CYBERNETIC COUNTERCULTURES INTENSIVE

Week 7. Planetary Cognition: Lovelock and Margulis

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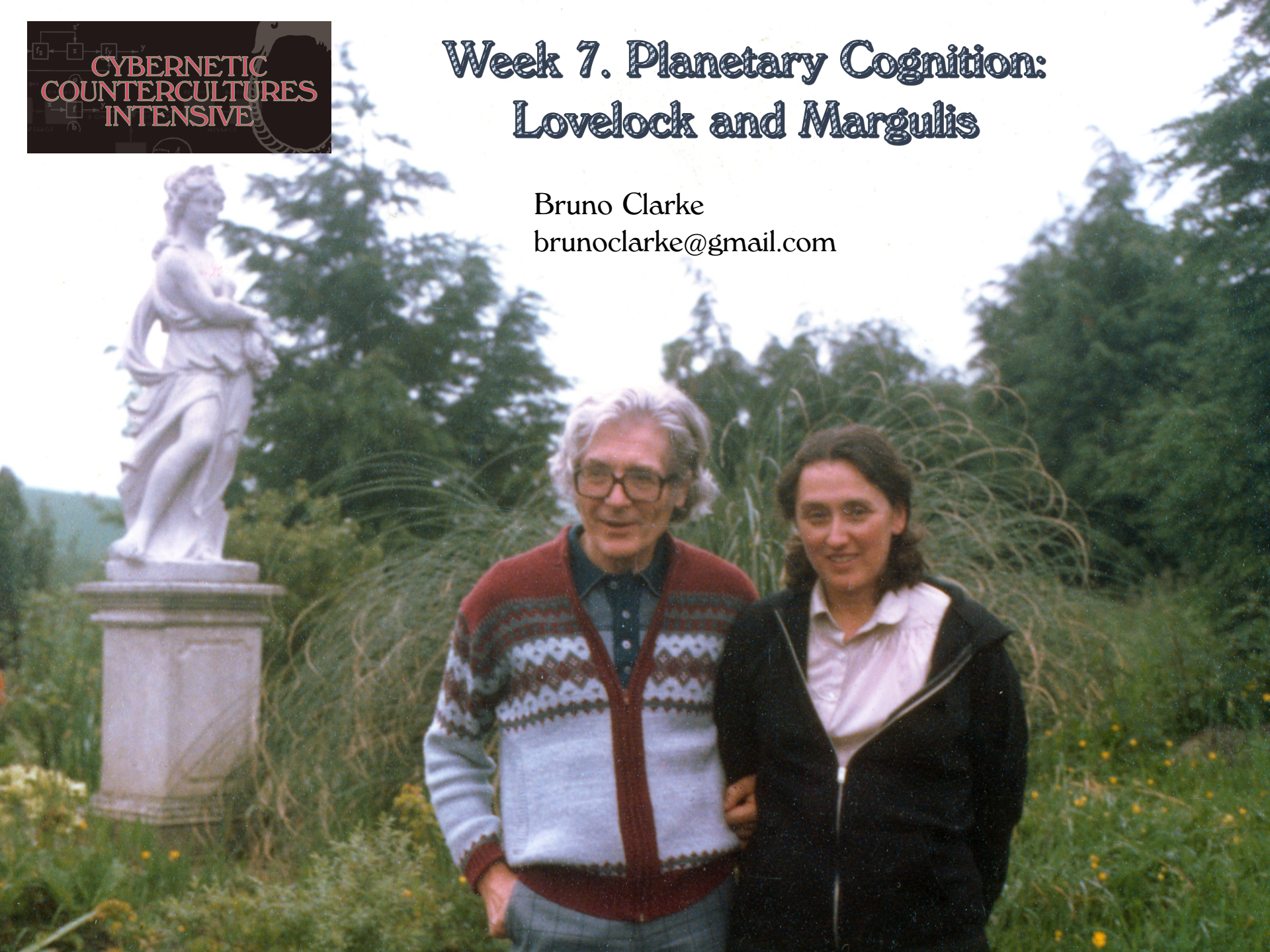

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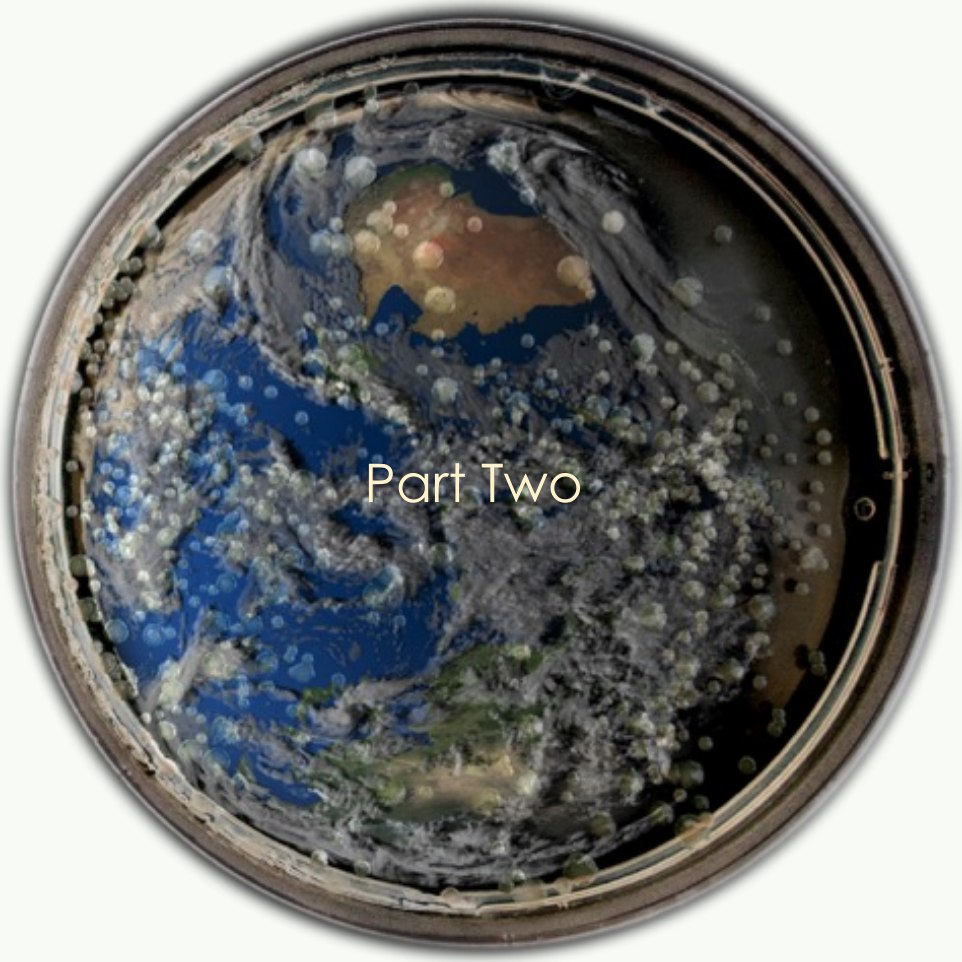

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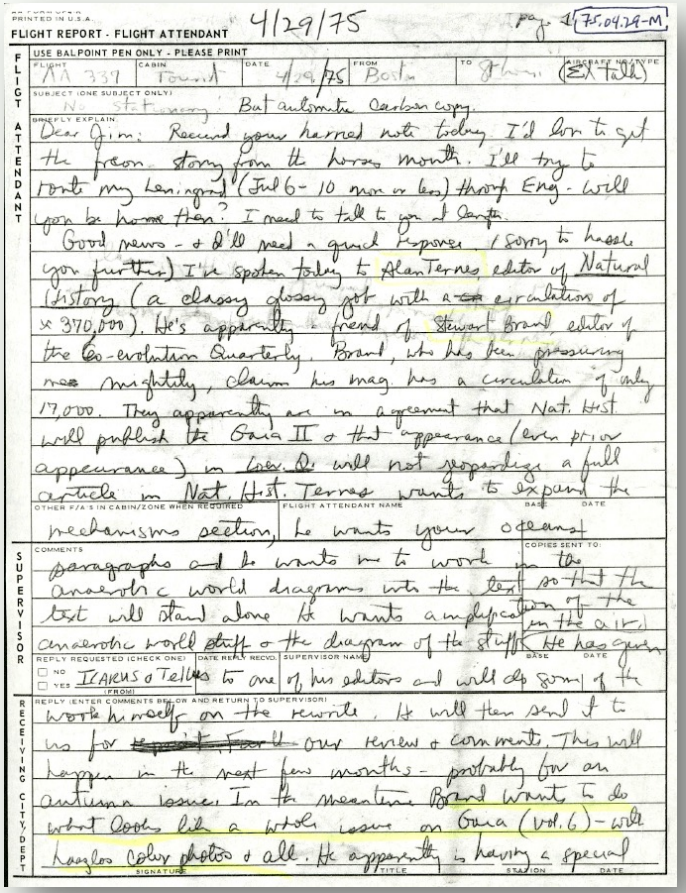
Gaia in the Cybernetic Countercultures

—Let's take a moment to note that the *Whole Earth Catalog* was never merely a lifestyle catalog for hippies and communalists. It had all manner of brilliant expository content, frontloaded in every number by "Understanding Whole Systems," which was at heart a cybernetics-themed book review section.

Its spin-off *CoEvolution Quarterly* has evolved into a *magazine* that mixes a significant amount of article content with the WEC"s stock in trade, curated "objective" (non-commercial) product reviews with purchasing information.

Being the first outlet ever to present the authors of the Gaia hypothesis to a non-specialist audience covers it in glory, at least in hindsight. The same goes for much of its extensive presentations of cutting-edge Cybernetic Countercultures content. This is of course a mere sliver of its entire substance, but it's arguably its most valuable and historically consequential component.

In 1970 it was Carl Sagan who put his ex-wife Lynn Margulis in touch with James Lovelock. In 1975, it was also Carl Sagan who brought the Gaia hypothesis to the attention of Stewart Brand.



FLIGHT REPORT · FLIGHT ATTENDANT

4/29/75

Page 1 [75.04.29-M]

FLIGHT ATTENDANT

USE BALPOINT PEN ONLY PLEASE PRINT

FLIGHT: AA 339 | CABIN: Tourist | DATE: 4/29/75 | FROM: Boston | TO: [illegible] | AIRCRAFT NO./TYPE: (EX Talk)

SUBJECT (ONE SUBJECT ONLY): N. Stat[illegible] But automatic carbon copy.

BRIEFLY EXPLAIN:

Dear Jim: Received your harried note today. I'd love to get the Gaea story from the horses mouth. I'll try to route my Lexington (Jul 6- 10 mon or less) thru Eng - Will you be home then? I need to talk to you a bunch.

