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focus

Human rights are not enough*

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The scientist and author Lewis Thomas (1913–1993) once said: "If we look at the Earth and people from far away, from a planetary perspective we are like ants." He went on to say: "They are so much like people as to be an embarrassment. They farm fungi, raise aphids as livestock, launch armies for wars, use chemical sprays to alarm and confuse their enemies, capture slaves. The families of weaver ants engage in child labour, holding their larvae like shuttles to spin out the thread that sews the leaves together for their fungus gardens. They exchange information ceaselessly. They do everything that we do except watch television.".

To see the Earth as if it were an ant's nest is one of the gifts brought back from our journeys into space. Scientists call the nests of social insects like wasps and ants "superorganisms" because they can regulate their inner environment almost as well as humans can regulate our bodies. These insects keep their nest always comfortable without any sense of purpose and without a plan. They do it automatically. The view from space also led me to see our planet as if it were a superorganism, something able to regulate the climate and atmosphere so as always to be comfortable for life. And this view of the world which I have called Gaia is the subject of this article.

Earth self-regulation: The Gaia ecosystem

So let us assume that the Earth self regulates; that on our planet organisms, rocks, air and oceans all act in unison to keep the climate and chemistry comfortable. I am not asking the reader to suspend science and believe in some mysterious Earth mother with teleological powers, but to imagine a planet-sized ecosystem, Gaia, something that emerged when organisms and their material environment evolved together.

Why do it anyway? Simply because our place as one of many species on this planet is more clearly seen in a view of the whole Earth than in the subdivides parts of it. More than this, I do believe that those voyages outside the Earth thirty or forty years ago were one of humans' greatest achievements. They made us aware for the first time that our world was really finite and let us see how beautiful and different it was from those barren dead sister planets Mars and Venus. We then began to understand that unless we recognised the needs of the Earth, humans had no future.

But first I must return to the beginning and remind how the idea of Gaia began. In 1961 the american space agency NASA invited me to join with them and explore the Moon and the planets. Before that invitation I thought space travel was science fiction, but I soon discovered that their intention was serious. A major goal of the Lunar and Planetary division of NASA was the search for the presence of life on Mars. My work would involve brief visits to that famous institute, the Jet Propulsion Laboratory (JPL), in Pasadena, California. They wanted me for my ability to design and make sensitive analytical instruments, but soon after joining them I became interested in their methods for detecting life on Mars. I expected that the biological experiments would have the same excellence that I found in the exquisite engineering and physics of the JPL. Instead I found them unimaginative and unlikely to work even if Mars had life on it. Perhaps I was overcritical. It is not easy to design an experiment to find life on a distant planet when there is no knowledge of the life form being sought. Most of them were an automated version of the biologist's laboratory here on Earth, wonderfully engineered but based on the doubtful assumption that life on Mars would be the same as it is here. The bacteriologists, for example, proposed a robot to scoop a sample of Martian soil and apply it to a culture plate. It would then look for the growth of bacteria from the soil. There were many reasons why such an experiment could fail to detect life. Martian life might not include bacteria; even if it did, their biochemistry might be different. The experiment might land at a barren site. Even on the Earth if the experiment landed on a polar ice cap it would not have found life.

Reacting to my criticism, the biologists challenged me to offer an alternative life detection experiment that would work. After much hard thinking I suggested that they should try a top down view of the whole planet. The simplest and most general life detection experiment would be the chemical analysis of the Martian atmosphere. The reasoning behind

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such a test for life goes like this. A lifeless planet would have an atmosphere determined by physics and chemistry alone and the chemical composition would be close to the chemical equilibrium state. But on a planet that bore life, the organisms at the surface would be obliged to use the atmosphere as a source of raw materials and as a depository for wastes. Such a use of the atmosphere would change its chemical composition. It would depart from equilibrium in a way that would show the presence of life. Dian Hitchcock joined me then, and together we examined atmospheric evidence from the infrared astronomy of Mars. We compared this evidence with evidence about the sources and sinks of atmospheric gases on the one planet we knew bore life, Earth. We found an astonishing difference between the two planetary atmospheres. Mars was close to chemical equilibrium, and its atmosphere was dominated by carbon dioxide. The Earth's atmosphere in great contrast is in a state of deep chemical disequilibrium. In our atmosphere carbon dioxide is a mere trace gas, and the coexistence of abundant oxygene with methane and other reactive gases shows a near infinite degree of chemical disequilibrium, something impossible on a lifeless planet. Even the abundant nitrogen and water of the Earth are difficult to explain by geochemistry. No such anomalies are present in the atmospheres of Mars or Venus, and their existence in the Earth's atmosphere signals the presence of living organisms at the surface. There was no escaping the probable conclusion of chemistry: Mars was lifeless.

