



## Ecosphere, biosphere, or Gaia? What to call the global ecosystem

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### ABSTRACT

The terms biosphere, ecosphere, and Gaia are used as names for the global ecosystem. However, each has more than one meaning. Biosphere can mean the totality of living things residing on the Earth, the space occupied by living things, or life and life-support systems (atmosphere, hydrosphere, lithosphere, and pedosphere). Ecosphere is used as a synonym of biosphere and as a term for zones in the universe where life as we know it should be sustainable. Gaia is similar to biosphere (in the

sense of life and life-support systems) and ecosphere (in the sense of biosphere as life and life-support systems), but, in its most extreme form, refers to the entire planet as a living entity. A case is made for avoiding the term Gaia (at least as a name for the planetary ecosystem), restricting biosphere to the totality of living things, and adopting the ecosphere as the most apt name for the global ecosystem.

**Key words.** Biosphere, ecosphere, extraterrestrial ecospheres, Gaia, global ecosystem, global organism, Teilhard de Chardin, Vernadsky.

### INTRODUCTION

It is almost impossible to read books about the global environment without confronting the words biosphere, ecosphere, or Gaia. They are all used as names for the global ecosystem. However, they each have at least two meanings and are not synonymous. The differences between them are the source of much confusion (Huggett, 1995). In brief, the term 'biosphere' can mean three things. First, the biosphere is the totality of life on Earth – all living organisms. Second, the biosphere is the geographical space occupied by life – all living organisms plus the space in which they dwell. Third, the biosphere is all life together with life-support systems (atmosphere, hydrosphere, lithosphere, and pedosphere). The term 'ecosphere' is used in two ways: first, as name for the totality of life plus life-support systems, in which sense it is a synonym for the third meaning of 'biosphere'; and second, as a term for zones in the universe where terrestrial-type life should be sustainable. The term 'Gaia', like ecosphere, is a name for the sum of living things and their supporting environment. In its most extreme form, Gaia refers to the entire planet as a living entity. This brief paper tries to clarify the meanings of the three words and assess their value as descriptors of the global ecosystem.

### BIOSPHERE

#### The biosphere as the vital skin of the Earth

The idea of the biosphere was suggested by Jean-Baptiste de Lamarck, although he did not invent the word. Lamarck (1802) opined that a study of the Earth should include considerations of the atmosphere (meteorology), the external crust (hydrogeology), and living organisms (biology – a word Lamarck did coin). Subsequent scholars have suggested that, in viewing all living things as a separate terrestrial entity, Lamarck identified the biosphere without naming it.

The word biosphere was coined by the Austrian geologist Eduard Suess in 1875 in the last and most general chapter of his short book *Die Entstehung der Alpen (The Origin of the Alps)*. In this chapter, Suess presented a holistic view of the Earth, recognizing several interrelated envelopes surrounding a core and mantle: the atmosphere, the hydrosphere, the lithosphere, and the biosphere. Suess saw that plants feed from the soil (a product of the lithosphere) and, at the same time, draw on the air (atmosphere) to breathe. He submitted that at the interface between the atmosphere, lithosphere, and hydrosphere, lies the sphere of living organisms or biological processes –

'eine selbständige Biosphäre', an independent biosphere (Suess, 1875, p. 159; see also Suess, 1909, p. 637).

The first development of the biosphere as an idea resulted from meetings between three people in Paris between 1922 and 1925: Pierre Teilhard de Chardin, his close friend Edouard Le Roy, and Vladimir Ivanovich Vernadsky, about whom much will be said later. These three gave much thought to Suess's idea of the biosphere (and, incidentally, came up with the notion of the noosphere).