Good news - & I'll need a quick response (sorry to hassle you further) I've spoken today to Alan Ternes, editor of Natural History (a classy glossy job with a circulation of ~ 370,000). He's apparently a friend of Stewart Brand editor of the Co-evolution Quarterly. Brand, who has been pressuring me mightily, claims his mag. has a circulation of only 17,000. They apparently are in agreement that Nat. Hist will publish the Gaia II & that appearance (even prior appearance) in Nat. Hist will not jeopardize a full article in Nat. Hist. Ternes wants to expand the mechanisms section, he wants your opinions

OTHER F/A'S IN CABIN/ZONE WHEN REQUIRED | FLIGHT ATTENDANT NAME | BASE | DATE

SUPERVISOR

COMMENTS: paragraphs and he wants me to work in the anaerobic world diagrams with the text so that the text will stand alone. He wants a amplification of the anaerobic world stuff & the diagram of the stuff. He has given

COPIES SENT TO:

REPLY REQUESTED (CHECK ONE) | DATE REPLY RECVD. | SUPERVISOR NAME | BASE | DATE

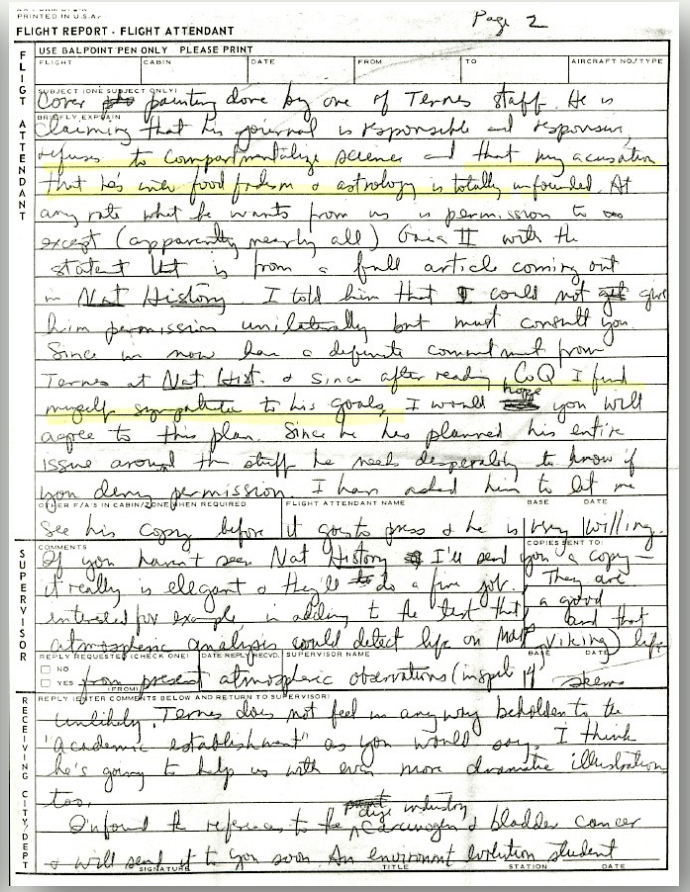
☐ NO ☐ YES — ICARUS & Telos to one of his editors and will do some of the

RECEIVING CITY DEPT

REPLY (ENTER COMMENTS BELOW AND RETURN TO SUPERVISOR) (FROM)

work himself on the rewrite. It will then send it to us for [illegible] our review & comments. This will happen in the next few months - probably for an autumn issue. In the meantime Brand wants to do what looks like a whole issue on Gaia (vol. 6) - with Douglas Colin photos & all. He apparently is having a special

SIGNATURE | TITLE | STATION | DATE



FLIGHT REPORT · FLIGHT ATTENDANT

Page 2

FLIGHT ATTENDANT

USE BALPOINT PEN ONLY PLEASE PRINT

FLIGHT | CABIN | DATE | FROM | TO | AIRCRAFT NO./TYPE

SUBJECT (ONE SUBJECT ONLY): Cover [illegible] painting done by one of Ternes staff. He is

BRIEFLY EXPLAIN:

claiming that his journal is responsible and responsive refuses to compartmentalize science and that my accusation that he's into food faddism & astrology is totally unfounded. At any rate what he wants from me is permission to use excerpts (apparently nearly all) Gaia II with the statement that it is from a full article coming out in Nat History. I told him that I could not give him permission unilaterally but must consult you. Since in now has a definite commitment from Ternes at Nat Hist. & since after reading CoQ I find myself sympathetic to his goals, I would hope you will agree to this plan. Since he has planned his entire issue around the stuff he needs desperately to know if I can have permission. I have asked him to let me

OTHER F/A'S IN CABIN/ZONE WHEN REQUIRED | FLIGHT ATTENDANT NAME | BASE | DATE

See his copy before it goes to press & he is very willing.

SUPERVISOR

COMMENTS: If you haven't seen Nat History I'll send you a copy — it really is elegant & they'll do a fine job. They are interested for example in adding to the text that a good atmospheric analysis could detect life on Mars (Viking) life

COPIES SENT TO:

REPLY REQUESTED (CHECK ONE) | DATE REPLY RECVD. | SUPERVISOR NAME | BASE | DATE

☐ NO ☐ YES — from present atmospheric observations (insp[illegible] Sken-

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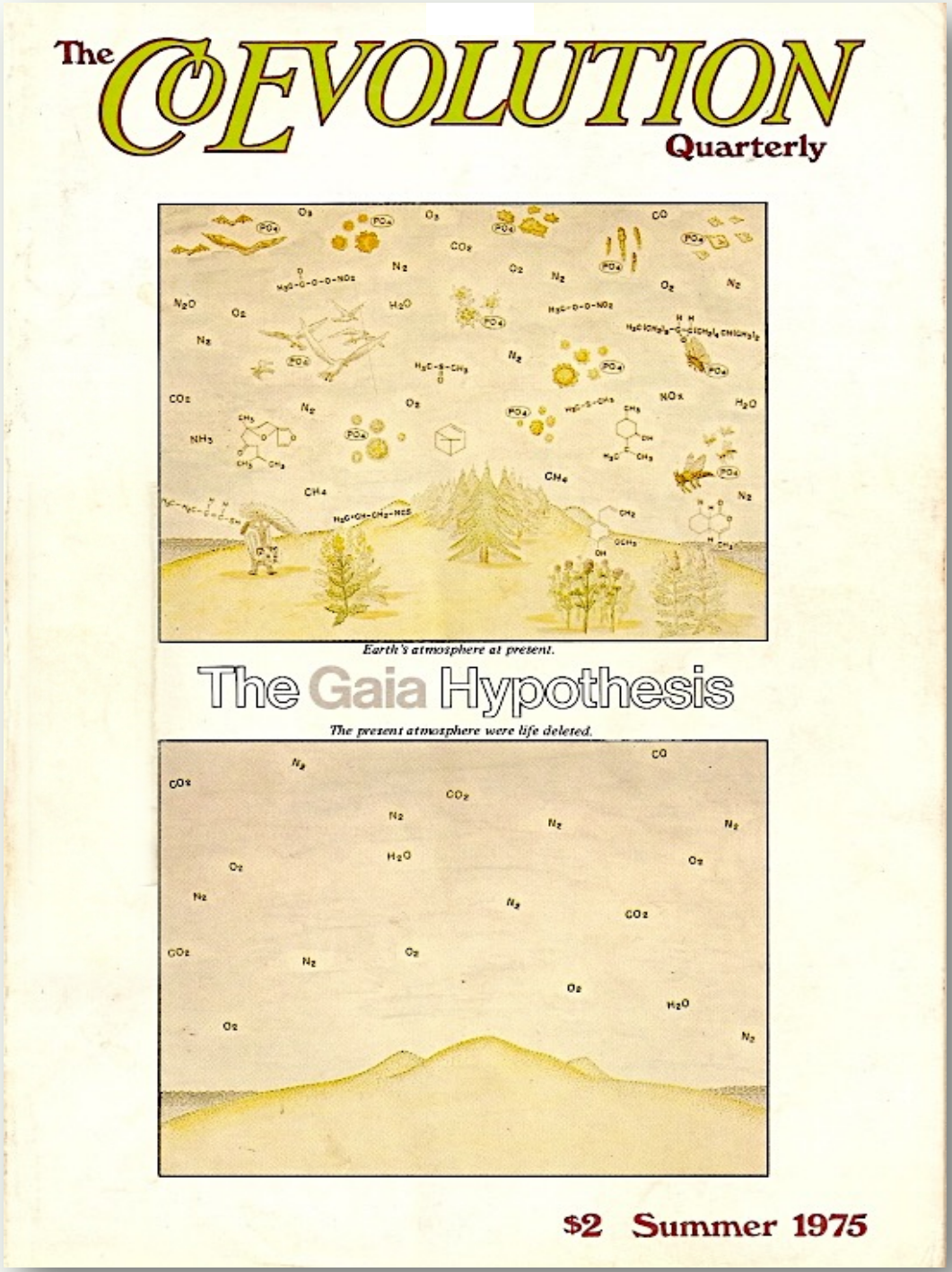
REPLY (ENTER COMMENTS BELOW AND RETURN TO SUPERVISOR) (FROM)

tadsky). Ternes does not feel in any way beholden to the "academic establishment" as you would say. I think he's going to help us with even more dramatic illustrations too.

I've found the references to the present [illegible] industry & Carcinogen & bladder Cancer & will send it to you soon. An Environment Evolution student

SIGNATURE | TITLE | STATION | DATE

". . . Good news—and I'll need a quick response (sorry to hassle you further) I've spoken today to Alan Ternes, editor of *Natural History* (a classy glossy job with a circulation of @ 370,000). He's apparently a friend of Stewart Brand, editor of the *CoEvolution Quarterly*. Brand, who has been pressuring me mightily, claims his mag. has a circulation of only 17,000. . . . **Brand wants to do what looks like a whole issue on Gaia (vol. 6) . . . . He is claiming that his journal is responsible and responsive, refuses to compartmentalize science and that my accusation that he's into food faddism and astrology is totally unfounded.** . . . I told him that I could not give him permission unilaterally but must consult you." (Lynn Margulis to James Lovelock, April 29, 1975)



—Figure legend from p.35: "Earth's atmosphere at present: examples of major volatiles. . . . Spores of: ferns, club mosses, zygomycetes, ascomycetes, basidiomycetes, slime molds, bacteria. All contain nucleic acids and other organic phosphates, amino acids and so forth. Animal products: butyl mercaptan, plant products: myoporum, catnip (nepetalactone), eugenol, geraniol, penine, isothiocyanate (mustard); unknown; PAN (peroxacetyl nitrate), dimethyl sulphide, dimethyl sulfoxide; gases: nitrogen, oxygen, methane, carbon monoxide, carbon dioxide, ammonia."

—It's interesting to note that just preceding the Gaia article is a two-page Carl Sagan review of publications on "Earth from space." This is not Sagan's usual cosmic orientation! But here, it seems, he lends a hand to introduce the Gaian angle.

Understanding Whole Systems

Three From Space

BY CARL SAGAN

One of the many benefits of space flight are the exquisite photographs of the Earth which have been returned – at first almost as an accidental by-product. Now manned Earth orbital missions and unmanned meteorological and Earth resources satellites regularly return a bonanza of portraits of our planet with ground resolutions ranging from hundreds of kilometers to tens of meters. In such photographs we can discern much of the intricate and exquisite meteorology, geology and biology of our planet. It is impossible to view such pictures without acquiring a new perspective on our tiny world: "If we could but see ourselves as others do." The "others" are a little uncertain still, but there is no doubt that viewing the best color photographs of the Earth is an act of enlightenment for the geologist, meteorologist and biologist; for the planetary scientist interested in comparing other planets with his own; and for those simply interested in an unparalleled aesthetic experience.

