a way between the Scylla and Charybdis of modern times can be found. The ship of humankind has sailed almost up to the reef, and we can see the waves breaking over it. We know, however, that a way between the rocks exists somewhere. It has to be found. Science gives us that assurance, but the search demands energy, boldness and discipline from the crew. Everyone must know his place as danger looms. These qualities, however, can be conferred only by a new humanism, the keys of which were discovered by Vladimir Ivanovich Vernadsky and Pierre Teilhard de Chardin.

GREGORY STOCK

Gregory Stock (b. 1949) received a Ph.D. in biophysics from Johns Hopkins University and an MBA from the Harvard Business School. He is currently directing the Program on Science, Technology, and Society at University of California at Los Angeles (UCLA) and is a visiting senior fellow at the Center for the Study of Evolution and the Origin of Life. His book *Metaman* (1993) explores the broad evolutionary significance of humanity's recent technological progress and concludes that we are on our way to becoming a form of hybrid super-organism—a cross between organism and machine. Stock does not tackle the issue of the noosphere, or the evolution of the biosphere directly, but his analysis raises a number of common themes of various extracts presented here. Could this be one possible path of the noosphere? Or is it altogether something different?

METAMAN: THE MERGING OF HUMANS AND MACHINES INTO A GLOBAL SUPER-ORGANISM

For more than 3.5 billion years, the planet has teemed with life, and now, in a virtual instant, a part of that life has suddenly organised itself into a dense net of activity that is spreading over the globe and consciously reshaping large regions of its surface. We know this structure as human civilisation.

This resemblance to life is not mere coincidence; the thin planetary patina of humanity and its creations is truly a living entity. It is a 'super-organism' —a community of organisms so fully tied together that it is a single living being. Rather than refer to this entity by a term filled with prior associations, let us start afresh and simply call it 'Metaman', meaning beyond, and transcending, humans. This name both acknowledges humanity's key role in the entity's formation and stresses that, though human-centred, it is more than just humanity. Metaman is also the crops, live-stock, machines, buildings, communications transmissions, and other non-human elements and structures that are part of the human enterprise.

Metaman ceaselessly monitors itself and its environment, interprets what it perceives, and responds appropriately. This does not *necessarily* mean that Metaman is conscious, but this super-organism does have the functional equivalent of a nervous system…. Such networks as science, government, and business together constitute the broad cognitive systems that function as the 'brain' of Metaman…. Externally stored information is being returned to dynamic patterns of activity that combine and interact in increasingly complex ways with Metaman's network of global connections. 'Global memory' is more than a metaphor. Furthermore, climate simulations, election tallies, telephone switching systems and global banking systems are early glimmers of 'metathinking'. When Meta-man's global store of information exists largely as electronic patterns as readily manipulated as the volatile patterns in the human brain, Metaman will truly have a 'mind' of its own. Indeed, as its 'metathinking' becomes ever-richer and is coupled with an ever-fuller 'self-awareness' provided by its evolving sensory system, Metaman may evolve a sort of planetary 'consciousness'.

Is our feeling of uniqueness really an empty illusion, merely a manifestation of our own human pride and egocentricity? No. Though evolution is not a history of preordained progress towards the human form *per se,* it is definitely a story of the progressive development of complexity. The hierarchy from bacterium, to single-cell animal, to multicellular organism, to social super-organism reveals the nature not only of Metaman but of ourselves. Our special significance is clear. Poised at the boundary between the animal kingdom and Metaman, humans straddle two levels of organisational complexity. We are no more than animals, and yet we are *immeasurably* more: we are biological creatures with intimations of the divine. The attempt to understand and explain this duality is the essence of religion and philosophy: man has a soul, man has self-consciousness, man is aware of his own existence and morality. Ours is an exalted place, but it is also a humble one because we each are only a tiny part of something far larger and more powerful than ourselves — a concept strikingly similar to what lies at the core of all religion.

PETER RUSSELL

Peter Russell (b. 1946) studied mathematics, theoretical physics and computer science at Cambridge University. Since the mid-seventies, he has worked on various projects, including 'mind maps', self-development, creativity and environmental strategies. He is a frequent lecturer on learning and other methods to a variety of international organisations, educational institutions and corporations. In *The Global Brain Awakens* (1995) Russell presents a startling idea that would be all too easy to dismiss as too radical or 'new age'. However, a more careful look shows that his set of ideas presents a balanced view of the future, suggesting that the success of the 'global brain' is by no means assured and that society's current state is highly precarious. Again, the link to the ideas of the noosphere—a term Russell uses himself—are strong, particularly the notion of an emerging network of sufficient critical mass. Would the emergence of some form (or sense?) of a global brain represent the arrival of the noosphere? This question remains open to interpretation, as does the issue of what the arrival of the noosphere signifies.