Gaia and Mars

This was not the news our sponsors NASA wanted to hear. They were preparing at great expenses the Viking spacecraft to go to Mars to find life and here were we saying that there was none there. Worse than this, we had used NASA funds to view the Earth from space and conclude that there was life on it, something that could have led to the criticism of the whole space program. They asked me what could possibly be the value of such a discovery. I was unrepentant and answered that I saw great value in it. They, NASA, had unintentionally set up an environment in which it became, for the first time, natural to ask questions about the nature of the Earth's atmosphere in the context that it was a planet with life upon it. No one had looked at the atmosphere this way before and had the opportunity to see what a strange and beautiful anomaly is the Earth. We who live on Earth take for granted the steady constant chemical composition of our atmosphere. Changes do occur but only slowly compared with the residence time of the gases. No one had wondered how our atmosphere could remain stable and constant in composition by blind chemistry when it is a mixture of reactive gases. One afternoon in 1965 at the JPL in California, when thinking about the contradiction of our constant but highly unstable atmosphere, the thought came to me in a flash that such constancy required the existence of a regulator.

However, I lacked any idea of the nature of what could be regulating the composition of the Earth's atmosphere, except that the organisms on the Earth's surface were part of it. I learnt from astrophysics that stars increase their heat output as they age and that our Sun has grown in luminosity by 25% since life began. I realised that in the long term there might be climate regulation also. The notion of a control system involving the whole planet and the life upon it was now firmly established in my mind. Sometime near the end of the 1960's I discussed this idea with my near neighbour William Golding. He suggested the name Gaia as the only appropriate for so powerful an entity. Not long after this I began a collaboration on Gaia with the eminent biologist, Lynn Margulis, that has continued until now.

What is Gaia? Gaia is the name the ancient Greeks gave to their goddess of the Earth and is the root of words like geography and geology. The goddess Gaia was at once gentle, feminine and nurturing, but also ruthlessly cruel to those who transgressed. Gaia is also a straightforward scientific theory about the Earth and the organisms that inhabit it. A theory that views the Earth as if it were alive. As if it were able to regulate the climate and chemistry to keep it comfortable for life. Gaia theory is testable and has a proper mathematical basis in a set of closely coupled differential equations. The main value of Gaia at its current stage is to provide a different way to look at the Earth. In science, Gaia theory has already led to significant discoveries but just as important, it forces us to question whether the good of humankind is the only thing that matters. If Gaia does exist then it must come before us for we cannot live without it.

The principles of Gaia are not new, they were first proposed over two hundred years ago by the father of geology, James Hutton. He said in 1795 "I consider the Earth to be a superorganism and its proper study should be by phisiology" [1]. His wise words were forgotten in the following century when science flourished abundantly, but also grew like a tree and separated into many separate branches. Hutton's view and Gaia are broad general science and almost incomprehensible to modern scientists most of whom are specialists. Gaia is an evolutionary theory that includes the material Earth and the organisms in a tightly coupled process. It is entirely consistent with Darwinian natural selection. The self regulation of the climate and the chemistry of the Earth are emergent properties that emerge automatically. Regulation goes on entirely without foresight or planning and there is no teleology involved. Let me say that as a scientist I wholly reject dogmatic certainties. I do not know if Gaia theory is right, only time and evidence will bring an answer.

Earth and Life sciences and Gaia

Working scientists usually judge a new theory from the usefulness of its predictions. By this measure, Gaia research is useful for it has advanced both Earth and Life sciences. Let me tell you about three of these advances. The first was the discovery that the elements iodine and sulphur are transported through the environment in the form of the gases methyl iodide and dimethyl sulphide and that both of these substances are the natural products of marine algae living at the ocean surface. I made this discovery during the voyage on a small ship from England to the southern hemisphere and back in 1972 [2]. Everywhere the ship sailed these gases were found to be part of the ocean environment. Before the voyage scientists wrongly assumed sulphur and iodine to pass through the atmosphere as fine particles of sea salt floatig in the air. Life they said plays no part in regulating the composition of the Earth, organisms merely turn over the chemicals that blind inorganic chemistry leaves for them to find. The second discovery was that the long term climate of the Earth is regulated by the pump down of carbon dioxide in a controlled way by organisms living in the soil.