Unfortunately, despite the fact that without exception the finest color photographs of the Earth have been taken from United States spacecraft, there has been little attempt in this country to publish representative (much less comprehensive) atlases of Earth photography. A few such photographs have been published in the NASA publication **This Island Earth** some years ago. Several books of Earth photographs have been published, written by NASA geologist Paul Lowman and printed in Switzerland. The latest, **The Third Planet: Terrestrial Geology in Orbital Photographs**, is instructive and well-produced and is a very useful adjunct to any study of the Earth. It uses exclusively Gemini and Apollo photographs from hand-held cameras.

Carl Sagan is, among other noteworthy things (see Sagan's Conjecture, p. 7), editor of the excellent space science journal **Icarus**, *$121.50/yr. (monthly) from Academic Press, 111 Fifth Ave., New York, NY 10003.*

– SB

But there are two new publications which deserve very serious attention. In 1969 List Verlag in Munich published the original German edition of **The Earth from Space** by the German scientists Bodechtel and Gierloff-Emden, who evidently prevailed upon the American Embassy in Bonn to provide their material. Professor Bodechtel is a geologist, Professor Gierloff-Emden a geographer. We now have available the English edition of this work and, in German, another more comprehensive book by the same authors. Both books are beautifully produced. The more recent one shows a very wide variety of locales and phenomena; the earlier book has something of a fixation on the Arabian peninsula. Both works are graced by excellent color key maps which greatly illuminate the photographs. There is also an accompanying text which provides excellent short descriptions of what we see; it is particularly useful in the geological sciences. We have volcanoes, rift valleys, impact craters, sand dunes, coral atolls; a placid looking "Bermuda triangle"; a snowy Denver nestling at the foot of the Rockies; an exquisite photograph of Nepal, the Himalayas and Mt. Everest; the flood plain of the Ganges; bushfires in northern Australia; a multitude of sinuous tributaried rivers; astonishing polar terrain and ice floes; and at about 100 meters resolution a wide variety of lines of evidence that the Earth is inhabited by creatures enamoured of squares and rectangles. [As a calibration for the photographic reconnaissance of Mars at resolution of 1 kilometer to 100 meters such photographs have been studied in two papers called: "A Search for Life on Earth at Kilometer Resolution", Kilston et al., Icarus, 5, 79, 1966; and "A Search for Life at Hundred Meter Resolution", Sagan and Wallace, Icarus, 15, 515, 1971.] The photographs in **The Earth from Space** are primarily from Gemini and Apollo; those in **Weltraumbilder die dritte Entdeckung der Erde** are primarily from ERTS and Skylab.

There are useful descriptions of observational techniques and only a few gaffes or important omissions: such as the statement that the Apollo color photographs of the Moon represent true greens, blues and browns; or, in a chapter on "Flying Spies", an omission of any hint that such techniques might have some politically stabilizing military function. Some of the definitions in the glossary are understandable but less than accurate: such as the definition of lasers as "very powerful and narrow beams of light".

After the publication of **The Earth from Space**, Bodechtel and Gierloff-Emden were evidently made principal investigators on subsequent NASA Earth orbital photography missions, so that they now can get their data directly. The American Embassy in Bonn is apparently freed for other functions. The authors and publishers are to be congratulated on their choice and exposition of photographs and the quality of photographic reproduction. I hope that **Weltraumbilder die dritte Entdeckung der Erde** will appear in a high quality English language edition. Both books should be in every library. ■

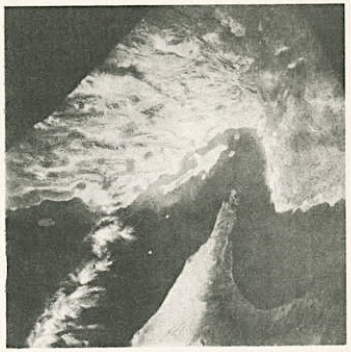
India – Gemini 11. From **The Third Planet**

Southeast Greece and the Aegean Sea. From **Weltraumbilder**

The Third Planet
(Terrestrial Geology in Orbital Photographs)
Paul D. Lowman, Jr.
1972; 165pp.
$32.00 + $10.00 airmail post.
from:
Weltflugbild
Verlag Reinhold A. Muller
Feldmeilen
Zurich, Switzerland

Weltraumbilder
(die dritte Entdeckung der Erde)
J. Bodechtel & H.-G. Gierloff-Emden
1974; 207pp.
$15.00 + $7.20 airmail post.
from:
Paul List Verlag KG, Munchen
SV Sudwest
8 Munchen 33
Postfach, 780, Germany

The Earth from Space
J. Bodechtel & H.-G. Gierloff-Emden
1974; 176pp.
$16.95 postpaid
from:
Arco Pub. Co., Inc.
219 Park Ave. South
New York, NY 10003
or Whole Earth



The Strait of Hormus, the gate to the Persian Gulf. From **The Earth from Space**

"We would like to discuss the Earth's atmosphere from a new point of view – that it is an integral, regulated, and necessary part of the biosphere... "This new way of viewing the Earth's atmosphere has been called the "Gaia" hypothesis. The term Gaia is from the Greek for "Mother Earth," and it implies that certain aspects of the Earth's atmosphere— temperature, composition, oxidation reduction state, and acidity— form a homeostatic system, and that these properties are themselves products of evolution."

FIGURE 1. Frontispiece* to Sachs von Lewenheimb, 1664, Oceanus Macro-Microcosmicus. This illustration stresses the analogies between the circulation of the blood and the circulation of water. According to W. Pagel (1), *"The subtitle of the dissertation [which addresses itself to the famous anatomist Thomas Bartholinus] explains that it deals with the analogies between the circular motion of the water from and back to the sea, on the one hand, and that of the blood from and back to the heart, on the other. This motion is "circular," not because it describes the geometrical figure of a circle, but because it reverts to its point of departure. The earth resembles the human body in that, like the latter, it is pervaded by canals and harbours an internal fire. The sea lets water rise by evaporation and return in the form of rain whereby the rivers and subterranean waters are nourished and these finally return the same water to the sea. The latter thereby acts not unlike the heart from which the blood goes out to the organs, starting on its way attenuated by the influx of heat and 'perfected' in the 'workshops' of the organs; finally, after its absorption and assimilation by the organs, its residue is drawn back into the heart in order to be attenuated again – just as the waters are diluted by joining the sea."*

*From the original treatise in the Wellcome Library by courtesy of the trustees.

The Atmosphere as Circulatory System of the Biosphere— The **Gaia** Hypothesis

BY LYNN MARGULIS AND JAMES E. LOVELOCK

We would like to discuss the Earth's atmosphere from a new point of view – that it is an integral, regulated, and necessary part of the biosphere. In 1664 Sachs von Lewenheimb, a champion of William Harvey, used the analogy shown in Figure 1 to illustrate the concept of the circulation of blood. Apparently the idea that water lost to the heavens is eventually returned to Earth was so acceptable in von Lewenheimb's time that Harvey's theory was strengthened by the analogy (1).

Three hundred and ten or so years later, with the circulation of blood a universally accepted fact, we find it expedient to revive von Lewenheimb's analogy – this time to illustrate our concept of the atmosphere as circulatory system of the biosphere. This new way of viewing the Earth's atmosphere has been called the "Gaia" hypothesis (2). The term Gaia is from the Greek for "Mother Earth," and it implies that certain aspects of the Earth's atmosphere – temperature, composition, oxidation reduction state, and acidity –

The Gaia Hypothesis ("Gaia" is pronounced to rhyme with papaya) treats the anomalous Earth atmosphere as an artifact of life and comprehends the planet itself as a single life.

The two old puzzles – 1) How does the bizarre Earth atmosphere maintain itself? and 2) How does fragile Earth life maintain itself? – solve each other. It took two remarkable scientists – Margulis & Lovelock – meeting outside their specialties to discover that convergence.

Lynn Margulis is a microbiologist at Boston University. Her best-known contribution is the symbiotic theory of the origin of complex cells (her book Origin of Eukaryotic Cells *is reviewed on p. 41). Popularization of that theory in* The Lives of a Cell *won Lewis Thomas a National Book Award last month. He even perpetuated Dr. Margulis' misspelling – "Myxotricha paradoxa" (should be Mixotricha, she notes).*

James Lovelock is the envy of every scientist, a successful free-lancer. Working out of a thatched cottage in the Salisbury Plain, England, this biospheric chemist has accumulated some 69 patents – most of them in what he calls "gas pornography" – chromatographic analysis of gases at the parts-per-billion level. The New Scientist *recently wrote of him, "In some ways, Jim Lovelock – begetter of the Gaia hypothesis – is one of the last of the old-style natural philosophers. A scientist who works from his own home because he believes that lack of security encourages creativity, he has invented – among other things – 'a magnificent Pandora's box', the electron capture detector gas chromatograph. Most sensitive of the analytical chemist's tools, it has been responsible for arousing concern about pesticide residues and Freons in the stratosphere, and may yet help to show that, thanks to Gaia, our fears of pollution-extermination are unfounded."*

It is an honor for The CoEvolution Quarterly *to be the first non-specialist American publication to carry the Gaia Hypothesis. Margulis and Lovelock will doubtless take some flak for appearing in suspect company – condom evaluations, poetry, and such – but both seem comfortable that their science is sound enough to withstand the science-plus context. We are grateful to Carl Sagan, who put us in touch with Lynn Margulis, and to* Natural History *editor Alan Ternes, who will publish an expanded version of this article in his magazine in September or October.*

Gaia is an old idea. She is one of the four primary divine beings of the Ancient Greeks – Chaos (Space), Gaia (Earth), Tartarus (the Abyss), and Eros (Love). But Gaia is still a new hypothesis, containing more questions than answers.

It is too early for proofs, conclusions, or morals, beyond the one increasingly obvious, that as long as human activity works against the self-balancing of biosphere and atmosphere there is no Teilhardian noosphere in evidence, just a damned human cartel.

In Gaia we are – all – Tangled Up In Blue.

– SB

—Margulis secured the article's frontispiece, Sachs von Lewenheimb's 1664 engraving "Oceanus Macro-Microcosmicus," to illustrate her analogy between the discovery of the circulation of the blood in the human body and the realization expressed as the Gaia hypothesis, that the circulation of the atmosphere is part of the "physiology" of a self-regulating planetary "body."