Teilhard first employed the term biosphere in a panegyric review of Suess's *The Face of the Earth* published in 1921. He used it subsequently in his philosophical essays, especially those written during 1925–26 (see Teilhard de Chardin, 1957), immediately after Vernadsky published the lectures that he had delivered at the Sorbonne; and it figured prominently in his *The Phenomenon of Man* (1959). To Teilhard, the biosphere is the totality of living beings and is distinct from the other geospheres. This is made clear in a footnote in *The Future of Man* (1969, p. 163) where he states that he uses the term biosphere to mean 'the actual layer of vitalized substance enveloping the earth', and not just the terrestrial zone housing life. Thus, he departed from Vernadsky's view and created a terminological confusion that still persists (Grinevald, 1988).

### The biosphere as an integrated life and life-support system

Suess's word biosphere was adopted by Vernadsky in his biogeochemical studies made after the First World War. After having read Suess's masterwork, *Die Antlitz der Erde* (1883–1909), Vernadsky started to develop original ideas on biogeochemistry and his own view of the biosphere. He suggested that living organisms and their planetary environment evolve together and form a unit – the biosphere – which is partly created and controlled by life.

Vernadsky's views on the biosphere were first published in Russian in 1926, under the title *Biosfera*, and then in French in 1929, under the title *La biosphère* (see Vernadsky, 1998 for an English rendition). Several papers followed. Vernadsky defined the biosphere as 'the medium of life' (1944, p. 488) and 'the domain of life, but also, and more fundamentally, as the region where changes due to incoming solar radiation can occur' (1945, p. 1). He defined this domain or medium of life to include 'the whole atmospheric troposphere, the oceans, and a thin layer in the continental regions,

extending down three kilometers or more' (1945, p. 1). The following quotation reveals more clearly his thinking on the matter:

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, civilized man, as well as his inevitable companions, penetrates deep below the relief, in contact with the troposphere, for several kilometers 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 kilometers and possibly even more, has now become apparent.

The lower boundary of the biosphere thus lies several kilometers 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. (Vernadsky, 1944; p. 488–489)

It can be seen that, to Vernadsky, the biosphere was all life and life-support systems – living organisms and the media in which they live (air, water, soil, sediment). This contrasted with Teilhard's view that the biosphere is simply the totality of all living beings. However, Teilhard and Vernadsky did share a cosmic and planetary vision of life (Grinevald, 1988; p. 14).

The essays in which Teilhard set down his doctrine of the biosphere and noosphere appeared before *La biosphère*, and Teilhard never referred to Vernadsky's book in his subsequent writings. The result is that Teilhard's view of the biosphere became established in Western scientific circles, not Vernadsky's. Even in his native Russia it sank almost without trace during the early 1930s, although it could be argued that it later found expression in the work of Vladimir Nikolaevich

Sukachev, a Russian plant ecologist who developed the concept of the biogeocoenose, similar to Tansley's concept of the ecosystem (e.g. Sukachev & Dylis, 1968). The term biosphere was occasionally used in the Vernadskian sense by Western ecologists (e.g. Florkin, 1943; Allee *et al.*, 1949; Duvigneaud, 1974). The key player in bringing Vernadsky to the notice of western scientists was George Evelyn Hutchinson (1965, 1970). Hutchinson revived interest in Vernadsky's biosphere by arranging the publication of two papers, the first in 1944 and the second in 1945. These papers had little impact at the time. However, in the early 1970s, global ecology arose as a discipline and biogeochemical cycles became a sharp focus of research. It was then that the Vernadskian vision of the biosphere started to blossom, again, largely through the writings of Hutchinson.

### The biosphere as the space in which life resides

The thrust of Hutchinson's work on biogeochemistry was inspired by Vernadsky's ideas. In 1965, in *The Ecological Theater and the Evolutionary Play*, and in 1970 in the *Scientific American*, Hutchinson brought Vernadsky's biosphere to general notice. Following Vernadsky, Hutchinson defined the biosphere as 'that part of the earth in which life exists'. He was aware that this definition immediately raises problems and demands qualifications. As he explained:

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 dry, too cold or too hot to support metabolizing organisms (except technically equipped human explorers), but in such places 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 be best regarded as small volumes of the biosphere nipped off and projected temporarily into space. (Hutchinson, 1970)

Hutchinson's definition is not exactly the same as Vernadsky's because it stresses the space occupied by life, and it does not make explicit the unitary nature

of the biosphere as a functional entity comprising life and life-support systems.