There is only one source of the gas carbon dioxide: volcanoes and volcanic processes, which bring it from the Earth's interior. There is only one long term sink for carbon dioxide: its removal from the air during the weathering of calcium silicate rocks. Geochemists had assumed that weathering was a purely inorganic process in which organisms played no part. With my colleagues Michael Whitfield and Andrew Watson, we proposed that weathering takes place at least thirty times faster when organisms are present [3, 4]. Our proposition was experimentally confirmed by the American scientists Schwartzman and Volk [5]. It means that organisms control the abundance of atmospheric carbon dioxide and therefore the climate also. When it is cold, soil organisms grow poorly and the pump down of carbon dioxide is slow, as a consequence carbon dioxide builds up in the air, and the world warms. When it is hot, organisms grow fast and pump down carbon dioxide rapidly so as to cool the Earth. This is one process by which the Earth could have kept cool and comfortable in spite of a 25% increase in solar heat since life began. But there is a puzzle concerning the working of this pump in the present world. It is hotter now than it was in the ice age, but the carbon dioxide has increased, not decreased, or remained constant as would be expected if regulation were taking place. How could this be?

The third discovery to come from Gaia is part of the explanation. The gas dimethyl sulphide (DMS) has been found to do much more than merely carry sulphur from the ocean, where sulphur is abundant, to the land, where it is scarce and needed. Dimethyl sulphide oxidises in the air to produce two strong acids, methane sulphonic acid (MSA) and sulphuric acid. These acids are known to be the major source of the nucleating particles on which cloud droplets form. Wihout the formation of DMS by the organisms living in the oceans there would be fewer and less dense clouds and the Earth would be a hotter place. This work was done in collaboration with my colleagues Robert Charlson, Andi Andreae and Stephen Warren and reported in 1987 [6]. Again it was the Gaian view that motivated the search for a connection between the organisms living in the oceans and climate. We wondered if the algal production of DMS could be part of a Gaian feedback mechanism for keeping the Earth cool. As evidence accumulated it pointed not to regulation but the opposite, a tendency to destabilise climate. The strongest evidence came from the chemical analysis of the ice cores taken in Antarctica. These showed clearly that as the Earth grew warmer following the last glaciation so the quantity of MSA laid down on the ice grew less. This means the warmer it becomes the fewer the clouds and the hotter the climate. Just like the carbon dioxide puzzle there is a positive feedback on warming, the opposite of climate self regulation in the Gaian way.

Some like it hot

I learnt early in my life as a scientist that evidence that appears to contradict a theory under test is more likely in the end to confirm it. The bad news for theory testers is neutral or uncertain evidence. The apparent contradiction can come simply from viewing the problem in the wrong way. In the present instance, if we consider the Earth system to be in a temporary state of failure then positive feedback is not unexpected. Consider the last time you had a fever. When a fever starts, the processes that normally cool, like sweating and the dilation of the blood vessels of the skin, cease to operate; we also produce more heat by shivering. These are all positive feedbacks characteristic of disease. Yet, who would doubt that we normally regulate our body temperature very well?

By looking at the present Earth as a fevered system the positive feedbacks between climate and carbon dioxide and between climate and clouds make sense. The first thing to note is that the Earth's climate for most of the present geological period, the pleistocene, has been cold. Only about one tenth of the time is spent in interglacials like now. Moreover, the Antarctic ice records the deposition during the glaciation of seven times as much sulphur acid as now; in addition, the carbon dioxide was less than 200 parts per million in the glacial state. Both facts imply a more abundant, or more vigorous, biosphere than we have now. Perhaps the system really does prefer it cool and the present interglacial, although comfortable for us, is a fever as far as the planet is concerned.

