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THE GAIA HYPOTHESIS AS A PARADIGM FOR ATTRACTING WOMEN AND MINORITY STUDENTS TO THE SCIENCES

Jeffrey B. Noblett

Department of Geology
The Colorado College
Colorado Springs, Colorado 80903

A significant concern for many of us who teach science has been the oft-reported declining interest in science on the part of secondary school students and majors at undergraduate institutions. One approach to attracting new students involves examining the tenets by which science is conducted and considering a variety of paradigms as teaching tools. Nearly twenty years after its re-introduction to science by James Lovelock (Lovelock acknowledges numerous predecessors, not the least of whom is James Hutton, the 'father' of modern geology), the Gaia hypothesis is being taught in secondary schools and undergraduate institutions, and is being actively tested at numerous research centers around the world (based on presentations at the 1988 Chapman Conference on the Gaia Hypothesis, sponsored by the American Geophysical Union and others). With the publication of Lovelock's new book *Ages of Gaia* and a fairly extensive literature throughout the 1980's on everything from computer models of the theoretical Daisyworld to discussions of the role of phytoplankton in Gaian feedback systems, there is sufficient material to examine Gaia in a science curriculum.

Gaia may be much more than a simple hypothesis; it has the hallmark of a new paradigm from which to engage in scientific research. Because this paradigm corresponds well with criticisms of science from the extensive literature in feminist philosophy and related areas, and because Gaia resonates with belief systems of nominally underdeveloped cultures/tribal systems around the world, I am suggesting that examination of the Gaian paradigm may lead to a significant interest in science from people (especially women and minorities) who are currently very underrepresented in science fields. At the very least, a willingness to listen to the critiques

of science about the way in which problems are formulated, solutions conceived, and research methods selected is a prerequisite to augmenting interest in science.

The Gaia Hypothesis

In the late 1960's a British scientist, James Lovelock, hired by NASA to determine how to detect life on Mars, ended up proposing that not Mars, but the Earth was alive. By this, he meant that the Earth itself behaved as a self-regulating system. Instead of the conventional view that life exists only because material conditions on Earth happen to be just right, he argued that life defines the material conditions needed for its survival and makes sure they stay there! In viewing the Earth as a living planet, Lovelock suggests that we need to develop the science of geophysiology.

Geophysiology is the science of planetary medicine, viewing the Earth as a living being, not as a machine. Scientists would investigate feedback loops to demonstrate the interdependency of the Earth's circulatory systems. If life exists at the planetary scale, these loops must be global in extent. The key question seems to be not whether life interacts with the planet, but whether it regulates the planet (a self-regulating, self-organizing entity).

Lynn Margulis of Boston University amplified this explanation, referring to Gaia as approximately the surface of the Earth and arguing that the Earth's temperature, acidity, alkalinity, redox relations, and composition of reactive gases are all maintained (not necessarily constant) through time by the behavior, growth and interactions of living organisms. Thus, she views Gaia as a complex entity involving Earth's biosphere, atmosphere, oceans, and soil; the totality constitutes a feedback (cybernetic) system which seeks to optimize the physical and chemical environment for life.

Lovelock continues in *Ages of Gaia* that Gaia is a tightly coupled system of life and its environment which includes both (1) living organisms, subject to the rules of Darwinian natural selection and (2) the physical and chemical constraints (i.e., environment) that establish the limits of life. This view shows that (1) life occurs on a planetary scale and is effectively immortal (1/4 of the age of the universe), without need to reproduce; (2) there can be no par-

tial occupation of a planet by life; and (3) Darwin's adaptation is incomplete - because organisms alter their environment, the coupled process must be understood.

The problem of perceiving Gaia is not unlike that of seeing the back of your own eyeballs or even seeing the forest for the trees. We are an aspect of Gaia. People who have difficulty understanding how the physical environment is a functional aspect of Gaia could consider the redwood tree, which contains only about 1% living material, the rest being inert.

I would suggest that, at the very least, the Gaian perspective involves a Kuhnian-like paradigm shift from which to pursue science. Gaia is a guiding principle for research which contrasts neatly with 'machina': the traditional view of Earth as a machine. Has either paradigm been proven? Which view fits better with our natural experience? Is the Earth a spaceship which we operate or is it a living system of which we are a part?

Testing the Hypothesis

Defining life has proven difficult to lexicologists; defining a testable hypothesis for Gaia is equally elusive. Nonetheless, two aspects of Lovelock and his colleagues' work demonstrate Gaian principles of research.

The Daisyworld computer model is well described in the literature (Lovelock, *Ages of Gaia*, Ch. 3; Lovelock, *Bulletin of American Meteor Society*, 67, pp. 392-397; Watson and Lovelock, *Tellus*, 35B, pp. 284-289). In brief, they conceived of a cloudless world on which two species of daisies (dark and light) interacted with solar luminosity and planetary albedo to regulate global temperature. More complex models involving increasing solar luminosity, twenty-species of daisies, and foxes, rabbits and daisies revealed insight into the stability of diverse ecological systems and measures of a planet's health. The advantage of this geophysiology over traditional ecology models is explained by Lovelock in his new book.