THE GLOBAL BRAIN AWAKENS: OUR NEXT EVOLUTIONARY LEAP

THE EMERGING GLOBAL BRAIN

The interlinking of humanity that began with the emergence of language has now progressed to the point where information can be transmitted to anyone, anywhere, at the speed of light. Billions of messages continually shuttling back and forth, in an ever-growing web of communication, linking the billions of minds of humanity together into a single system. Is this Gaia growing herself a nervous system?

The parallels are certainly worthy of consideration. We have already noted that there are, very approximately, the same number of nerve cells in a human brain as there are human minds on the planet. And there are also some interesting similarities between the way the human brain grows and the way in which humanity is evolving.

The embryonic human brain passes through two major phases of development. The first is a massive explosion in the number of nerve cells. Starting eight weeks after conception, the number of neurons explodes, increasing by many millions each hour. After five weeks, however, the process slows down, almost as rapidly as it started. The first stage of brain development, the proliferation of cells, is now complete. At this stage the foetus has most of the nerve cells it will have for the rest of its life.

The brain then proceeds to the second phase of its development, as billions of isolated nerve cells begin making connections with each other, sometimes growing out fibres to connect with cells on the other side of the brain. By the time of birth, a typical nerve cell may communicate directly with several thousand other cells. The growth of the brain after birth consists of the further proliferation of connections. By the time of adulthood, many nerve cells are making direct connections with as many as a quarter of a million other cells.

Similar trends can be observed in human society. For the last few centuries, the number of 'cells' in the embryonic global brain has been proliferating. But today population growth is slowing, and at the same time we are moving into the next phase — the linking of the billions of human minds into a single integrated network. The more complex our global telecommunication capabilities become, the more human society is beginning to look like a planetary nervous system. The global brain is beginning to function.

PLANETARY AWAKENING

This awakening is not only apparent to us, it can even be detected millions of miles out in space. Before 1900, any being curious enough to take a 'planetary EEG' (i.e. to measure the electromagnetic activity of the planet) would have observed only random, naturally occurring activity, such as that produced by lightning. Today, however, the space around the planet is teeming with millions of different signals, some of them broadcasts to large numbers of people, some of them personal communications, and some of them the chatter of computers exchanging information. As the usable radio bands fill up, we find new ways of cramming information into them, and new spectra of energy, such as light, are being utilised, with the potential of further expanding our communication capacities.

With near instant linkage of humanity through this communications technology, and the rapid and wholesale dissemination of information, Marshall McLuhan's vision of the world as a global village is rapidly becoming a reality. From an isolated cottage in a forest in England, I can dial a number in Fiji, and it takes the same amount of time for my voice to reach down the telephone line to Fiji as it does for my brain to tell my finger to touch the dial. As far as time to communicate is concerned, the planet has shrunk so much that the other cells of the global brain are no further away from our brains than are the extremities of our own bodies.

At the same time as the speed of global interaction is increasing, so is the complexity. In 1994, the worldwide telecommunications network had a billion telephones. Yet this network, intricate as it might seem, represents only a minute fraction of the communication terminals in the brain, the trillions of synapses through which nerve cells interact. According to John McNulty, a British computer consultant, the global telecommunications network of 1975 was no more complex than a region of the brain the size of a pea. But overall data-processing capacity is doubling every two and a half years, and if this rate of increase is sustained, the global telecommunications network could equal the brain in complexity by the year 2000. If this seems to be an incredibly rapid development, it is probably because few of us can fully grasp just how rapidly things are evolving.

The changes that this will bring will be so great that their full impact may well be beyond our imagination. No longer will we perceive ourselves as isolated individuals; we will know ourselves to be a part of a rapidly integrating global network, the nerve cells of an awakened global brain.