"We agree that the laws of physics and chemistry are basic to the understanding of atmospheric phenomena but insist that the laws of biology must be considered as well. It is our contention that the paucity of overall understanding of certain aspects of the atmosphere, especially composition and temperature, is due to too narrow a paradigm: the idea that the atmosphere is an inert part of the inorganic environment and therefore amenable to methods of study that involve only physics and chemistry. ¶ In this paper we explore what is perhaps a more realistic view—that the atmosphere is a nonliving, actively regulated part of the biosphere. In our model atmospheric temperature and composition are regulated with respect to certain biologically critical substances: hydrogen ions, molecular oxygen, nitrogen and its compounds, sulfur and its compounds, and some others, whose abundance and distribution in the atmosphere are presumed to be under biological control. . . . The purpose of this paper is simply to present our reasons for believing the atmosphere is actively controlled."

form a homeostatic system, and that these properties are themselves products of evolution (3, 4).

From recent articles and books (e.g., 5 and 6) one gets the impression that fluid dynamics, radiation chemistry, and industrial pollution are the major factors determining the properties of the atmosphere. The Gaia hypothesis contends that biological gas exchange processes are also major factors, especially processes involving microorganisms. Man's impact on the atmosphere may have been overestimated. Man is only one of some three million species on Earth, all of which exchange gas and most of which exchange gas with the atmosphere. Man has been around for only a few million years while microorganisms have existed for thousands of millions of years. It is probably not so much the products of the several billion smaller organisms living in every pail of rich soil or water.

It seems to us that early 20th Century nonmicrobiological analysis of the Earth's lower atmosphere will one day be considered as ignorant as early 19th Century nonmicrobiological analysis of fermentation or disease is today.

In an excellent introduction to atmospheric science Goody and Walker (7) say, "There is a great difference between research in the laboratory and studies of the Earth and planets. In the laboratory the scientist can perform controlled experiments, each carefully designed to answer questions of his own choosing. Except in minor respects, however, the Earth and planets are too large for controlled experimentation. All we can do is observe what happens naturally in terms of the laws of physics and chemistry."

We agree that the laws of physics and chemistry are basic to the understanding of atmospheric phenomena but insist that the laws of biology must be considered as well. It is our contention that the paucity of overall understanding of certain aspects of the atmosphere, especially composition and temperature, is due to too narrow a paradigm: the idea that the atmosphere is an inert part of the inorganic environment and therefore amenable to methods of study that involve only physics and chemistry.

In this paper we explore what is perhaps a more realistic view — that the atmosphere is a nonliving, actively regulated part of the biosphere. In our model atmospheric temperature and composition are regulated with respect to certain biologically critical substances: hydrogen ions, molecular oxygen, nitrogen and its compounds, sulfur and its compounds, and some others, whose abundance and distribution in the atmosphere are presumed to be under biological control. Biological gas exchange processes, thought to be involved in possible control mechanisms, are discussed elsewhere (8). The purpose of this paper is simply to present our reasons for believing the atmosphere is actively controlled.

Traditional atmospheric studies have left us with some strange anomalies. The atmosphere is an extremely complex blanket of gas in contact with the oceans, lakes, rivers (the hydrosphere) and the rocky lithosphere. It has a mass of about 5.3 x 10^{21} grams.

Lynn Margulis

(The mass of the oceans — the other major fluid on the surface of the Earth — is almost a thousand times heavier, being about 1.4 x 10^{24} grams.) Since the atmospheric mass corresponds to less than a millionth of the mass of the Earth as a whole, one would expect small changes in the composition of the solid earth to cause large changes in the composition of the atmosphere. Yet even in the face of a large number of potential perturbations, the atmosphere seems to have remained dynamically constant over long periods of time.

Many facts about the atmosphere are known — its composition, its temperature and pressure profiles, certain interactions with incoming solar radiation, and the like (7). Some of these are shown in Tables 1 and 2. However as the efficacy of long range weather forecasting attests, there is no consistent model of the atmosphere that can be used for the purpose of prediction (6). The Earth's atmosphere

James Lovelock

defies simple description. From the point of view of chemistry it sustains such remarkable disequilibrium that Sagan (9) was prompted to remark that given the temperature, pressure, and amount of oxygen in the atmosphere, "one can calculate what the thermodynamic equilibrium abundance of methane ought to be . . . the answer turns out to be less than 1 part in 10^{36}. This then is a discrepancy of at least 30 orders of magnitude and cannot be dismissed lightly."

(more →)

TABLE 1. Reactive gases in the atmosphere (billions of tons/year)

Gas	Concentration in parts per million	How much of the gas comes from Inorganic Sources Volcanic, etc.?	Gaian* ?	Biological Sources Gaian* ?	Human ?	Residence time	Where does the gas come from principally?
Nitrogen (N_2)	790,000	0.001	1	0		1-10 million years	bacteria from dissolved nitrate in soil
Oxygen (O_2)	210,000	0.00016	110	0		1000 years	algae and green plants, given off in photosynthesis
Carbon Dioxide (CO_2)	320	0.01	140	16		2-5 years	respiration, combustion
Methane (CH_4)	1.5	0	2	0		7 years	fermenting bacteria
Nitrous Oxide (N_2O)	0.3	less than 0.01	0.6	0		10 years	bacteria and fungi
Carbon Monoxide (CO)	0.08	less than 0.001	1.5	0.15		a few months	from methane oxidation (methane from bacteria)
Ammonia (NH_3)	0.006	0	1.5	0		a week	bacteria and fungi
Hydrocarbons (CH_2)$_n$	0.001	0	0.2	0.2		hours	green plants, industry
Methyl Iodide (CH_3I)	0.000001	0	0.02	0		hours	marine algae
Hydrogen (H_2)	0.0000005	0	?	?		2 years	bacteria, methane oxidation?
Methyl Chloride (CH_3Cl)	0.000000001	0	?	?		?	algae?

*Gaian = nonhuman biological sources.

Gaia

It appeared to us that the Earth's biosphere was able to control at least the temperature of the Earth's surface and the composition of the atmosphere. Prima facie, the atmosphere looked like a contrivance put together co-operatively by the totality of living systems to carry out certain necessary control functions. This led us to the formulation of the proposition that living matter, the air, the oceans, the land surface were parts of a giant system which was able to control temperature, the composition of the air and sea, the pH of the soil and so on so as to be optimum for survival of the biosphere. The system seemed to exhibit the behaviour of a single organism, even a living creature. One having such formidable powers deserved a name to match it; William Golding, the novelist, suggested Gaia — the name given by the ancient Greeks to their Earth goddess . . . .

Man's present activity as a polluter is trivial and he cannot thereby seriously change the present state of Gaia let alone hazard her existence. But there is an aspect of man's activities more disturbing than pollution. If one showed a control engineer the graph of the Earth's mean temperature against time over the past million years, he would no doubt remark that it represented the behaviour of a system in which serious instabilities could develop but which had never gone out of control. One of the laws of system control is that if a system is to maintain stability it must possess adequate variety of response, that is, have at least as many ways of countering outside disturbances as there are outside disturbances to act on it. What is to be feared is that man-the-farmer and man-the-engineer are reducing the total variety of response open to Gaia.

The growing human population of the Earth is leading us to use drastic measures to supply this population with resources, of which food has prime importance. Natural distribution of plants and animals are being changed, ecological systems destroyed and whole species altered or deleted. But any species or group of species in an ecological association may contribute just that response to an external threat that is needed to maintain the stability of Gaia. We therefore disturb and eliminate at our peril; long before the world population has grown so large that we consume the entire output from photosynthesisers, instabilities generated by lack of variety of response could intervene to put this level out of reach . . . .

Now for one more speculation. We are sure that man needs Gaia but could Gaia do without man? In man, Gaia has the equivalent of a central nervous system and an awareness of herself and the rest of the Universe. Through man, she has a rudimentary capacity, capable of development, to anticipate and guard against threats to her existence. For example, man can command just about enough capacity to ward off a collision with a planetoid the size of Icarus. Can it then be that in the course of man's evolution within Gaia he has been acquiring the knowledge and skills necessary to ensure her survival?

Excerpted from "The Quest for Gaia", by James Lovelock & Sydney Epton, The New Scientist, 6 Feb 75

"Table 2 shows that given the quantity of oxygen in the atmosphere not only the major gases such as nitrogen and methane but also the minor atmospheric components are far more abundant than they ought to be according to equilibrium chemistry. Even though the minor constituents differ greatly in relative abundance, they sustained very large fluxes—comparable to those of the major constituents. The Earth's atmosphere is certainly not at all what one would expect from a planet interpolated between Mars and Venus. It has too little CO_2, too much oxygen, and is too warm. We believe the Gaia hypothesis provides the new approach that isneeded to account for these deviations.

¶ "A new framework for scientific thought is justified if it guarantees new observations and experiments.... The Gaia hypothesis of the atmosphere as a circulatory system raises useful scientific questions and suggests experiments that based on the old paradigm would never be asked...."

TABLE 2. Composition of the atmosphere: gases in disequilibrium

Gas	Abundance	Flux (moles/yr x 10^{13})	Disequilibrium factor	Oxygen used up in the oxidation of these gases (moles/yr x 10^{13})	abiological process	Source of gas % contribution by biological process	
						human	gaia*
Nitrogen	78%	3.6	10^{10}	11	.001	0	>99
Methane	1.5 ppm	6.0	10^{30}	12	0	0	100
Hydrogen	0.5 ppm	4.4	10^{30}	2.2	?	0	?
Nitrous oxide	0.3 ppm	1.4	10^{13}	3.5	.02	0	>99
Carbon monoxide	0.08 ppm	2.7	10^{30}	1.4	.001	10	90
Ammonia	0.01 ppm	8.8	10^{30}	3.8	0	0	100

*gaia = nonanthropogenic biological sources; for details see Table 1.
? = some quantities not known. ppm = parts per million

TABLE 3. Some critical biological elements that may be naturally limiting

Element	Use in biological systems	Possible form of fluid transport
MAJOR ELEMENTS		
C (carbon)	all organic compounds	CO_2; food; organic compounds in solution; biological volatiles; carbonate, bicarbonate, etc.; usually not limiting
N (nitrogen)	all proteins and nucleic acids	N_2, N_2O, NO_3^-, NO_2^- (often limiting)
O, H (oxygen, hydrogen)	H_2O in high concentration for all organisms	rivers, oceans, lakes
S (sulfur)	nearly all proteins (cysteine, methionine, etc.); key coenzymes	dimethyl sulfide; dimethyl sulfoxide, carbonyl sulfide
P (phosphorus)	all nucleic acids; adenosine triphosphate	unknown (biological volatiles? spores? birds? migrating salmon?)
Na, Ca, Mg, K (sodium, calcium, magnesium, potassium)	membrane and macromolecular function	usually not limiting except in certain terrestrial habitats (27)
TRACE ELEMENTS		
I (iodine)	limited to certain animals (e.g., thyroxine)	methyl iodide
Se (selenium)	enzymes of fermenting bacteria (production of ammonia, hydrogen; animals (26))	unknown (dimethyl selenide?)
Mo (molybdenum)	nitrogen fixation enzymes of bacteria & blue green algae; carbon dioxide reductase (*Clostridium*)	unknown

Gaia – the Greek personification of Earth as a goddess. Terra cotta statuette from Tanagra; in the Musee Borely, Marseille. From Encyclopedia Britannica.