After 1970, the word biosphere became popular in scientific and lay circles. Its three different meanings persisted. Thus, it has recently been taken as 'the rough total of all living organisms' (Gillard, 1969) and 'the living system' (Golley, 1978); 'the thin shell of air, water and soil around the Earth where life exists' (Bolin, 1980; p. 3); 'the thin layer of soil, rock, water, and air that surrounds the planet Earth, along with the living organisms for which it provides support, and which modify it in directions that either enhance or lessen its life-supporting capacity' (Dasmann, 1976; p. 6) and 'the planetary system that includes and sustains life' (Botkin, 1990; p. 229). Hybrid definitions have also evolved. Thus in a recent textbook of physical geography we learn that:

The biosphere is the zone of life, the home of all living things. This includes the earth's vegetation, animals, and human beings. Since there are living organisms in the soil and plants are rooted in the soil, part of the soil layer (which is otherwise a component of the lithosphere) may be included in the biosphere. (de Blij & Muller, 1993; p. 14)

Some dictionaries carry the various meanings of biosphere: for instance, *The Random House Dictionary of the English Language* (1987) informs us that the biosphere is '1. the part of the earth's crust, waters, and atmosphere that supports life', and '2. the ecosystem comprising the entire earth and the living organisms that inhabit it'. The term enjoys currency in the titles of major research initiatives into environmental matters, for example, in the International Geosphere-Biosphere Programme, which was launched in 1986, and in the Project for Ecologically Sustainable Development of the Biosphere, which is run by the International Institute for Applied Systems Analysis at Laxenburg in Austria.

## ECOSPHERE

### The terrestrial ecosphere

Some ecologists preferred to limit the biosphere to all living things, as Teilhard de Chardin had done. By insisting on this restriction, ecologists found themselves lacking a word to describe the total ecosystem – the totality of living organisms and the inorganic

environment that sustains them. Cole (1958) coined the term ecosphere to play that role.

Cole's intention in coining the word ecosphere was to combine two concepts: the biosphere and the ecosystem. The biosphere he took to mean the totality of living creatures on the Earth, crediting Lamarck and Vernadsky with its conception and development. The ecosystem he took as a community of organisms (animals and plants) together with their inorganic environment. This conception was clearly inspired by Tansley's (1935) image of an ecosystem: a community of organisms together with their physical environment. To Cole, the ecosphere is the global ecosystem, 'the sum total of life on earth together with the global environment and the earth's total resources' (Cole, 1958; p. 84).

Cole's term ecosphere was reinvented by Gillard (1969), who thought it useful for describing 'that part of our sphere in which there is life together with the living organisms it contains'. He was forced into this position because he chose to adopt Teilhard de Chardin's definition of the biosphere, largely, it would seem, because it mirrored Lamarck's 'definition', which predated Vernadsky's.

The term ecosphere is used by ecologists and biogeographers. Tivy employed it in *Biogeography: a Study of Plants in the Ecosphere* (1982). Commoner (1972) used the idea of the ecosphere as a framework in which to consider the 'environmental crisis', although he spoke of the ecosphere as 'the home that life has built for itself on the planet's outer surface' (1972, p. 11), a definition redolent of Hutchinson's biosphere. I used it in three recent books (Huggett, 1995, 1997, 1998).

### Extraterrestrial ecospheres

A possible reason for not adopting Cole's 'ecosphere' is that the word was first used in a different context. In 1953, in a book entitled *The Green and Red Planet: a Physiological Study of the Possibility of Life on Mars*, Hubertus Strughold used the term ecosphere to define the zones in the universe that would be habitable by living organisms:

Only a small zone about 75 million miles wide – out of the 4300 million that stretch between the sun and Pluto at its farthest point – provides a planetary environment well-suited to the existence of life. We might call this zone the thermal ecosphere of the sun.