To test these ideas further my colleagues Lee Kump and I have made numerical models based on Gaia theory. These models included plant life on the life surfaces to pump down carbon dioxide and algal growth in the ocean to generate cloud cover. We assumed that the optimum temperature for plant growth was 18ϒC and the optimum sea temperature for algal growth 10ϒC. This was not because algae have a different temperature preference to land organisms but because, for geophysical reasons, ocean temperatures above 10ϒC are associated with the formation of stable layers of warm water floating at the surface. These layers soon become depleted of nutrients and the algae cease to flourish. Our models predicted the self regulation of climate during the glacial cool state. The production of clouds by marine organisms and the pumping down of carbon dioxide both exerted a negative feedback on warming and kept a steady climate. The models also predicted the system to be close to the limit of stable operation and that even a small increase of solar heat could precipitate a change to a warmer and less stable climate. Before and after this change the system was in positive feedback [7, 8].

A glance at a satellite view of the Earth taken to show plant growth on the land and algal growth in the oceans confirms that dense algal growth is limited to the ocean near the poles, and to upwelling water near the edge of continents. In both of these regions the temperature is below 10ϒC.

The land surfaces between 30ϒN and 30ϒS, where the temperature is above 18ϒC for most of the year, are either desert or tropical rain forest. We know that such forests are unstable and do not recover if removed; they are also ecosystems that are managing their own regional climate and would be likely to decline with increasing temperature. The models and the evidence are consistent with Gaian self regulation in the long term, but with a temporary failure in the present feverish world. The immediate cause of the change from glacial to interglacial was almost certainly one of the small regular changes in the Earth's inclination and orbital position with respect to the sun, the Milankovich effect. By itself, the increase in heat received is insufficient to cause the large change in climate from the ice age to the interglacial. The Milankovich effect was the trigger, not the prime cause of the change [9].

If this planetary view of the present climate is correct, it suggests that we have chosen a bad moment to add greenhouse gases to the air and to use so much of the natural ecosystems of the land surface for agriculture. More seriuosly, the consequences of these acts could be amplified by the positive feedback of the system, and the climate of the coming century made hotter than is usually forecast.

From space exploration to space exploitation

I started this article by praising journeys into space, and explained how they led to the discovery of Gaia. It is important to distinguish space exploration, which allows us to see and understand the Earth, from space exploitation which sees space as the new frontier. Space exploration would not have happened when it did, had it not been for the cold war between the super-powers; the enormous cost could only come from a military budget. This is forgotten when scientists and politicians talk of space exploitation for the good of mankind. It is naïve and full of hubis to think of having dominion over the other planets. It is foolish and vain to plan to make Mars a second home for people, when we are so far from knowing how to live with ourselves and with the Earth. Even more absurd is the idea of colonies floating in space. Those who look to space as the new frontier ignore the mess they leave behind. Their bravado is in stark contrast to the words of the true space explorers, those brave astronauts who made their journeys to the moon. They saw the awesome immensity of space and how small is the Earth and realised poignantly that it really is home. I recall so well Jim Lovell, one of the three that nearly did not return, telling me that even his thumb nail, held at arm's length, masked the Earth when seen from the distance of the Moon.

The exploration of space changed the balance of power between religion and science, and strengthened the authority of science in its claim to explain the mysteries of the Earth and the Universe. The superstitious and dogmatic side of religion lost much of its power over simple people when it became known that men had walked on the Moon. In 1969, when the first men landed on the Moon, I was with my family in the far west of Ireland; in those days one of the most beautiful, least touched, and devoutly religious places in Europe. During the week that followed the landing people from the region called at our home and asked if it was true that men had landed on the Moon. I said "yes did you not hear it on the radio?" They replied "yes, but we needed to hear it from your lips to know it was true". When I asked why, they said, "We need to know the truth. We want to know that there are no angels and heaven up there in the sky."

The true value of those journeys into space, whether real or in the mind, was to reveal the Earth as a live planet. They made us realise for the first time that humanism is not enough. The view from space teaches that we are part of a greater entity, the Earth, and that our survival and its good health are inextricably entwined. Perhaps in time we can expand our view to encompass the larger systems of the Galaxy and the Universe. Now the Earth needs our full attention.