Table 2 shows that given the quantity of oxygen in the atmosphere not only the major gases such as nitrogen and methane but also the minor atmospheric components are far more abundant than they ought to be according to equilibrium chemistry. Even though the minor constituents differ greatly in relative abundance, they sustain very large fluxes – comparable to those of the major constituents. The Earth's atmosphere is certainly not at all what one would expect from a planet interpolated between Mars and Venus. It has too little CO_2, too much oxygen, and is too warm. We believe the "Gaia" hypothesis provides the new approach that is needed to account for these deviations.

A new framework for scientific thought is justified if it guarantees new observations and experiments.

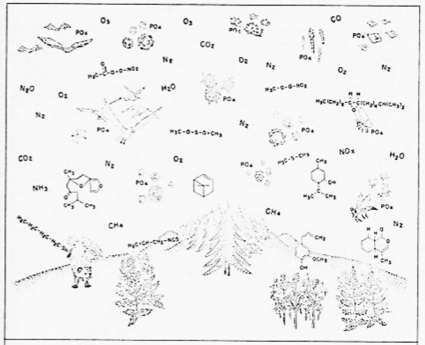


FIGURE 2. Earth's atmosphere at present: examples of major volatiles. (Key: the following compounds and spores are in the picture. It is left to the reader to identify them. See 28 for many details.) Spores of: ferns, club mosses, zygomycetes, ascomycetes, basidiomycetes, slime molds, bacteria. All contain nucleic acids and other organic phosphates, amino acids and so forth. Animal products: butyl mercaptan, plant products: myoporum, catnip (nepetalactone), eugenol, geraniol, pinene, isothiocyanate (mustard); unknown; PAN (paroxacetyl nitrate), dimethyl sulfide, dimethyl sulfoxide; gases: nitrogen, oxygen, methane, carbon monoxide, carbon dioxide, ammonia.

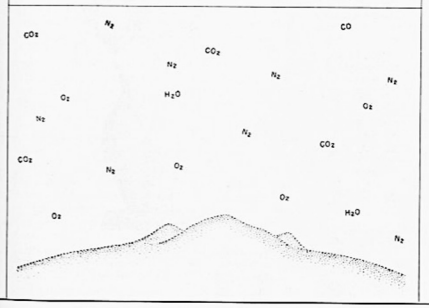


FIGURE 3. The present atmosphere were life deleted. *[Also see CQ cover.]*

The recognition that blood in mammals circulates in a closed, regulated system gave rise to meaningful scientific questions such as: How is blood pH kept constant? By what mechanism is the temperature of mammalian blood regulated around its set point? What is the purpose of bicarbonate ion in the blood? What is the role of fibrinogen? If the blood were simply an inert environment (as the atmosphere is presently viewed) such questions would seem irrelevant and never be asked at all.

Let us consider another analogy. Bees have been known to regulate hive temperatures during midwinter at about 31°C, approximately 59°C above ambient (10). Under threat of desiccation they also maintain high humidities. While the air in the hive is not alive, it maintains an enormous disequilibrium due to the expenditure of energy by the living insects – ultimately of course, solar energy. How is the hive temperature maintained? How does the architecture of the hive aid to reduce desiccation? How does the behavior of the worker bees alter temperature? These are all legitimate scientific questions, generated by the circulatory system concept.

The Gaia hypothesis of the atmosphere as a circulatory system raises comparable and useful scientific questions and suggests experiments that based on the old paradigm would never be asked, for example: How is the pH of the atmosphere kept neutral or slightly alkaline? By what mechanism(s) has the mean midlatitude temperature remained constant (not deviated more than 15°C) for the last 1000 million years? Why are 0.5 x 10^9 tons nitrous oxide (N_2O)

"Given the Gaia hypothesis one deduces that all the major biological elements (Table 3) must either be not limiting to organisms (in the sense that they are always readily available in some useful chemical form) or they must be cycled through the fluids on the surface of the earth in time periods that are short relative to geological processes.... Biological growth is based on continual cell division that requires the doubling of cell masses in periods of time that are generally less than months and typically, days or hours. On lifeless planets there is no particular reason to expect this phenomenon of atmospheric cycling, nor on the earth is it expected that gases of elements that do not enter metabolism as either metabolites or poisons will cycle rapidly.... **Because biological solutions to problems tend to be varied, redundant, and complex, it is likely that all the mechanisms of atmospheric homeostasis will involve complex feedback loops....**"

released into the atmosphere by organisms? Why is about 2×10^9 tons of biogenic methane pumped into the atmosphere each year (representing nearly 10% of the total terrestrial photosynthate)? What are the absolute limits on the control mechanisms, i.e., how much perturbation (emanations of sulfur oxides, chlorinated compounds and/or carbon monoxide; alterations in solar luminosity; and so forth) can the atmosphere regulatory system tolerate before all its feedback mechanisms fail?

The Gaia approach to atmospheric homeostasis has also led to a number of observations that otherwise would not have been made, for example, an oceanic search was undertaken for volatile compounds containing elements that are limiting to life on the land, and large quantities of methyl iodide and dimethyl sulfide were in fact observed (11).

Given the Gaia hypothesis one deduces that all the major biological elements (Table 3) must either be not limiting to organisms (in the sense that they are always readily available in some useful chemical form) or they must be cycled through the fluids on the surface of the earth in time periods that are short relative to geological processes. (Attempts to identify volatile forms of these elements are in progress.) The cycling times must be short because biological growth is based on continual cell division that requires the doubling of cell masses in periods of time that are generally less than months and typically, days or hours. On lifeless planets there is no particular reason to expect this phenomenon of atmospheric cycling,

The atmosphere, therefore, is the mysterious link that connects the animal with the vegetable, the vegetable with the animal kingdom.

—Dumas and Boussingault, 1844

nor on the earth is it expected that gases of elements that do not enter metabolism as either metabolites or poisons will cycle rapidly; (e.g., based on the Gaia hypothesis, nickel, chromium, strontium, rubidium, lithium, barium and titanium will not cycle, but cobalt, vanadium, selenium, molybdenum, iodine and magnesium might (12).) Because biological solutions to problems tend to be varied, redundant, and complex, it is likely that all of the mechanisms of atmospheric homeostasis will involve complex feedback loops [see (8) for discussion.] Since, for example,

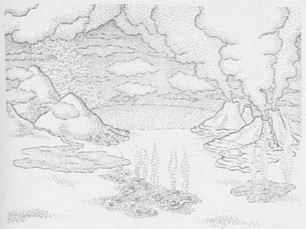


FIGURE 4. Scene from a geothermal area in Fig Tree times (about 3400 million years ago).

FIGURE 5. Scene from a geothermal area in Gunflint times (about 2000 million years ago). *[Also see CQ cover.]*

no volatile form of phosphorus has ever been found in the atmosphere, and since this element is present in the nucleic acids of all organisms, we are considering the possibility that the volatile form of phosphorus at present is totally "biological particulate." Figures 2 and 3 rather fancifully compare the Earth's atmosphere at present to what it might be if life were suddenly wiped out.

Ironically, it is the past history of the earth with its extensive sedimentary record (fraught, as it is, with uncertainties in interpretation) that might provide the most convincing proof for the existence of continued biological modulation. If one accepts the current theories of stellar evolution, the sun, being a typical star of the main sequence, has substantially increased its output of energy since the earth was formed some

Gaia and cybernetics

There is little doubt that living things are elaborate contrivances. Life as a phenomenon might therefore be considered in the context of those applied physical sciences which grew up to explain inventions and contrivances, namely thermodynamics, cybernetics and information theory.

The first cautious approach to a classification of life, reached general agreement as follows 'Life is one member of the class of phenomena which are open or continuous reaction systems able to decrease their entropy at the expense of free energy taken from the environment and subsequently rejected in a degraded form' (Bernal, 1951; Wigner, 1961).

This may also be expressed in the form of the equation of continuity for entropy (Denbigh, 1951).

$$\varrho \frac{dS}{dt} + \operatorname{div} S = \theta$$

Where θ is the rate of internal creation of entropy, ϱ the density and S the entropy; div S is the outflow of entropy and $\varrho(dS/dt)$ the rate of change of entropy in the enclosed region; θ must by second law be zero or positive; the possibility that div S can be large and positive makes possible a negative trend for $\varrho(dS/dt)$.

This classification is broad and includes also phenomena such as vortices and flames and many others. Life differs from such primitive processes of the abiological steady state in the singularity, persistence and size of the entropy reduction it sustains. Although limited, this phenomenological description of the class of process, which includes life, is helpful in our search for proof of the existence of Gaia in two ways. Firstly by serving to define the boundary of the internal region where entropy is reduced and secondly by suggesting that the recognition of a living entity can be based upon the extent of its physical and chemical disequilibrium from the background environment.

On the matter of boundaries, it is obvious that a man, as an example of a living entity, takes in free energy in the form of the chemical potential difference between food and oxygen and sustains a low internal entropy through excretion of waste chemicals and heat. To a man, the environment to which entropy is discarded includes the atmosphere and his boundary is therefore his skin. It might seem pointless therefore on Earth to seek the existence of a general living system, Gaia, in terms of entropy reductions within the atmosphere which clearly for some species is a sink for degraded products and energy but this neglects the fact that photosynthetic life uses premium radiation direct from the sun to sustain a high chemical potential gradient within the atmosphere on a planetary scale. For a tree, the boundary within which entropy is reduced is not its surface in contact with the atmosphere but rather the interface between the sun with the atmosphere as an extension of the tree. The tree produces not only food for consumers but also the equally important gas, oxygen, which does not accumulate within the tree waiting to be eaten.

When the whole assembly of life is so seen it is clear that the true boundary is space. The outgoing entropy flux from the Earth indeed from Gaia 'if she exists', is long wavelength infra red radiation to space. This then, is the physical justification for delineating the boundary of life as the outer reaches of the atmosphere. There is also to a lesser extent an inner boundary represented by the interface with those inner parts of the Earth as yet unaffected by surface processes. We may now consider all that is encompassed by the bounds as putative life. Whether or not Gaia is real will depend upon the extent to which the entropy reduction within a compartment such as the atmosphere is recognisably different from the abiological steady state background.

On the matter of recognition a debt is owed to the fertile concept of information theory, Shannon & Weaver (1963). It has been demonstrated, for example, by Evans (1969) that the classical properties, entropy and free energy, have exact information theoretic equivalents. Thus the information (I) of a system can be defined as

$$I = S_0 - S$$

where S_0 is the entropy of the components of the system at thermodynamic equilibrium and S the entropy of the system assembled. This relationship can be transferred directly from information theoretic to classical thermodynamic terms as follows:

$$I = (E + PV - TS - \Sigma N, N_1)/T$$

where the right hand side of the equation expresses information in terms of temperature (T), pressure (P), internal energy (E), volume (V), entropy (S), and the chemical potential (N) of the molecules present; it follows that information is a measure of disequilibrium in the classic sense and recognisability in the information theoretic sense.

By examining the extent to which the atmosphere is in chemical and physical disequilibrium both within itself and with the surface of the Earth we have a measure of the extent to which it is recognisable as a separate identity against a neutral background equilibrium state. Whether or not it is seen to be a component part of Gaia will depend upon the size of the disequilibrium revealed.

