MATHEMATICS AND EVOLUTION: A PROPOSAL

Ralph Abraham

Dedicated to:

Lewis Fry Richardson (1881-1953)
Kurt Lewin (1890-1947)
Buckminster Fuller (1895-1984)
Ludwig von Bertalanffy (1901-1972)

CONTENTS

FOREWORD

In May of 1985, I met Ervin Laszlo, Rianne Eisler, and David Loye for the first time. This meeting led to our still evolving relationship, to the formation of GERG (the General Evolution Research Group) in June of 1986, and to a series of papers on dynamics and society which I write in reluctant response to GERG stimuli. This is the third paper of this series.

As described in the preceding paper, *Mathematics and Evolution: A Manifesto*, I propose to experiment with social interventions based upon complex dynamical models of global systems. In this sequel, I present an introduction to the philosophical basis, hermeneutics, two exemplary modeling schemes, and a plan for an institute to actually implement schemes such as these. The four parts are self-standing essays, all inspired by the *Manifesto*, which also combined four essays.

My own proposal for social intervention, described in some detail in these pages, is more of a continuous, low-level injection, rather than a massive bolus of medicine. The overall idea is to implement the hermeneutical circle (or spiral) of conscious selection in cultural evolution, while minimizing the risk of a devastating mistake.

Richardson, Lewin, Fuller and Von Bertalanffy all tried to implement hermeneutics in social interventions. This work is dedicated to these four pioneers

ESSAY I: MATHEMATICAL HERMENEUTICS

Dedicated to:
Kurt Lewin (1890 - 1947)

Abstract:

After Descartes and Mersenne, mechanics (the art of making mathematical models for processes) became disenchanted, and fell into disrepute. The advent of the computer revolution has brought a shift of style in mechanics and in applied mathematics in general. This provides an opportunity for the reenchantment of mechanics, by integrating modeling more tightly into the hermeneutical circle of *action research*. This paper introduces the basic concepts of this reenchanted circle, *action mechanics*, and suggests its potential importance for post-modern society.

1. Introduction: The World according to Grok.

It would be convenient to shorten hermeneutics (Palmer, 1969; Lee, 1987) to ***herm***, much as we substitute math for mathematics, as we must use it so frequently in this article. However, we need refer also to ***hermetics***, also named after the mythic hero and contemporary of Moses (Fowden, 1986). So, instead of ***herm***, which would be ambiguous, we will use *grok* as a familiar name for hermeneutics (and ask you to suspend any negative reactions). This suggests itself also as a translation into English of *Verstehen*, which is a principle aspect of hermeneutics, after Dilthey, rather than the common German verb. The basic idea is this: we grok something (a text, artifact, art work, poem, archeological find, letter, phone message, natural process, etc.) by a cycle of observing, thinking, poking, observing, and so on. This is not the same as explaining it, representing it, translating it, etc. This cyclical activity is a basic object of hermeneutical thought, called the *hermeneutical circle*. Some think of it more as a spiral, as the turning of this circle is the motor of the evolution of our consciousness, or the convergence of our groking.

In this short article, we cannot do justice to these important and difficult ideas, but will be satisfied to give pointers to the extensive literature. To see the world according to grok, then, you might start with Lee (1987), Berman (1981), Bateson (1979), and Palmer (1969). Our goal here is to view the mathematics and computer revolution of our times according to grok. We feel that this perspective may be crucial for our own evolution, in the struggle with the challenges of post-modern planetary society (Capra, 1987; Abraham, 1986; Tillich, 1961; Bateson, 1979; Bateson, 1984; White, 1967).

2. Hermeneutics, the History of Consciousness, and Cognitive Resonance.

The history of our subject, the resynthesis of natural philosophy, or *physiology* as Thales named it, may be traced back to Cro-Magnon, or Stonehenge at least. But we will be satisfied with the historical traditions. In brief, these are:

* The ancient Greek, from Thales to Hypatia, including the Mysteries;

* The Alexandrian Hermetic corpus, its devious transmissions through the Dark Ages, its arrival in

Italy after the fall of Byzantium and flight of the Greeks in 1456; and

* The Neoplatonic fragments surviving in the early Christian mystic, Sufi and Cabalist communities, propelled towards Italy along with the expulsion of the Jews in 1492.