What dangers lie ahead

Even if we reform immediately, we shall still see the Earth change and we, its first social intelligent species, are privileged to be both the cause and the spectators. The change in climate imminent is as large as between the ice age and now. To comprehend the magnitude of the change ahead glance back to the depth of the last ice age, some tens of thousands of years ago. Then the glaciers reached as far south as latitude 35ϒ in North America and to the Alps in Europe. The sea was more than 100 metres lower than now, and therefore an area of land as large as Africa was above water and plants grew there. The tropics were like the warm temperate regions are now. In all it was a pleasant world to live on and there was more land. What could take place, as a result of our presence so far, is a change as great as that from the last ice age until about 100 years ago. To understand what has already begun and could happen in the next century, imagine the start of a heat age. An age when temperature and sea levels climbed, by fits and starts, until eventually the world was torrid, ice free, and all but unrecognisable. Eventually is a long time ahead, it might never happen to that extent, what we have to prepare for now are the incidents of a changing climate, just about to begin. These are likely to be surprises, things that even the most detailed of big science models do not predict. Think of the ozone hole, this was a real surprise. The most expensive computer modelling and monitoring of the Earth's ozone layer failed to see or predict it. It was seen by observers looking at the sky with simple instruments. Surprise may come as climatic extremes, like ferocious storms, or as unexpected atmospheric events. Nature is nonlinear and unpredictable and never more so than in a period of change.

This is an occasion when we cannot look to Gaia for help. If the present warm period is a planetary fever, we should expect that the Earth left to itself would be relaxing into its normal comfortable ice age. Such comfort may be unattainable because we have been busy removing its skin for farm land, taking away the trees that are the means of recovery. We also are adding a vast blanket of greenhouse gases to the already feverish patient. Gaia is more likely to shudder, then move over to a new stable state, fit for a different and more amenable biota. It could be much hotter, but whatever it is, no longer the comfortable world we know. These are not fictional doom predictions, they have real possibility. We have already changed the atmosphere to an extent unprecedented in recent geological history. We seem to be driving ourselves heedlessly down a slope into a sea that is rising to drown us. Among the things we must not do is cling to the illusion that we can manage the Earth. Management implies that contemporary science can fully explain the Earth, and that people are willing and able to work together to keep the Earth a fit and comfortable place for life.

These assumptions are naïve. They are like assuming the passengers on a plane, whose pilot had died, could land it safely with no more help than the pilot's manual. Does anyone believe that we, intelligent carnivores prone to tribal genocide, could, by some act of common will, change our natures and become wise and gentle gardeners, stewards, taking care of all of the natural life of our planet? I would sooner expect a goat to succeed as a gardener as expect humans to become managers of the Earth. Do we want to be bureaucrats in charge of the Earth? Do we want to be made accountable for his health? There can be no worse fate for people than to conscript them in such a hopeless task; to make them responsible for the smooth running of the climate. To make them responsible for the chemistry of the oceans, the air, and the soil. Something, that until we began to dismantle it, Gaia gave free.

Conclusion

So what should we do? The past President of the Czech republic, the playwright Vaclav Havel, has a way of looking at the Earth and ourselves that at least offers guidance. On the occasion of his receipt of the Freedom Medal of the United States of America, Havel gave an address to the people of America in which he made as the theme "We are not here for ourselves alone". He went on to remind his audience that science had been successful in displacing religion as the source of knowledge about the Universe, life and the Earth. This he said was a triumph. At the same time, however, modern science while destroying the older faith has failed to offer any alternative code of moral conduct. Because of this the post modern world has no code of behaviour other than a belief in human rights. There is now no code of obligation to guide behaviour among ourselves and with the Earth. Havel offered two scientific contributions from post modern science which could be ingredients in a new moral theology. First the Cosmic Anthropological Principle which suggests that we are not here by accident or as the consequence of some random event. Second, Gaia theory which tells us that we are part of a larger entity and that our comfort and happiness depend on our living well with the Earth and the life that inhabits it. So Gaia in a way gives back that sense of moral obligation that science had stripped away. As Havel said, "We are not here for ourselves alone."

I have spoken as an independent scientist, and it may seem that by stressing the need to take care of the Earth I am indifferent to human needs. Nothing is further from my mind, I want my grandchildren to inherit a world that has a future for them. To make sure that this happens we first need to recognise that human rights are not enough, and to survive we must also take care of the Earth. There is no tenure for anyone on this planet, not even a species.

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