6

EPILOGUE: THE NOOSPHERE AND CONTEMPORARY GLOBAL ISSUES

Regardless of which world view is taken, the noosphere represents an essential phase in the history of our planet. In essence, it involves the 'coming of age' of a species—in this case, *Homo sapiens*—which, in *reflecting* on itself and its environment, fundamentally alters the evolutionary process and future development on Earth. Whether or not such a phase is a unique occurrence in the vast time and space of the universe remains an open question and is not our concern here. What matters is that the noosphere is an unprecedented event on Earth and that society appears to be entering a critical period in this phase. In many senses, the Earth has become a single system, an interwoven relationship of global mind and global action. The collective actions of dinosaurs, which appear to have dominated the Earth for millions of years, undoubtedly had pronounced physical impacts on the environment—perhaps, over time, on a global scale. But any planetary change resulting from the actions of these species appears not to have been a *conscious* form of change. Today, for better or for worse, humans are altering our world at the global level, but they are doing so consciously. Even critics of the noosphere idea —namely those denying any sense of progress or human pre-eminence as a species—would agree that the current era is unique in its ability to reflect upon its past, present and future. But even if one accepts the noosphere as fact, it leaves open the question of where it is taking us. Once again, we are faced with two questions: in what direction does public opinion want the noosphere to go and in which directions is the noosphere capable of going? Practically speaking, and in today's world, this translates into asking how the noosphere can be applied to help to solve problems in such areas as environment, health, poverty, violence and inequality. Before turning to these questions, however, it is useful to review several basic views of the noosphere as they have appeared throughout this book.

WHITHER THE NOOSPHERE?

Of the four framework definitions of 'noosphere' given in Chapter 1, two of them paint a generally rosy picture of our future, one is largely neutral, and one hints at an emergent form of unpredictable balance. A first optimistic view of the noosphere is inherently tied to notions of irreversibility and inevitability. Humanity is seen to be on its way to a higher plane of existence and there is no stopping this progression. A second optimistic view would seem to support the same notions—or at least not deny them—although the driving force is not spiritual energy but rather human creativity in the form of technology. A third view shares a positive view of science, technology and human potential, but remains fundamentally tied to the immutable physical constraints of the biosphere. Humanity, in this view, needs to design suitable ways to manage the world and all will be fine. A fourth view—the least explicitly articulated—suggests potential for equilibrium between the noosphere and the biosphere, but draws attention to the inherent unpredictability manifest in human progress. In this way, the spiritual element becomes important in creating a balance between humanity, physical constraints and elements of surprise.

A good number of the readings in this anthology have, in one manner or another, raised the notion of irreversibility. Particularly in the work of Teilhard de Chardin and Le Roy, the noosphere idea carries with it a sense of irreversible 'progress' or at least a sense of final (even inevitable) history. A sense of irreversibility, and even inevitability, is equally present in those who appear to assume that society is marching towards a new form of super-organism or super-tech society. In general, the scientific reaction to such ideas has been highly sceptical, and not just because of their challenge to well-established ideas and theories. Yet scepticism of the notion of inevitable human 'progress' is well-founded in so far as it uncovers hidden ideas of strict predetermination or design. As Steven Jay Gould (1995:52) and others go to great pains to emphasise: 'There is no progress in evolution…. We're not marching toward some greater thing.' Similarly, we are reminded of historian A.J.P. Taylor's comment (1967:47) at the end of his introduction to *The Communist Manifesto:* 'The inevitable rarely happens in real life.' We might also recall the Russian saying that history is unpredictable.

On the surface, such criticisms may appear incompatible with the ideas of the noosphere. However, for the third and fourth senses of 'noosphere', at least, this is not the case. Vernadsky's notion of a co-evolving biosphere and noosphere, or the view that humans are free to develop their future, although unpredictably, do not necessarily go against the strict sense of progress used by evolutionary biologists. Indeed, Darwinism is often mistaken to be a theory of random chance (and therefore random change) by many people outside biology. For example, in his 1927 Gifford Lecture, A.S.Eddington (1929:72) famously suggested that: 'If an army of monkeys were strumming on typewriters they might write all the books in the British Museum.' This statement has been widely understood as an example of why Darwinian evolution could *not* explain such complicated objects as Shakespeare's sonnets or the human eye by mere chance—as they are seen to be simply too complex. This is over-simplistic. As British scientist Richard Dawkins (1996:75) stresses, Darwinism is 'a theory of random mutation plus *non-random* cumulative natural selection.' Darwinism is, therefore, fundamentally about the *cumulative* process of evolution. Eddington's statement can therefore be correct, but only as part of non-random cumulative natural selection—otherwise monkeys hitting the keyboard purely randomly would take an eternity to produce such works. Empirical evidence shows that nature puts forth a variety of functioning eyes over millions of years and that Shakespeare's works were the result of many years of cumulative labour. The French scientist Henri Poincaré (1908:168) made a similar point with regard to science more generally: 'The wise should note: We make science with facts as we make a house with stones; but an accumulation of facts is no more science than a pile of stones is a house.' Without the cumulative aspect, science, and society at large, would be utterly different.