Through all this voyage physiology maintained its integrity. This is shown as the trunk of the tree of perennial philosophy, in Fig. 1, in the style of Ramon Lull (Yates, 1982).

And then, suddenly, the branchings.

First, the basic split between Physicalism and Vitalism (Kuhn, 1977; Berman, 1981; Davis and Hersh, 1986; Lee, 1987) triggered, perhaps, by the burning of Bruno (Yates, 1964; Berman, 1981) in 1600, or the dream of Descartes in 1617 (Davis and Hersh, 1986), or the efforts of Mersenne in 1623. This conflict still dominates the growth of science. Soon after, Hermeticism (the magical Alexandrian heritage fundamental to the Renaissance) departed from Vitalism, and virtually died. Then, the birth of Organicism from Physicalism (Haraway, 1976), an attempt to regain the advantages of Vitalism without its spirit. And from Organicism and Holism, the birth of General Systems Theory (Davidson, 1983), and recently, General Evolution Theory (Jantsch, 1981; Laszlo, 1987). Meanwhile, after Goethe, Hermeneutics split off from Vitalism, trying to keep the flame alive in the openness of the social sciences, after biology was converted to Physicalism (Palmer, 1969; Lee, 1987). From Lewin's contact with the tradition of Dilthey in Berlin, Action Research branched from Hermeneutics (Lewin, 1948; Bateson, 1979), courageously carrying out the grok program in the social science context.

And as we see in Fig. 1, these two inner branches, evolution theory and action research, may be about to rejoin, in an attempt to repair the Physicalist/Vitalist split of 400 years, and reenchant the world.

We may regard the evolution of consciousness, and the growth of this tree, as a manifestation of morphic resonance. (In this context, we may call this *cognitive resonance.*) For the process of the grok circle, in the mind of an individual scholar, is an oscillation (perhaps with a relatively long temporal period). Thus, a group (circle, school, community) of scholars may be regarded as a *vibratory field* (Abraham, 1987). Through mutual coupling of these oscillators, via written or spoken communications, the vibratory field evolves towards some kind of coherent, cooperative behavior, or self-resonance. Adjacent schools (for example, English and Continental schools of metascience) may then resonate with each other, as do adjacent piano strings. In this way, the mechanics of resonance may be employed in a grok circle, supporting the understanding of the history of consciousness and the evolution of culture. Thus cultural evolution may be envisioned as an autopoietic process in a vibratory field, in the spirit of general evolution theory, paralleling like models for physical and biological evolution. The harmony of these spheres, interacting by resonance, comprises a model for the planetary mind. The planetary mind may itself be a resonance phenomenon, in which noogenesis is directed by nature herself. It may even *be* nature herself.

3. The Hermeneutic Circle, the History of Science, and Action Research.

The grok spiral, in the history of science, is the basis of one of the main branches of the philosophy of science (Radnitzky, 1973). Lewin put it as simply as possible in 1945 (Sanford, 1970):

> *action research consists of "analysis, fact-finding or evaluation; and then a repetition of this whole circle of activities; indeed, a spiral of such circles"*

In fact, the cycle may be interpreted as observation/analysis, experiment/theory, intervene/explain, or participate/model. In any case, each side of the cycle is very complex, and has an extensive literature.

The concept of *model*, for example, varies through an enormous spectrum of meanings, from paradigm in the sense of Kuhn (1970), to homology, simile, analogy, metaphor, explanation, theory, or catachresis (Boltzmann, 1902; Hesse, 1961; Pepper, 1961; Black, 1962; Hesse, 1966; Achinstein, 1968; Kordig, 1971; Hein, 1971; Leatherdale, 1974; Haraway, 1976; Maclagen, 1977, p. 66; Rosenblueth and Wiener, 1945), to artifact, exemplar, or just plain model. In fact, here we are dealing with attempts to circumscribe cognitive strategies of mimesis or representation, in general, in a spectrum from larger to smaller representations. And *observation* similarly has its own spectrum of meanings. These range from detached observer totally isolated from the target

