Letter from the Desk of David Challinor
February 2001

In 1979 a British scientist, J.E. Lovelock, published *Gaia, A New Look at Life on Earth*. The book created a stir because it proposed a hypothesis that the whole earth was a living organism. His theory, first presented at a meeting in Princeton in 1969, was considered radical, but in the last twenty years my impression is that many people now feel that he may indeed be on to something. This month's letter will consider Gaia in the light of what we have learned in the past twenty years that support Lovelock's hypothesis.

The word Gaia derives from Ge--the Earth goddess of the ancient Greeks and the root of geology, geography, etc. Gaia is used to categorize the quality of our planet as a living organism. What is meant by "living" is still not clearly defined and thus the theory of Gaia is scientifically untestable. However, we do have an inherent concept of what it means to be alive, and thus it is worth while to investigate Lovelock's hypothesis.

Much recent scientific research has moved towards exploring ever smaller components of life. Thus there is a massive effort to record the human genome, to analyze the changeable protein coat of HIV and physicists seek ever smaller particles of matter. Lovelock has gone in quite the opposite direction by hypothesizing that our planet is a "living" entity and--by extrapolation--perhaps the whole universe.

"Live" is hard to define perhaps because we must rely on what we inherently feel. We "know" what is not alive, such as a fish on a supermarket counter, but a similar feeling can apply to a burned-out light bulb. When physicists such as Schroedinger and Wigner have attempted to define life, their conclusion as quoted from Lovelock is, "that life is a member of the class of phenomenon which are open or continuous systems able to decrease their internal entropy at the expense of substances or free energy taken in from the environment and subsequently rejected in a degraded form."

This definition is not only hard to follow but so general that it is difficult to apply to specific questionable life forms. Boiled down to its essence it seems that life requires an abundant flow of energy that tends to shape or form itself as it consumes such energy and at the same time it must excrete the resulting waste products. We can consider the whole Earth to see how it fits these essential features. The "Living Planet" is a common synonym for the globe in contrast to our "dead" moon or even some or all of the planets. I would posit that a living planet is one that can repair itself from damage sustained and maintain its living components through whatever evolutionary changes they may have made. How such self-perpetuating organisms appeared on Earth is still unclear, but that is a separate subject. Nonetheless like all living organisms, the earth and indeed our solar system had a "birth", a beginning, and will have an end about seven billion years from now when the Sun burns out.

What made Lovelock's theory so radical at the time was his claim that our atmosphere, the thin gaseous envelope that protects us from lethal radiation, and allows all aerobes to breathe, is an extension of Earth's biosphere and maintained in equilibrium by living matter on Earth. Lovelock argues that since the birth of life 3.5 billion years ago, the earth's climate has changed relatively little, despite variation in the Sun's heat, in the Earth's surface configuration and in the mixture of atmospheric gases. The climate, in other words, must be and, indeed, has been designed to sustain life, and the atmosphere as Lovelock points out is a "biological construction," not living but like a cat's fur…an extension of a living system designed to maintain a chosen environment." That climate and the Earth's chemical properties have always been perfect to sustain life can hardly have been achieved by chance. Stromatolites*, which still exist on the west coast of Australia, were photosynthesizing more than three billion years ago and thus were among the early releasers of O_2 to the atmosphere. However, it is crucial that the percentage of O_2 in the atmosphere be stable and not too high. Today it is roughly 20%. Were it much higher it could fuel disastrous oxidation such as uncontrollable fires on Earth. The principal point to remember is that our atmosphere maintains its equilibrium. The combination of gases is just right to sustain and protect life and gaseous equilibrium in turn is maintained by the activities of living matter in the biosphere. The study of such self regulatory systems is called cybernetics.

Lovelock illustrates self-regulation by our ability to stand upright even when walking across a tilted floor or on a deck of a heaving ship. Our brains give continual signals to our muscles from information it in turn receives from the sensory organs in our bodies, thereby achieving the goal of keeping erect. The Earth's goal is to maintain optimal physical and chemical conditions for life. Thus since Earth first began spinning around the sun with life aboard (about 3.5 billion years ago), its mean surface temperature has not varied more than a few degrees (C) from its current levels, thereby allowing continuous life!

A big advance in our understanding of how the Earth functions came with NASA's manned and robot space craft that allowed us to see an entire half of our planet at once. The human reaction at such a sight (from a personal conversation with astronaut Mike Collins) was how small it looked from 225,000 miles away and the beauty of its white swirling clouds against the predominant blue oceans.