Seen this way, the idea of the noosphere and Darwinism are not incompatible. But could such reconciliation make the noosphere a sterile idea? Not necessarily. According to the Belgian biologist and Nobel laureate Christian de Duve, one can reject the idea of pre-design and ultimate causes and explain life in terms of the laws of physics and chemistry, while still finding meaning in the underlying structure. Indeed, in this way, de Duve prefers Teilhard de Chardin's notion of a meaningful universe over the 'meaningless' one of Jacques Monod:

> My reasons for seeing the universe as meaningful lie in what I perceive as its built-in necessities. Monod stressed the improbability of life and mind and the preponderant role of chance in their emergence, hence the lack of design in the universe, hence its absurdity and pointlessness. My reading of the same facts is different. It gives chance the same role, but acting within such a stringent set of constraints as to produce life and mind obligatorily, not once but many times. To Monod's famous sentence 'The universe was not pregnant with life, nor the biosphere with man,' I reply: 'You are wrong. They were.'
>
> (de Duve 1995a:300)

Such a view has parallels with the 'science of complexity' as developed at the Santa Fe Institute in New Mexico and briefly discussed in Chapter 3. Complexity is posited as a world view or general theory that explains dynamics in terms of 'emergent systems' and 'non-equilibrium flows', driven by internal attractors (Kauffman 1995). In this sense, the future could appear to be open to the extent that humans have a small input with potentially broad implications (perhaps similar to a butterfly flapping its wings and the resultant influence on the weather across the globe). As John Holland (1992:17), a pioneer in work on complex adaptive systems, describes it: 'A complex adaptive system has no single governing equation, or rule, that controls the system. Instead, it has many distributed, interacting parts, with little or nothing in the way of a central control.' There is no single control mechanism in such systems—no single cell that controls an organism or individual that controls the world economy—but rather control is spread among the whole. There is, for example, no master neuron in the brain controlling the neural net. In this way, one can accept the emergence of a noosphere—of whatever shape or form—as neither an inevitable nor irreversible process, but rather as a naturally emergent one. It also suggests a view that combines a sense of optimism which is driven, but not directed, by biogeophysical realities. However, complexity science is not without critics such as John Horgan (1996b:14), who suggests that this paradigm is based on 'an overly optimistic interpretation of certain developments in computer science and math.' While proponents of complexity science offer convincing counter-arguments (e.g. Kauffman 1996), its potential to explain the larger picture of things is still limited by the fact that it remains a reductionist-based approach (Funtowicz and Ravetz 1994).

Is there any room for theories of convergence? E.O.Wilson (1998a), the widely respected biologist, has asserted that we are moving (or at least should be) towards what he calls 'consilience' (or jumping together). Wilson (1998b:2,049) suggests that 'the time has come to look at ourselves as a biological as well as a cultural species, using all of the intellectual tools we can muster.' Perhaps we can imagine such a convergence (or co-evolution) form of mental and biological spheres (Figure 6.1). The late Sir Karl Popper suggested that neither unqualified determinism nor indeterminism is acceptable. What is needed is a new method to 'explain freedom; and it must also explain how freedom is not just chance but, rather, the result of a subtle interplay between *something almost random or haphazard,* and *something like a restrictive or selective control'* (Popper 1972:241). An adapted notion of the noosphere—one that views society as both controlling and controlled by nature—captures the underlying theme of this book. Thus, the noosphere is perhaps best described as the entire sphere of human ideas and technology evolving as an integral part of the biosphere. Such a conception carries both a warning and note of optimism. On the one hand, in the fate of the biosphere lies the fate of society: destroy the biosphere and society will be destroyed; but on the other hand, this conception of the noosphere allows for the idea of positive evolution prompted by human creativity and action.