Excerpted from "Atmospheric Homeostasis by and for the Biosphere: The Gaia Hypothesis", by James Lovelock & Lynn Margulis, Tellus *1974, (1-2).*

Notes. These two pages nicely show the disciplinary split between Margulis and Lovelock.

As in the extract just given, Margulis narrates Gaia in terms of biological and ecological considerations of "circulation": metabolism, growth, nutrient cycling and availability, and so on.

Under the subtitle "Gaia and Cybernetics," Stewart Brand (presumably) splices in a long excerpt from a previous Gaia article lead-authored by Lovelock, in which the main considerations regarding "Life" are thermodynamic and information-theoretic.

The dubious math that Heinz von Foerster calls out in "Gaia's Cybernetics Badly Expressed" appears here.

". . . The fossil record suggests that, from an astronomical point of view, conditions have been moderate enough for organisms to tolerate and the biosphere has been in continuous existence for over 3000 million years.... Furthermore, since concentrations of atmospheric oxygen only a few percent higher than ambient lead to spontaneous combustion of organic matter, including grasslands and forests, the most reasonable assumption is that the oxygen value of the atmosphere has remained relatively constant for quite long time periods. ¶ How can these observations be consistently reconciled? How can we explain the simultaneous presence of gases that are extremely reactive with each other and unstable with respect to minerals in the crust and at the same time note that the resident times in the atmosphere are very short with respect to sediment forming and mountain building geological processes?...

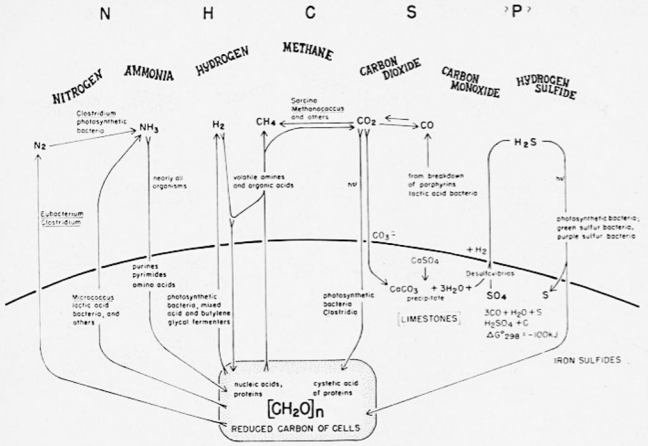


FIGURE 6. A reconstruction of possible anaerobic cycles: 3400 million years ago (genera of microorganisms catalizing the reactions are underlined).

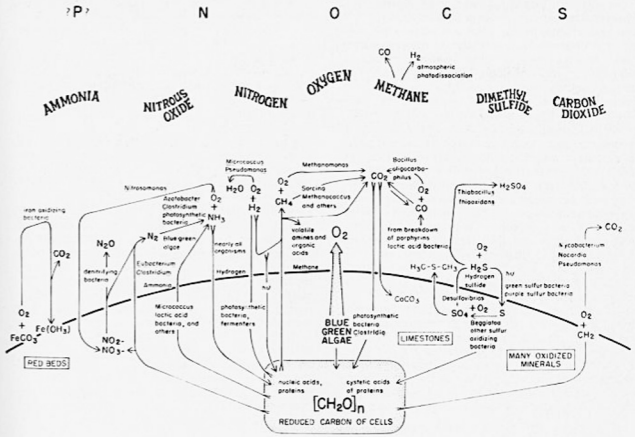


FIGURE 7. A reconstruction of possible microbial aerobic cycles: 2000 million years ago.

4500 million years ago. Some estimates for the increase in solar luminosity over the past history of the earth are as much as 100%; most astronomers apparently accept an increase of at least 25% over 4.5 billion years (13). Extrapolating from the current atmosphere, given solar radiation output and radiative surface properties of the planet, it can be concluded that until about 2000 million years ago either the atmosphere was different (e.g., contained more ammonia) or the earth was frozen. The most likely hypothesis is that the earth's atmosphere contained up to about one part in 10^5 ammonia, a good infrared absorber (14). Other potential "green house" gases apparently will not compensate for the expected lowered temperature because they do not have the appropriate absorption spectra or are required in far too large quantity to be considered reasonable (14). [There are good arguments for the rapid photodestruction of any atmospheric ammonia (15).] However, it has been argued that ammonia is required for the origin of life (16), and there is good evidence for the presence of fossil microbial life in the earliest sedimentary rocks [3400 million years ago (17).] There is no geological evidence that since the beginning of the earth's stable crust the entire earth has ever frozen solid or that the oceans were volatilized, suggesting that the temperature at the surface has always been maintained between the freezing and the boiling points of water. The fossil record suggests that, from an astronomical point of view, conditions have been moderate enough for organisms to tolerate and the biosphere has been in continuous existence for over 3000 million years (17, 18). At least during the familiar Phanerozoic (the last 600 million years of earth history for which an extensive fossil record is available) one can argue on paleontological grounds alone that through every era the earth has maintained tropical temperatures at some place on the surface and that the composition of the atmosphere, at least with respect to molecular oxygen, could not have deviated markedly. That is, there are no documented cases of any metazoan animals (out of about 2 million species) that can complete their life cycles in the total absence of O_2 (19). All animals are composed of cells that divide by mitosis. The mitotic cell division itself requires O_2 (20). Thus it is highly unlikely that current concentrations of oxygen have fallen much below their present values in some hundreds of millions of years. By implication, oxygen and the gases listed in Table 2 have been maintained at stable atmospheric concentrations for time periods that are very long relative to their residence times. (Residence time is the time it takes for the concentration of gas to fall to 1/e or 37% its value; it may be thought of as "turnover time.") Furthermore, since concentrations of atmospheric oxygen only a few per cent higher than ambient lead to spontaneous combustion of organic matter, including grasslands and forests, the most reasonable assumption is that the oxygen value of the atmosphere has remained relatively constant for quite long time periods (21).

How can these observations be consistently reconciled? How can we explain the simultaneous presence of gases that are extremely reactive with each other and unstable with respect to minerals in the crust and at the same time note that their residence times in the atmosphere are very short with respect to sediment forming and mountain building geological processes? In this respect Table 3 can be instructive. For one can see that even though absolute amounts of the gases vary over about 3 orders of magnitude, the fluxes are remarkably similar. These gases are produced and removed primarily by nonhuman biological processes. [See Table 1 and (8).] While the processes involved in atmospheric production and removal of reactive gases are not primarily dependent on human activity, for the most part they are not based on animal or plant processes either [see (8) for a version of the table that lists these.] It is mainly the prokaryote microorganisms that are involved in gas exchange; the rapidly growing and dividing masters of the microbiological world that make up in chemical complexity and metabolic virtuosity what they lack in advanced morphology. These organisms presumably played a similar role in biogeochemical processes in the past as they do today. There is direct fossil evidence for the continued existence of Precambrian microorganisms (17). That they have an ancient history can also be deduced from current studies of their physiology. Among hundreds of species of these prokaryotic microorganisms are many obligate anaerobes, that is, organisms poisoned by oxygen. (All organisms are poisoned by oxygen at concentrations above those to which they are adapted.) Hundreds of others are known that are either microaerophils (adapted to concentrations of oxygen less than ambient) or facultative aerobes (can switch their metabolism from oxygen-requiring to oxygen-nonrequiring).

As a group, the prokaryotic microbes show evidence that the production and release of molecular oxygen into the atmosphere was an extremely important environmental determinant in the evolution of many genera. Prokaryotic microbes (in the form known as the blue green algae, cyanophytes) were almost certainly responsible for the original transition to the oxygen-containing atmosphere about 2000 million years ago (17, 18).

Figures 4 and 5 present scenes before and after the transition to oxidizing atmosphere respectively. Figures 6 and 7 are reconstructions of anaerobic

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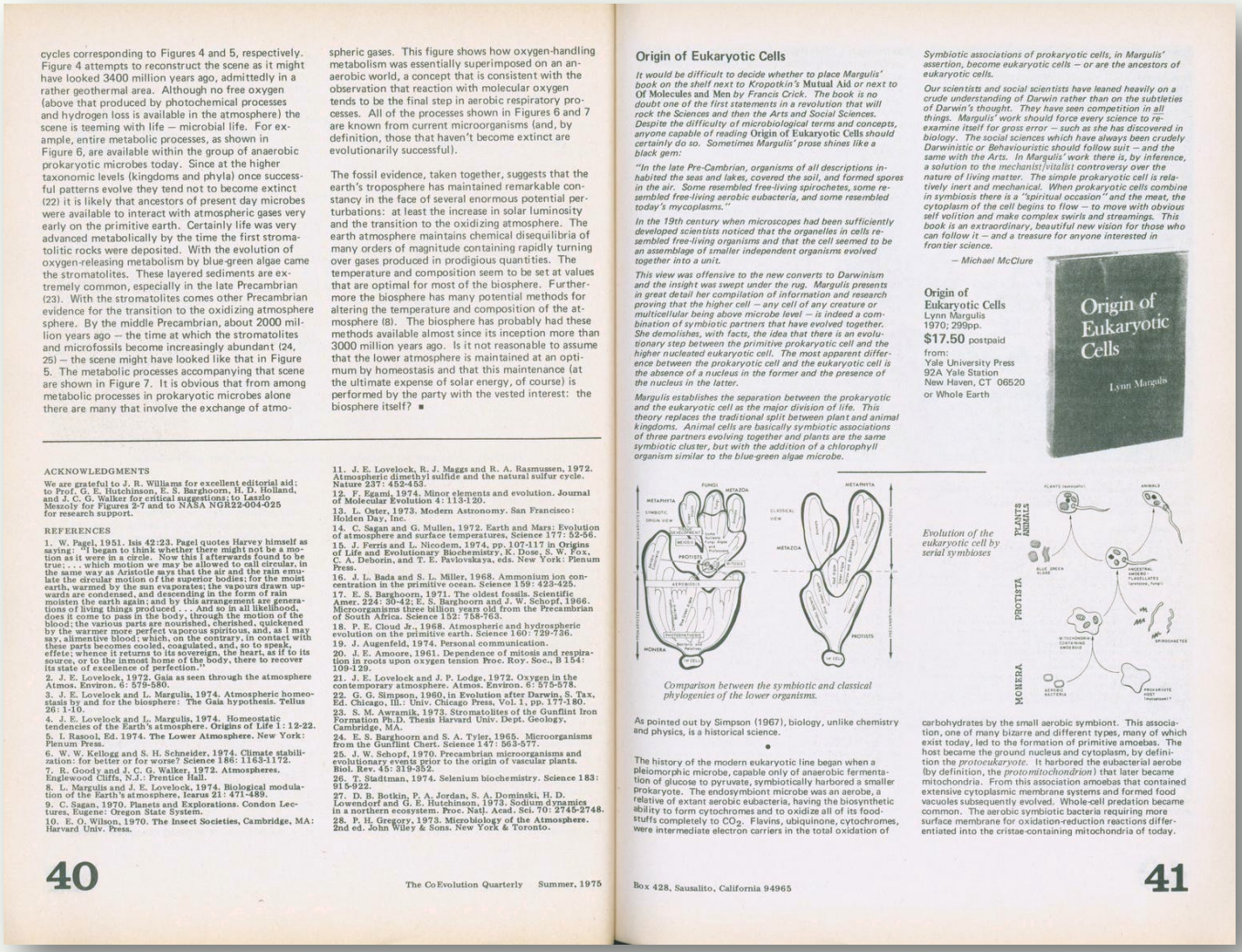
"The fossil evidence, taken together, suggests that the earth's troposphere has maintained remarkable constancy in the face of several enormous potential perturbations: at least the increase in solar luminosity and the transition to the oxidizing atmosphere. The earth atmosphere maintains chemical disequilibria of many orders of magnitude containing rapidly turning-over gases produced in prodigious quantities. The temperature and composition seem to be set at values that are optimal for most of the biosphere. Furthermore the biosphere has many potential methods for altering the temperature and composition of the atmosphere. The biosphere has probably had these methods available almost since its inception more than 3000 million years ago. Is it not reasonable to assume that the lower atmosphere is maintained at an optimum by homeostasis and that this maintenance (at the ultimate expense of solar energy, of course) is performed by the party with the vested interest: the biosphere itself?" ▪