Other stars may have such ecospheres of their own, with planets in them that are capable of supporting life similar to ours. (Strughold 1953; p. 43)

Astronomers have subsequently used the word ecosphere to mean regions in space where conditions would allow living things to exist (at least, living things as we know them). And it is Strughold's idea of an ecosphere, not Cole's, that is encountered in most dictionaries. For instance, it appears in the 1972 *Supplement to the Oxford English Dictionary* where it is defined as 'The region of space including planets whose conditions are not incompatible with the existence of living things', and in the *Glossary of Geology* where we are told that it means 'Portions of the universe favourable for the existence of living organisms' (Bates & Jackson, 1987). Hutchinson's (1970) idea of temporary biospheres (=ecospheres) created in spacecraft seems to fit this definition, even though the 'favourable conditions' in spacecraft are artificially produced.

### GAIA

Gaia is a third word that is sometimes used as a name for the global ecosystem. It comes from the Gaia hypothesis, which is the latest recasting of the ancient, holistic belief that there exists interconnectedness and harmony among the phenomena of Nature. It was first suggested by the atmospheric chemist James Lovelock, supported by microbiologist Lynn Margulis, and named by novelist William Golding.

There are at least two versions of the Gaia hypothesis: weak Gaia and strong Gaia (Kirchner, 1991). Weak Gaia is the assertion that life wields a substantial influence over some features of the abiotic world, notably the temperature and composition of the atmosphere. In other words, it makes the simple proposal that the Earth's climate and surface environment are actively regulated by animals, plants, and microorganisms. Strong Gaia is the unashamedly teleological idea that the Earth is a superorganism which controls the terrestrial environment to suit its own ends, whatever they might be.

In some of his writings, Lovelock seems to favour strong Gaia. He believes that it is useful to regard the planet Earth not as an inanimate globe of rock, liquid, and gas, driven by geological processes, but as a sort of biological superorganism, a single life-form, a living

planetary body that adjusts and regulates the conditions in its surroundings to suit its needs (e.g. Lovelock, 1991). For Lovelock, Gaia and the biosphere are different things:

The name of the living planet, Gaia, is not a synonym for the biosphere. The biosphere is defined as that part of the Earth where living things normally exist. Still less is Gaia the same as the biota, which is simply the collection of all individual living organisms. The biosphere and the biota taken together form part but not all of Gaia. Just as the shell is part of a snail, so the rocks, the air, and the oceans are part of Gaia. (Lovelock, 1988; p. 10)

The weak version of Gaia is an hypothesis about the planet Earth, its surface sediments, and its atmosphere, which involves the interaction of the biota with surficial materials creating anomalies of temperature, chemical composition, and alkalinity (Margulis & Hinkle, 1991, p. 11). This global view of interactions between life and life-support systems has much in common with Vernadsky's view that the biosphere is the interacting sum of all animate objects and the inanimate materials they require for their survival. Thus, Vernadsky's biosphere and weak Gaia appear to have much in common, and are both quite different from strong Gaia. However, as Grinevald (1988) points out, too little of Vernadsky's writings has been translated from the Russian yet to decide just how close are his concept of the biosphere and Gaia (see also Grinevald, 1992, 1993).