The noosphere idea relates to good news but also to the fundamental role of mind over matter. Despite those who see the brain as largely a quantitative super-computer, the idea of a

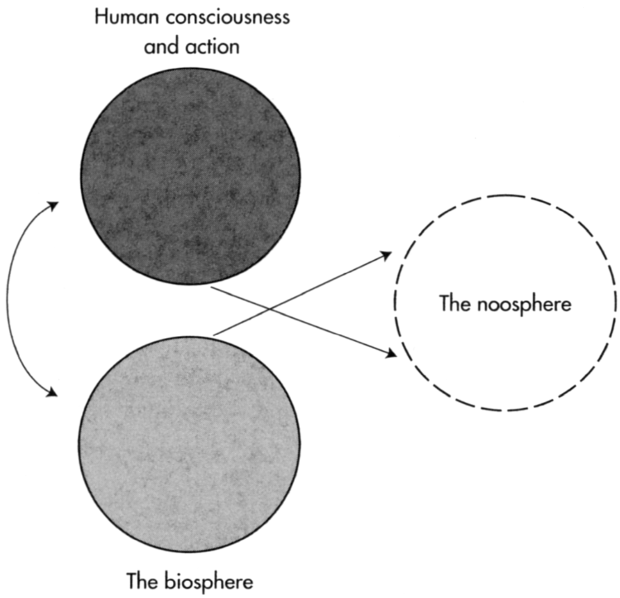

Figure 6.1 The noosphere as a complementary, emergent mental/biological sphere

qualitatively different realm gains ground where there is at least an interaction with the physical (Eccles and Popper 1990) or possibly a different quantum process (Penrose 1995). The noosphere idea implies that mind processes extend in time and space through a focus on the human mind. Although prehistorians (Mithen 1996) assume that an evolution in the mind is associated particularly with the emergence of language, other suggestive work looks for mind in animals at least (Thomas 1996). Mind is then a force possibly dating back to the biological 'big bang' that has a role in driving physical evolution, and it may survive destructive forces.

NOOSPHERIC INSTITUTIONS

Where does the idea of the noosphere point us with regard to solving today's global problems? We should first note that current solutions to global problems seem to have too little effect. Thus far in global history, eco-development endeavours have been limited because the political will has been weak and because power is in the hands of a commercial elite who favour the wealth of the few rather than the well-being of the many or the harmonies of nature. Pollution, global warming, poverty (over a billion absolute poor), access to sanitation (nearly three billion have not) and consequent bad health remain as problems and intensify. On top of this is the abuse of human rights and the spread of war and violence.

Noospheric institutions—the UN and increasingly the NGO movement—a 'public' Internet, and growing contacts between various sorts of intelligentsia are a counterpoint to the negative aspects of competitive dynamics. Mind lends itself to the co-operative processes that are vitally needed to overcome present global conflicts, be they between nations or with the kingdom of nature. There could be a very major benefit for eco-development if we admit to the community of mind, the animal kingdom. Even global structures are built on individual minds, which are the product of a thoroughgoing educational system.

The essential first contribution of noosphere ideas to resolving this situation is ethical. Noosphere pioneers Teilhard de Chardin and Le Roy were brought up in a religious atmosphere, but the idea was also developed by the scientist Vernadsky. There is an underpinning of utopian views based on religious commandments, which have come in turn to include (Wall 1994; Clark 1993) Eastern as well as Western elements, even if the emphasis has remained pragmatic. The ethical dimension was important too in the Soviet Union, especially among the followers of Vernadsky. Communism has been compared to Calvinism. Ethical ideas are also present in United Nations thinking (most recently in the guidelines being prepared for the Earth Charter, which Gorbachev (1997) has called the new ten commandments), in NGO initiatives like the WWF New Road, and in the new age movement, which claims Teilhard de Chardin as founding father.

What will enhance a cosmopolis or the noosphere is education, or more precisely learning, since the former is still too top-down. The telecommunications network and especially the Internet provides a means of sustaining such networks, especially as the costs are dropping astronomically and the burgeoning NGO movement involves the energy of the grass roots and the young especially. The Internet and other global systems will work only so long as certain other criteria are met—such as the International Telecommunications Union's goal of putting everybody on-line is quickly achieved; if traditional means, notably books, can coexist alongside; if there are audiovisuals to reach the probable third of humankind who are not literate; and if there are thesauruses to allow quick searching and sorting of the information overload. An open learning system is also required with manuals available in the multitude of languages alongside the English of cyberspace.