cycles corresponding to Figures 4 and 5, respectively. Figure 4 attempts to reconstruct the scene as it might have looked 3400 million years ago, admittedly in a rather geothermal area. Although no free oxygen (above that produced by photochemical processes and hydrogen loss is available in the atmosphere) the scene is teeming with life — microbial life. For example, entire metabolic processes, as shown in Figure 6, are available within the group of anaerobic prokaryotic microbes today. Since at the higher taxonomic levels (kingdoms and phyla) once successful patterns evolve they tend not to become extinct (22) it is likely that ancestors of present day microbes were available to interact with atmospheric gases very early on the primitive earth. Certainly life was very advanced metabolically by the time the first stromatolitic rocks were deposited. With the evolution of oxygen-releasing metabolism by blue-green algae came the stromatolites. These layered sediments are extremely common, especially in the late Precambrian (23). With the stromatolites comes other Precambrian evidence for the transition to the oxidizing atmosphere sphere. By the middle Precambrian, about 2000 million years ago — the time at which the stromatolites and microfossils become increasingly abundant (24, 25) — the scene might have looked like that in Figure 5. The metabolic processes accompanying that scene are shown in Figure 7. It is obvious that from among metabolic processes in prokaryotic microbes alone there are many that involve the exchange of atmospheric gases. This figure shows how oxygen-handling metabolism was essentially superimposed on an anaerobic world, a concept that is consistent with the observation that reaction with molecular oxygen tends to be the final step in aerobic respiratory processes. All of the processes shown in Figures 6 and 7 are known from current microorganisms (and, by definition, those that haven't become extinct are evolutionarily successful).

The fossil evidence, taken together, suggests that the earth's troposphere has maintained remarkable constancy in the face of several enormous potential perturbations: at least the increase in solar luminosity and the transition to the oxidizing atmosphere. The earth atmosphere maintains chemical disequilibria of many orders of magnitude containing rapidly turning over gases produced in prodigious quantities. The temperature and composition seem to be set at values that are optimal for most of the biosphere. Furthermore the biosphere has many potential methods for altering the temperature and composition of the atmosphere (8). The biosphere has probably had these methods available almost since its inception more than 3000 million years ago. Is it not reasonable to assume that the lower atmosphere is maintained at an optimum by homeostasis and that this maintenance (at the ultimate expense of solar energy, of course) is performed by the party with the vested interest: the biosphere itself? ▪

ACKNOWLEDGMENTS

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Origin of Eukaryotic Cells

It would be difficult to decide whether to place Margulis' book on the shelf next to Kropotkin's Mutual Aid *or next to* Of Molecules and Men *by Francis Crick. The book is no doubt one of the first statements in a revolution that will rock the Sciences and then the Arts and Social Sciences. Despite the difficulty of microbiological terms and concepts, anyone capable of reading* Origin of Eukaryotic Cells *should certainly do so. Sometimes Margulis' prose shines like a black gem:*

"In the late Pre-Cambrian, organisms of all descriptions inhabited the seas and lakes, covered the soil, and formed spores in the air. Some resembled free-living spirochetes, some resembled free-living aerobic eubacteria, and some resembled today's mycoplasms."

In the 19th century when microscopes had been sufficiently developed scientists noticed that the organelles in cells resembled free-living organisms and that the cell seemed to be an assemblage of smaller independent organisms evolved together into a unit.

This view was offensive to the new converts to Darwinism and the insight was swept under the rug. Margulis presents in great detail her compilation of information and research proving that the higher cell — any cell of any creature or multicellular being above microbe level — is indeed a combination of symbiotic partners that have evolved together. She demolishes, with facts, the idea that there is an evolutionary step between the primitive prokaryotic cell and the higher nucleated eukaryotic cell. The most apparent difference between the prokaryotic cell and the eukaryotic cell is the absence of a nucleus in the former and the presence of the nucleus in the latter.

Margulis establishes the separation between the prokaryotic and the eukaryotic cell as the major division of life. This theory replaces the traditional split between plant and animal kingdoms. Animal cells are basically symbiotic associations of three partners evolving together and plants are the same symbiotic cluster, but with the addition of a chlorophyll organism similar to the blue-green algae microbe.

Symbiotic associations of prokaryotic cells, in Margulis' assertion, become eukaryotic cells — or are the ancestors of eukaryotic cells.

Our scientists and social scientists have leaned heavily on a crude understanding of Darwin rather than on the subtleties of Darwin's thought. They have seen competition in all things. Margulis' work should force every science to re-examine itself for gross error — such as she has discovered in biology. The social sciences which have always been crudely Darwinistic or Behaviouristic should follow suit — and the same with the Arts. In Margulis' work there is, by inference, a solution to the mechanist/vitalist controversy over the nature of living matter. The simple prokaryotic cell is relatively inert and mechanical. When prokaryotic cells combine in symbiosis there is a "spiritual occasion" and the meat, the cytoplasm of the cell begins to flow — to move with obvious self volition and make complex swirls and streamings. This book is an extraordinary, beautiful new vision for those who can follow it — and a treasure for anyone interested in frontier science.

— Michael McClure

Comparison between the symbiotic and classical phylogenies of the lower organisms.

Evolution of the eukaryotic cell by serial symbioses

As pointed out by Simpson (1967), biology, unlike chemistry and physics, is a historical science.

•

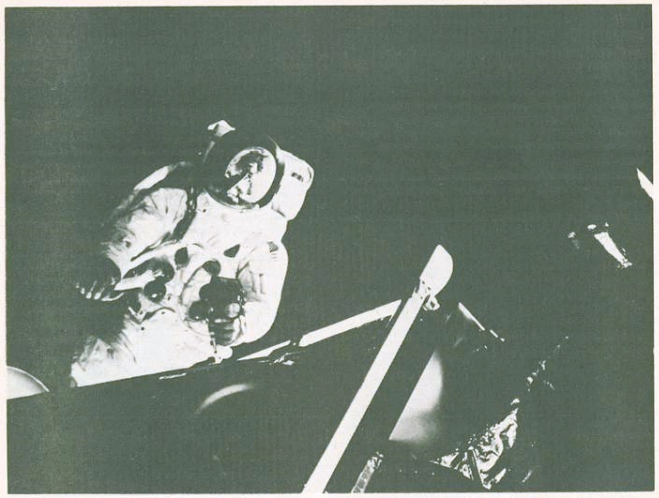
The history of the modern eukaryotic line began when a pleiomorphic microbe, capable only of anaerobic fermentation of glucose to pyruvate, symbiotically harbored a smaller prokaryote. The endosymbiont microbe was an aerobe, a relative of extant aerobic eubacteria, having the biosynthetic ability to form cytochromes and to oxidize all of its foodstuffs completely to CO_2. Flavins, ubiquinone, cytochromes, were intermediate electron carriers in the total oxidation of carbohydrates by the small aerobic symbiont. This association, one of many bizarre and different types, many of which exist today, led to the formation of primitive amoebas. The host became the ground nucleus and cytoplasm, by definition the *protoeukaryote*. It harbored the eubacterial aerobe (by definition, the *protomitochondrion*) that later became mitochondria. From this association amoebas that contained extensive cytoplasmic membrane systems and formed food vacuoles subsequently evolved. Whole-cell predation became common. The aerobic symbiotic bacteria requiring more surface membrane for oxidation-reduction reactions differentiated into the cristae-containing mitochondria of today.

Nicely, Margulis's lead-authored Gaia article is immediately followed by a review of her *Origin of Eukaryotic Cells* contributed by the Beat poet and all-around wild man of letters Michael McClure:

"Our scientists and social scientists have leaned heavily on a crude understanding of Darwin rather than on the subtleties of Darwin's thought. They have seen competition in all things. Margulis' work should force every science to reexamine itself for gross error—such as she has discovered in biology. The social sciences which have always been crudely Darwinistic or Behavioristic should follow suit—and the same with the Arts."

–And if that weren't enough, the next two pages return to the phenomenon that defines a major ambiance of the Whole Earth ethos, now called "the Overview Effect"—a transcript of a talk given by Rusty Schweickart, the "hippie astronaut." Brand's headnote reads: "Like a prayer, like a benediction, Apollo 9 astronaut Russell Schweickart spoke these words last summer before a brainy group meeting on 'Planetary Culture' at the spiritual community of Lindisfarne, Long Island." This is our segue to the Lindisfarne Association.

"Tethered outside his spacecraft, Schweickart felt he underwent a metaphysical experience as he stared at the Earth, contemplating its place in the universe." (Wikipedia)



Russell Schweickart exits the Apollo 9 Lunar Module in Earth orbit, March 1969. "Now you're no longer inside something with a window looking out at a picture, but now you're out there and what you've got around your head is a goldfish bowl and there are no limits here."

Who's Earth

BY RUSSELL SCHWEICKART

Photos by NASA

Like a prayer, like a benediction, Apollo 9 astronaut Russell Schweickart spoke these words last summer before a brainy group meeting on "Planetary Culture" at the spiritual community of Lindisfarne, Long Island.

Schweickart himself seemed amazed at what he was saying, amazed at the gathering he was attending, amazed – still – at the events which led him to drift bodily free between Earth and Universe. Remember the starchild at the end of "2001"? Like that.

This is just the conclusion of his tape – $6.50 for the cassette from Lindisfarne Association, Box 1395, Southampton, NY 11968.

– SB

Up there you go around every hour and a half, time after time after time. You wake up usually in the mornings. And just the way that the track of your orbits go, you wake up over the Mid-East, over North Africa. As you eat breakfast you look out the window as you're going past and there's the Mediterranean area, and Greece, and Rome, and North Africa, and the Sinai, the whole area. And you realize that in one glance that what you're seeing is what was the whole history of man for years – the cradle of civilization. And you think of all that history that you can imagine, looking at that scene.