The plankton connection (*Nature*, 326, pp. 655-661, *Science*, 237, pp. 1020-1022) may be an example of a real earth system which

contains the elements of a negative feedback system regulating global temperature. Though the cycle has not yet been fully established, research on this global scale is critical to examining the Gaia hypothesis.

Implications of the Gaia Hypothesis

In the Gaian paradigm, the Earth is viewed as a living system rather than as a machine. Historians of science have reminded us that the experimental method was originally developed with this Gaian view, but that a fledgling science may have been forced to adopt a mechanical view with its implication of a creator to appease the religio-political powers of the times.

Humans are viewed as belonging to and embedded within the natural world rather than as separate 'objective' observers. Thus, nature is not something to be controlled or dominated, but to be cared about and worked with (geophysiology). Researchers must account for their relationship with nature in terms of depth of awareness, violence in attitude, and so on.

Emphasis is on complex, interacting systems (perhaps requiring computer capabilities we are just beginning to imagine) rather than on linear, reductionist, dichotomous reasoning. The latter approach brought us a great deal of understanding, but simple cause-effect reasoning is, according to Lovelock, inadequate to deal with global systems. Perhaps, we are simply maturing in our search for knowledge.

The Gaia hypothesis could produce a revolution in science of a magnitude comparable to the switch from Ptolemy to Coperinican paradigms. Copernicus moved us away from a geocentric perspective; Gaia moves us away from anthropocentric perspectives.

Critiques of Scientific Procedure

Following the demise of the logical positivists, most scientists have recognized that there is something inherently subjective in science, perhaps in any activity involving language and, thus, a socially-defined conceptual framework. Most undergraduate philos-

ophy of science courses include a variety of arguments critiquing any claims made by scientists to an untainted objectivity (that is, after all, what separates us from the creationists!). Discussion of Kuhn's notions of paradigm shift are commonplace. A recent significant addition to this philosophy of science has come from the realm of feminist philosophy. Many of these ideas resonate with ideas from various individual philosophers from our past, and there is considerable resistance to the use of the term feminism amongst my science colleagues (based largely on ignorance of the recent literature). I use the term here precisely because it is feminist philosophy which formulated and presented this critique in an identifiable form. The critique ranges from tentative hypotheses on science as a primarily white male social field (e.g., object relations theory, Gilligan's *In a Different Voice*) to a package of philosophical criticisms (e.g., see Harding, *The Science Question in Feminism*; Keller, *Science and Gender*; Bleir, *Feminist Approach to Science*; Harding, Barr, eds., *Sex and Scientific Inquiry*).

In brief, the criticisms of scientific procedure include the language of science and oft-cited analogies of their work with which scientists, unconsciously or not, identify nature and women, both to be controlled. The criticisms include the dualistic thinking approach and reductionist approaches of scientists as contrasted with more holistic inclusive approaches. Perhaps such compartmental thinking was crucial to the birth of the scientific process; feminists would urge us, however, to pursue a more complete empiricism, one which does not arbitrarily isolate categories of examination. The desire to separate ourselves as observers from the system which we are analyzing, feminists argue, is not only impossible, but may lead to a tendency to find domination and control of a nature separate from oneself to be a norm. Rather, the argument goes, by acknowledging one's place within the scheme of nature, a deeper understanding is possible (e.g., Barbara McClintock's Nobel-prize winning genetic research). Viewing competition or conflict as a norm rather than as a sign of insanity may have prevented researchers from seeing the role of cooperation or symbiosis in evolution. Above all, anthropocentric reasoning is seen as a hindrance to understanding nature as it is. After all, if Lynn Margulis is correct, perhaps bacteria are the norm for life.

The paradigm of Gaia obviously responds well to the feminist critiques. This is itself a testable hypothesis. If the feminists are correct, and science (including NSF and other granting agencies desiring women role models in science) actually wishes to attract more women, then developing research problems and pursuing solutions from the Gaian perspective should produce more women scientists (and perhaps a different type of science). The basis for this hypothesis is merely the acknowledgment that some men and women view the world diferently. This by no means suggests that men are incapable of understanding feminist philosophy, or women are incapable of practicing science. It does suggest that we re-examine the belief systems or conceptual framework which we each use in pursuing scientific knowledge of the natural world.

The impact of the Gaian approach became obvious to me recently while I was teaching introductory geology. The students had just listed all the qualities they perceived in modern science. I had then asked them what the differences were between men and women. After a fairly heated discussion, lists were compared and they discovered a nearly perfect correspondence between perceived male traits and scientific pursuits. I asked them to formulate an alternative, but equally empirical epistemology of science. That science, as we went on to discuss, was essentially Gaia, and was based on the list of female traits.

Since that class, a small but significant number of women, all of whom claimed no prior interest in pursuing science, (and two men, as well) have approached me about constructing a major which would include science and research, yet was not in any of our traditional departments (e.g., also including courses in literature, ethics, understanding how and why we choose to view nature as we do). This new interest of theirs in science can be directly related to Gaia. If we are sincere in our desire to include women in scientific research, particularly in new interdisciplinary understandings, should we be presenting Gaia as a possible paradigm? Can we extend this idea to inclusion of minority groups (Gaia clearly resonates with belief systems of Native Americans)? If the fundamental truth of science lies in its methodical pursuit of reliable, reproducable, testable knowledge, can we afford to leave old belief systems (e.g., the Earth is a machine) unchallenged?