The focus of any curriculum should be to support an appropriate technology based on the best science. Too often today the cutting edge of science is for commercial or military purposes, with scant attention to smaller-scale applications. The noosphere pioneers had a sneaking admiration for self-reliance of the American variety. Bergson had a picture of C.S. Peirce on his desk (Moore 1997), while Teilhard de Chardin thought the automobile to be fundamentally important. Noospheric science is, however, based on practicality as well as science—what works at the grass roots—which may help to explain the inclusion of what Western critics have called irrationality. For example, anthropologists (Pitt 1976) have shown that magic may complement science and be demonstrably effective as well as psychologically valuable. Moreover, an important proportion of Western medicine derives from traditional plant knowledge. Science is not without irrationalities and is certainly subculturally based. The essential future task may well be to incorporate the treasure houses of knowledge that do exist cross-culturally into the concept of the noosphere. This problem, it should be emphasised, is of great urgency. Perhaps two-thirds of the world's languages and cultures are threatened with extinction within the next generation as the old people of the oral cultures pass away without record. The efforts there are, at UNESCO for example, may be too little or too late. Cultural heritage is not popular in a world driven by materialism and consumption, where pluralism is seen as merely a cover for rebellion and disruption of the status quo.

NECESSARY PLURALISM

The power of mind has been well demonstrated by the postmodernists (Anderson 1996), who argue that language especially—if not wider thought control—is used to create mythologies for the benefit of a narrow power elite. Since the idea of the noosphere has emerged from an intellectual elite, this danger is presumably inherent in noosphere theory.

It has been argued (Dennett 1991; Shore 1996) that there are different kinds of mind, particularly in the six or more thousand subcultures identified by anthropologists. These differences, or indeed other forms of mind (including altered states of consciousness), do not pose an obstacle to noosphere theory, since the different systems can coexist in a pluralist structure, each lending a potentially important part to the whole. Many people in fact move easily across cultural boundaries in different worlds through processes of coexistence and adaptation (Pitt 1970). The noosphere idea stresses these cosmopolitan processes as well as the holism that embraces all world subcultures, which are anyway constantly changing. The noospheric structures are rather of a network nature, where there is a convergence of forces rather than a Cartesian diversification. Teilhard de Chardin believed that the age of the nation-state was disappearing, and certainly the idea of nationalism, which dates from the Treaty of Westphalia (1648), has been the cause of many, if not most, modern problems, most of which are related to the war machine. But if the nation should disappear, communications between various cultural groups will need to continue in an altered form.

Such communications still require a structure. Zolo (1997), among others, has argued for a cosmopolis that avoids the anarchy of the post-Westphalian world by stressing the benefits of globalisation. The problem, however, is that globalisation may create not only oppressive forms of 'coca-colonisation' but also new forms of stratification. A holistic vision is central to the noosphere concept, but also one that includes pluralistic and flexible approaches. In some respects, the world of the nation-state weakens the potential for pluralism and the noosphere, but the alternative of a world fragmented into thousands of competing cultures and sub-cultures is probably no more conducive to world peace and stability. The notion of a 'web'—a truly global Internet—with global connections but no centre is perhaps a glimpse of a way to realise greater potential. If the unity of humankind will prove to be a crucial factor in human development, community with nature will be at least equally important. The environmental movement is therefore central to the noosphere, alongside the preservation of cultural heritage. This complementarity of diversity is not a contradiction, since the unity and holism of the noosphere—as with the biosphere—is made up of a mosaic of different, and sometimes conflicting, components. It is not unlike Lovelock's notion of the living planet with its diverse elements, interactions and species that produces an emergent sense of whole.

Pluralism is often linked to the notion of balance. The idea that 'opposites attract' is an old one, found in the cultural roots of many societies, both modern and ancient. Among the bestknown of these are the 'ying', and 'yang' which is an ancient Chinese view of the world based on ceaseless natural cycles—such as floods and drought—and concerned with maintaining a balance between the great forces of nature. The tradition of romantic poetry, such as William Blake's *The Marriage of Heaven and Hell* also captures this sense of balance (Figure 6.2). Similarly, Isaac Newton's third law of motion holds that for every action there is an opposite and equal reaction. The Austrian-born physicist Fridtjof Capra offers an interesting perspective on combining these two ways of thinking in *The Tao of Physics:*