The atmosphere's bottom layer is called the troposphere and accounts for about 75% of the total atmospheric mass. It is only seven miles thick, a distance a good runner could cover in a half hour if he could run straight up. All clouds are in the troposphere and it contains virtually all the oxygen we breathe. Stratospheric air (the next level above) is both too cold and too thin to breathe. What I had not realized was that the current oxygen percentage of air (about 21%) is so critical a threshold, because the odds

* Layered growths that form in warm shallow seas when photosynthetic bacteria cause dissolved salts to precipitate.

of a forest fire being started by lightning grows by 70% for every 1% rise in O_2 level above the current 21%. That is where risk and benefit balance for us earthbound creatures.

Scientists now have a good idea of how this delicate oxygen level is maintained. One regulator is methane, a hot house gas, the major source of which seems to be the byproduct of anaerobic (non O_2 "breathing") bacteria in soils particularly wetlands. Some methane rises through the soil and travels all the way to the stratosphere where it breaks down into carbon dioxide (CO_2) and water vapor (H_2O). The water then splits again, with its oxygen descending to the troposphere to replenish any oxygen lost there while its hydrogen goes off into space. In the troposphere, however, methane gas breaking down also uses up a lot of oxygen. The process is a slow one and the addition of oxygen derived from methane and the loss of oxygen from the troposphere below keeps the level balanced. I have purposely simplified these complex chemical processes to illustrate the principal that this self-regulating action is sustained by the anaerobic bacteria and to a lesser extent by the gaseous discharge of ruminants, particularly cows. Other atmospheric gases such as nitrogen, whose content is little less than 80% of the air we breathe and small traces of ammonia also play key roles in maintaining the proper balance of gas mixtures and both are closely linked to terrestrial sources. The cycling of the chemical components of these gases between the atmosphere and the biosphere add to the evidence supporting the Gaia hypothesis.

The final element of our planet Lovelock used to illustrate his theory is the oceans. The sea has been remarkably stable both chemically and physically since life began--and is even older than we had once thought. The recent finding of a grain of zircon in a piece of rock from Australia indicates there were oceans when the Earth was only a few hundred million years old. Scientists had previously thought it was still too hot for water to be liquid. The total volume of its water appears to be unchanged even though during peaks of past glaciation a significant portion of water was ice. What is even more astounding is the stability of ocean salinity.

Parts of the ocean vary in salt content. For example, the Mediterranean is saltier than the Atlantic because its rate of evaporation is so fast that ocean water does not have the volume or time to get through the Straits of Gibraltar to offset the water loss. The oceans' salt probably comes mostly from land run off and sea floor spreading, but how is salt removed from the sea to keep its content in balance? This is a hard question and the answer is still theoretical. One idea is that sodium and magnesium sink to the sea floor in the rain of debris from the surface and end up trapped there, but there is no hard evidence that this actually occurs. Another theory is that hypersaline water, such as that concentrated in the central Mediterranean, sinks and fills depressions in the sea floor over hundreds of millions of years, thereby forming the salt domes and salt beds found below the terrestrial surface. For such massive evaporatory events to occur there probably would have to have been the kind of tectonic action that blocked the Straits of Gibraltar some ten or a dozen times, tens of millions of years ago. Deprived of an ocean water source, the entire sea dried up. How else to explain the mile thick evaporite (various salts) beds found by the research vessel *Glomar Challenger's* deep drilling there in 1970.

There remains an incredible amount to learn about the role of the oceans' conveyor belt system (see my June 1998 letter) in maintaining its uniform salinity or the degree to which an expanding growth of coral reefs over tens or hundreds of millions of years might have actually enclosed lagoons large enough to evaporate their water contents and thus by storing great volumes of salt in their beds contributed to the maintenance of the global ocean saline stability. In time scientists may find answers to such questions and thereby accumulate further evidence to support Lovelock's hypothesis as being "not false." Remember that hypotheses can never be true!

The role of humans in maintaining Gaia is important and our harnessing and releasing of energy has indeed achieved a significant level, but is still far short of that generated by such natural events as hurricanes, earthquakes, erupting volcanoes or large meteor collisions. As human biomass and its constituent dependents has increased this past century, so has human concern with its affect on the biosphere. Thus we now see evidence of self-regulation within our narrow human environment. To keep a Giaian perspective we humans must remember that we are very recent arrivals; appearing in just the last million of roughly three thousand million years of life on Earth. As the only surviving species in the genus *Homo,* our presence is ephemeral. The Sun, our major source of energy, will eventually burn out, but well before that time the process of Darwinian evolution will have either erased most evidence of our existence or, more optimistically, allowed us to colonize and adapt to extraglobal conditions about which we can today scarcely dream.

David Challinor
Phone: 202-673-4705
Fax: 202-673-4607
E-mail: ChallinorD@aol.com