### WHICH WORD FOR THE GLOBAL ECOSYSTEM?

So there are three words vying with one another as names for the global ecosystem. Which word suits the role best? Let us start by considering the word Gaia. Volk (1998) uses it as a name for the planetary ecosystem. This is possibly an imprudent practice because Gaia is an emotive word with a gamut of confusing undertones and overtones. Gaian terminology can be unscientific, and Volk knows this: 'Thinking of Earth's life-inhabited surface as a *physiological* system immediately conjures up an image of a giant volitional being, as does naming the system after a Greek goddess' (1998, p. viii). He cautions that 'We must exercise some care in applying this analogy' (1998, p. viii). He then professes that 'Beyond alluding to such concepts, I will not weave detailed arguments

for or against the idea that Earth is alive, that Gaia self-regulates, and that Gaia is a self-sustaining organism, or perhaps quasi-organism' (1998, p. viii-ix). His reason for this is that 'Such notions depend on a slew of ambiguous words that, however, carefully defined, either ready readers for an Earth-hug or raise their hackles. In either case, the reader's attention to the *science* of Gaia and its overarching principles may lapse' (1998, p. ix). He therefore tries to work a balancing act. As he explains: 'On the one hand, I experience a delightful sense of being inside a giant metabolism. This perception grows more acute the more I learn, but I am also convinced that Gaia is very different from any organism. Thus I can honestly apply the principles of science to study the global metabolism without postulating a global organism' (1998, p. ix).

So, realizing the deep pitfalls involved, why did Volk use the word Gaia? My view is that he was inveigled by the grandeur of Gaian imagery. A purely mechanistic world is characterless compared with the world of gods and goddesses, and of superorganisms with superphysiologies and (presumably) superanatomies. Volk is so won over by classical allusions that he does his own bit of image-making – solar influences become Helios and geological influences become Vulcan. However, it pays to take care when using such image-laden terminology, as it is taken to extremes by ardent proponents of a living world-organism, or what might be called the ultra-strong Gaians (e.g. Zoeteman, 1991), whose vitalistic agenda is an anathema to most scientists. For this reason, Gaia is not therefore a good word to use for the global ecosystem, leaving biosphere and ecosphere as other possibilities.

Plainly, Vernadsky's biosphere is equivalent to Cole's (and Gillard's) ecosphere. The term ecosphere, at least in the sense of Cole and Gillard, might therefore be regarded as superfluous. Polunin & Grinevald (1988) certainly think so. They are adamant that the biosphere is 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' (Polunin & Grinevald, 1988; p. 118). I do not agree. It seems to me logical to use 'ecosphere' to describe the totality of life and life-support systems, and to use 'biosphere' in the literal sense of the word as the sphere of life (the totality of living things). Grinevald would presumably deplore this suggestion because he regards the word 'ecosphere' as a 'neologism, introduced in flagrant ignorance of Vernadsky's teaching' that reduced the concept of the biosphere to a 'far narrower, more

pedestrian idea than what Vernadsky proposed' (1998, p. 21). However, I cannot see why using ecosphere in place of Vernadsky's biosphere in any way belittles Vernadsky's monumental achievement. I feel very strongly that the word ecosphere captures Vernadsky's conception of life and life-support systems far better than does the word biosphere and is an admirable descriptor of the global ecosystem.

The term ecosphere may also be applied to Hutchinson's artificial biospheres (=ecospheres) operating in manned spacecraft. It is less easy to reconcile with Strughold's extraterrestrial ecospheres where terrestrial-type conditions may allow the existence of terrestrial-type life. Strughold's 'thermal ecosphere of the sun' includes Mars, where temperature conditions are not unfavourable to life. However, Mars appears not to support life at present and so does not have a planetary ecosphere. Strughold's ecospheres are portions of solar systems in which planetary ecospheres might exist, but their existence cannot be confirmed until life is discovered on planets within them. They are potential extraterrestrial life-zones, rather than actual planetary ecosystems. For this reason, Strughold's definition of the term 'ecosphere' does not harmonize with Cole's definition.

On balance, it seems to me that, with apologies to Lovelock, Strughold, and Vernadsky, 'ecosphere' is the most appropriate term for all situations where living things and their supporting environment are taken as a whole. It may be applied to the terrestrial ecosphere and to artificial ecospheres, and it could be applied to other planets and satellites that support life.

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