> I see science and mysticism as two complementary manifestations of the human mind; of its rational and intuitive faculties. The modern physicist experiences the world through an extreme specialisation of the rational mind; the mystic through an extreme specialisation of the intuitive mind. The two approaches are entirely different and involve far more than a certain view of the physical world. However, they are complementary, as we have learned to say in physics. Neither is comprehended in the other, nor can either of them be reduced to the other, but both of them are necessary, supplementing one another for a fuller understanding of the world. To paraphrase an old Chinese saying, mystics understand the roots of the Tao but not its branches; scientists understand its branches but not its roots. Science does not need mysticism and mysticism does not need science; but men and women need both. Mystical experience is necessary to

Figure 6.2 'Proverbs of Hell' by William Blake from *The Marriage of Heaven and Hell* (1789–90). Blake wrote that 'Where man is not nature is barren. Truth can never be told so as to be understood, and not be believ'd. Enough! or Too much!'

> understand the deepest nature of things, and science is essential for modern life. What we need, therefore, is not a synthesis but a dynamic interplay between mystical intuition and scientific analysis.
>
> (Capra 1975:339)

While David Bohm (1996) and a number of other physicists are sympathetic to such ideas, John Polkinghorne, who is both a physicist and an ordained priest, takes synthesis to another level:

> In the end, the more we comprehend the universe, does it become more pointless or become more truly a cosmos, totally meaningful to us so that we are truly at home in it and not lone protesters against its absurdity? My instinct as a scientist is to seek a comprehensive understanding and I believe that it is my religious faith that enables me to find it.
>
> (1996:101)

A new and increasingly regarded perspective on the future—largely grounded on complexity science—has been labelled the 'Third Culture'. C.P.Snow (1959), famous for coining the term 'two cultures', foresaw the emergence of a third way, an idea that is now said to be ripe (Brockman 1985; Kelly 1998). This school of thought broadly accepts the idea that self-organisation is a general property of the universe and that systems therefore naturally progress from chaotic, disorganised, undifferentiated and independent systems into ordered, complex ones (Farmer 1995). Erich Jantsch (1980:307–8) saw a co-evolution of the micro- and macrocosmos through sociobiology and suggested that such a process allows us to finally discard the need for a special life force—such as Bergson's *élan vital* or the Hindu *prana*—as separate from the physical and that self-organisation in human terms becomes increasingly a process of self-realisation of outer (Darwinian nature) and inner forces in 'the crescendo of an ever more fully orchestrated consciousness.' Indeed, in Jantsch and Waddington's *Evolution and Consciousness: Human Systems in Transition* (1976) they foresaw the emergence of an 'imminent noetic regime'. In many ways the views of Capra, Bohm and others merge here.

Human activities that, for thousands of years, were unrelated are now closely intertwined. Industrialisation, human population growth, changes in consumption patterns and other alterations in human behaviour and action have changed the face of the Earth to a point where no corner of the natural environment remains free from influence (Turner *et al.* 1990a). Similar claims about growing social interdependence due to the flow of ideas, culture, tradable goods and the like have been made for some time (Muir 1932; Keohane and Nye 1977). The contrast of today's world with that of only a few centuries earlier is profound. War, plague or economic chaos could reign in Europe while China and the Americas went about their normal business. While only a few critics have taken on the concept of noosphere directly (as discussed in Chapter 1), others address different notions of evolving globalisation. As Kenneth Boulding (1983:268), who is generally optimistic on the noosphere, notes: 'If there are many very isolated systems, one can go wrong without the others going wrong. If there is only one system, then if something goes wrong, that is the end of it.' One is reminded of Easter Island — where the conscious destruction of the 'total' environment is attributed to the collapse of the society—with possible larger lessons for the planet as a whole (Bahn and Flenley, 1992).

The set of readings and discussions presented here shows that this idea has important precedents in noosphere thinking and that a review of the past will help us better to see the future. Today, human action and knowledge appear undeniably global in scope and consequence. The noosphere is typically seen as a positive phase in this perception, offering great potential for the development of society. However, a balanced view of the noosphere suggests that the only certainty is that whatever change that may occur will contain global consequences. It may well be that the 'challenge of unprecedented environmental change may speed up the noosphere' (Smil 1996:203). But the future state of the noosphere can either be attractive or very unattractive, and humans have the power to influence what that future state will be. This leaves us with a vision of the world that is not static but dynamic, where change is ubiquitous but not predetermined. As Margulis and Sagan (1995:138) note, 'the noosphere is still in its infancy' but 'may now be in its most impressionable stage.' Indeed, it appears to be a time of crucial decisions for our future.

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