And you go around down across North Africa and out over the Indian Ocean, and look up at that great subcontinent of India pointed down toward you as you go past it. And Ceylon off to the side, Burma, Southeast Asia, out over the Philippines, and up across that monstrous Pacific Ocean, vast body of water – you've never realized how big that is before.

And you finally come up across the coast of California and look for those friendly things: Los Angeles, and Phoenix, and on across El Paso and there's Houston, there's home, and you look and sure enough there's the Astrodome. And you identify with that, you know – it's an attachment.

And down across New Orleans and then looking down to the south and there's the whole peninsula of Florida laid out. And all the hundreds of hours you spent flying across that route, down in the atmosphere, all that is friendly again. And you go out across the Atlantic Ocean and back across Africa.

And you do it again and again and again.

And that identity – that you identify with Houston, and then you identify with Los Angeles, and Phoenix and New Orleans and everything. And the next thing you recognize in yourself, is you're identifying with North Africa. You look forward to that, you anticipate it. And there it is. That whole process begins to shift of what it is you identify with. When you go around it in an hour and a half you begin to recognize that your identity is with that whole thing. And that makes a change.

You look down there and you can't imagine how many borders and boundaries you crossed again and again and again. And you don't even see 'em. At that wake-up scene – the Mid-East – you know there are hundreds of people killing each other over some imaginary line that you can't see. From where you see it, the thing is a whole, and it's so beautiful. And you wish you could take one from each side in hand and say, "Look at it from this perspective. Look at that. What's important?"

And so a little later on, your friend, again those same neighbors, another astronaut, the person next to you goes out to the Moon. And now he looks back and he sees the Earth not as something big, where he can see the beautiful details, but he sees the Earth as a small thing out there. And now that contrast between that bright blue and white Christmas tree ornament and that black sky, that infinite universe, really comes through.

[more ➡]

The Mid-East. "You realize that in one glance that what you're seeing was the whole history of Man for years – the cradle of civilization . . . You look down there and you can't imagine how many borders and boundaries you've crossed again and again and again. And you don't even see 'em."

"You look down and see the surface of that globe that you've lived on all this time and you know all those people down there. They are like you, they are you, and somehow you represent them when you are up there —a sensing element, that point out on the end, and that's a humbling feeling. It's a feeling that says you have a responsibility. It's not for yourself. ¶ The eye that doesn't see does not do justice to the body. That's why it's there, that's why you're out there. And somehow you recognize that you're a piece of this total life. You're out on that forefront and you have to bring that back, somehow. And that becomes a rather special responsibility. It tells you something about your relationship with this thing we call life. And so that's a change, that's something new."

"Then looking down to the south and there's the whole peninsula of Florida laid out. And all the hundreds of hours you spent flying across that route, down in that atmosphere, all that is friendly again."

The size of it, the significance of it — it becomes both things, it becomes so small and so fragile, and such a precious little spot in that universe, that you can block it out with your thumb, and you realize that on that small spot, that little blue and white thing is everything that means anything to you. All of history and music and poetry and art and war and death and birth and love, tears, joy, games, all of it is on that little spot out there that you can cover with your thumb.

And you realize that that perspective . . . that you've changed, that there's something new there. That relationship is no longer what it was. And then you look back on the time when you were outside on that EVA and those few moments that you had the time because the camera malfunctioned, that you had the time to think about what was happening. And you recall staring out there at the spectacle that went before your eyes. Because now you're no longer inside something with a window looking out at a picture, but now you're out there and what you've got around your head is a goldfish bowl and there are no limits here. There are no frames, there are no boundaries. You're really out there, over it, floating, going 25,000 mph, ripping through space, a vacuum, and there's not a sound. There's a silence the depth of which you've never experienced before, and that silence contrasts so markedly with the scenery, with what you're seeing, and the speed with which you know you're going. That contrast, the mix of those two things, really comes through.

And you think about what you're experiencing and why. Do you deserve this? This fantastic experience? Have you earned this in some way? Are you separated out to be touched by God to have some special experience here that other men cannot have? You know the answer to that is No. There's nothing that you've done that deserves that, that earned that. It's not a special thing for you. You know very well at that moment, and it comes through to you so powerfully, that you're the sensing element for man.

You look down and see the surface of that globe that you've lived on all this time and you know all those

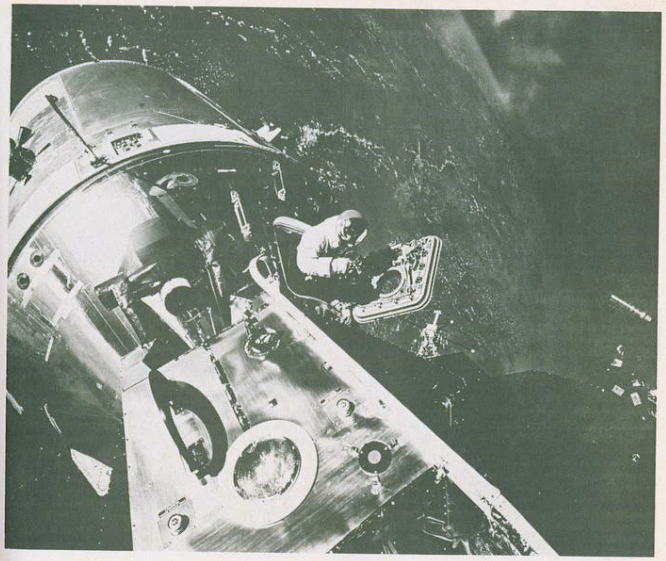


Photo by Russell Schweickart of David Scott standing out of the Apollo 9 Command Vehicle. "There are no frames, there are no boundaries. You're really out there, over it, floating, going 25,000 mph, ripping through space, a vacuum, and there's not a sound."

people down there. They are like you, they are you, and somehow you represent them when you are up there — a sensing element, that point out on the end, and that's a humbling feeling. It's a feeling that says you have a responsibility. It's not for yourself.

The eye that doesn't see does not do justice to the body. That's why it's there, that's why you're out there. And somehow you recognize that you're a piece of this total life. You're out on that forefront and you have to bring that back, somehow. And that becomes a rather special responsibility. It tells you something about your relationship with this thing we call life. And so that's a change, that's something new.

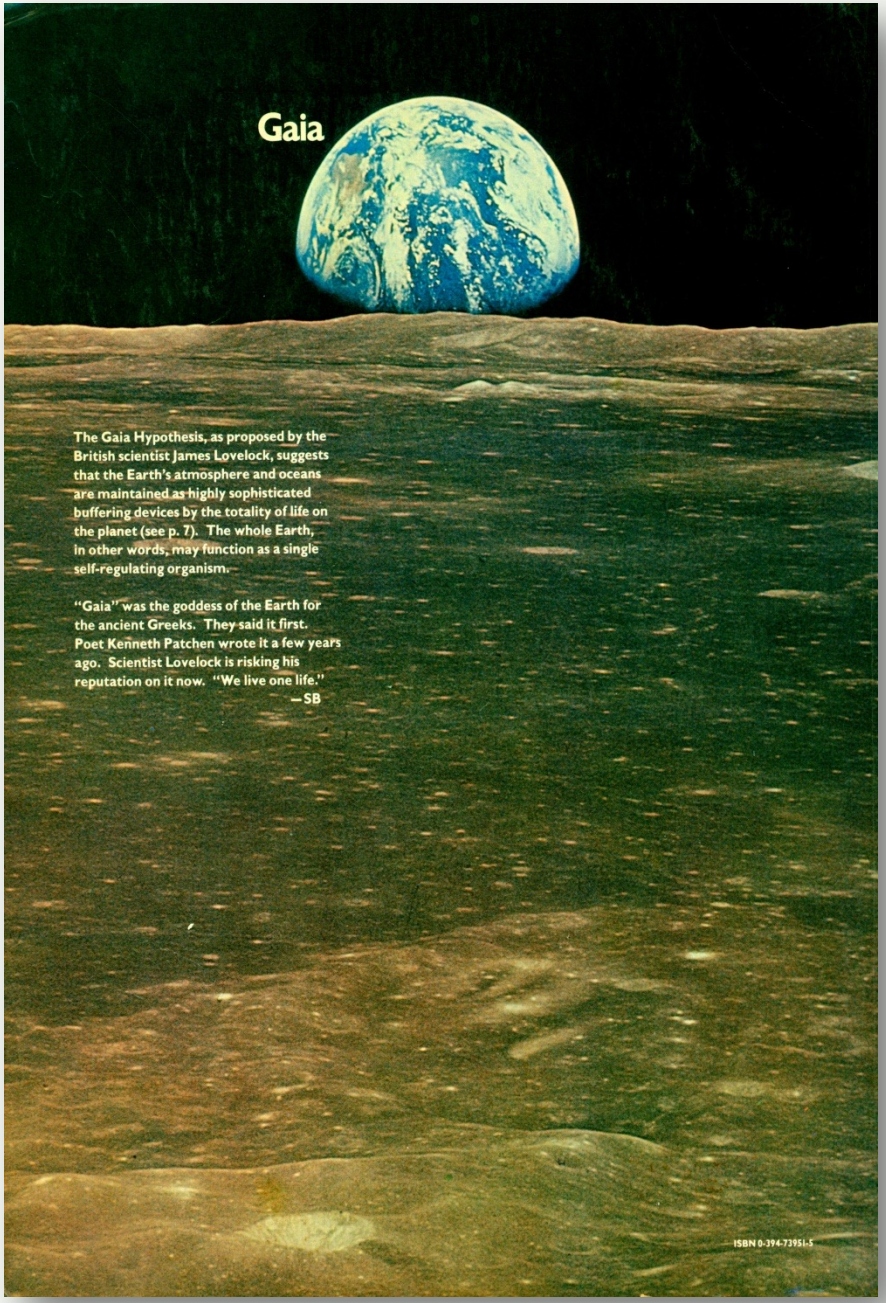
And when you come back, there's a difference in that world now, there's a difference in that relationship between you and that planet, and you and all those other forms of life on that planet, because you've had that kind of experience. It's a difference, and it's so precious. And all through this I've used the word *you* because it's not me, it's not Dave Scott, it's not Dick Gordon, Pete Conrad, John Glenn, it's you, it's us, it's we, it's life. It's had that experience. And it's not just *my* problem to integrate, it's not my challenge to integrate, my joy to integrate — it's yours, it's everybody's.

I guess that's really about all I'd like to say, except that — and I don't even know why, but to me it means a lot — I'd like to close this with a poem by e. e. cummings that has just become a part of me, somehow out of all this, and I'm not really sure how.

He says, that

> i thank You God for most this amazing
> day: for the leaping greenly spirits of trees
> and a blue true dream of sky; and for everything
> which is natural which is infinite which is yes.

Thank you. ■


Gaia
The Gaia Hypothesis, as proposed by the British scientist James Lovelock, suggests that the Earth's atmosphere and oceans are maintained as highly sophisticated buffering devices by the totality of life on the planet (see p. 7). The whole Earth, in other words, may function as a single self-regulating organism.
"Gaia" was the goddess of the Earth for the ancient Greeks. They said it first. Poet Kenneth Patchen wrote it a few years ago. Scientist Lovelock is risking his reputation on it now. "We live one life."
—SB
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