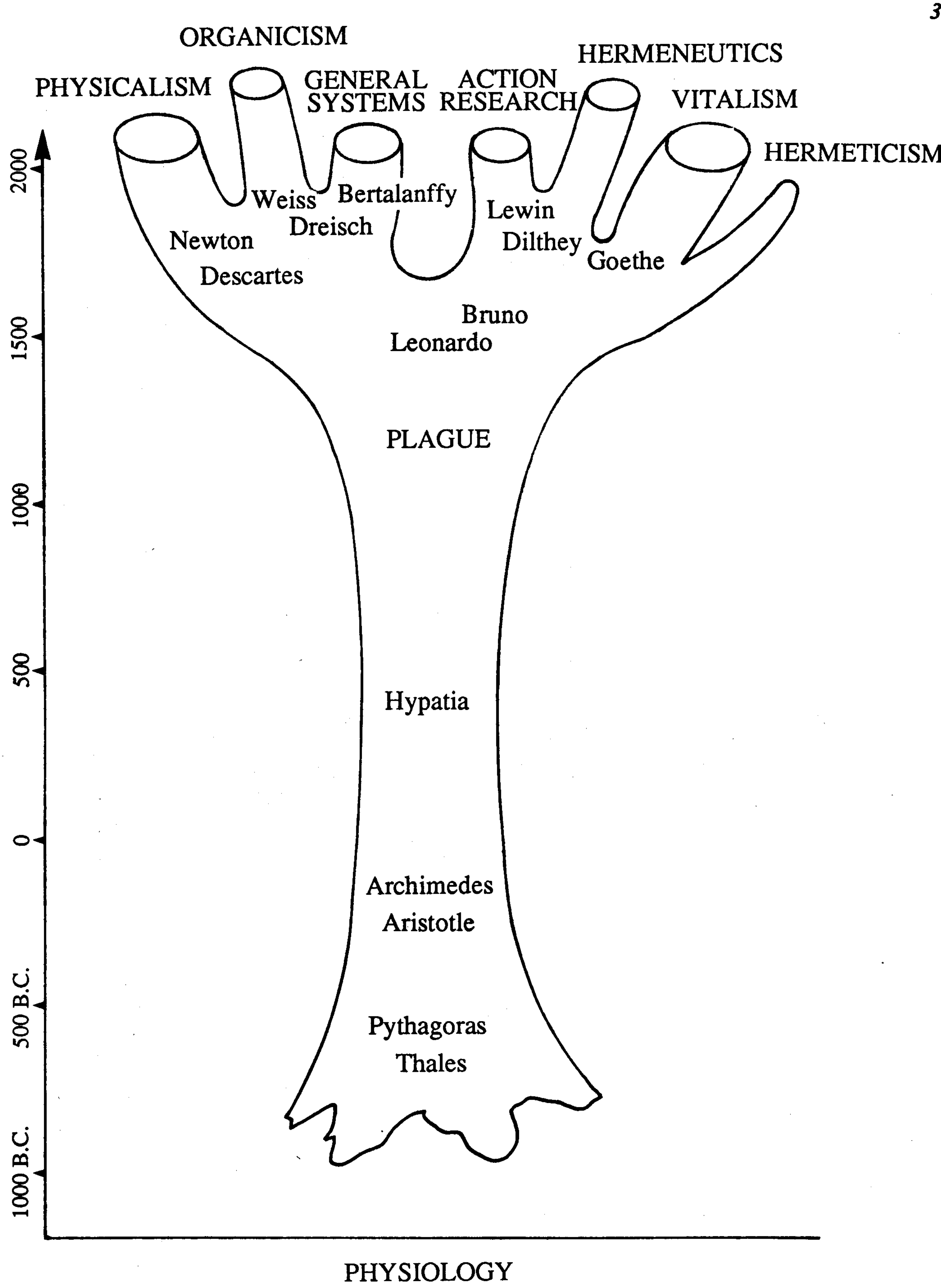
ORGANICISM
HERMENEUTICS
PHYSICALISM
GENERAL SYSTEMS
ACTION RESEARCH
VITALISM
HERMETICISM
Weiss
Bertalanffy
Dreisch
Lewin
Newton
Dilthey
Goethe
Descartes
Bruno
Leonardo
PLAGUE
Hypatia
Archimedes
Aristotle
Pythagoras
Thales
2000
1500
1000
500
0
500 B.C.
1000 B.C.
PHYSIOLOGY

FIGURE 1

system to diary of a lover: the spectrum of participation or involvement.

It is implicit in grok theory that *the model and the observation are linked.* They are linked in the grok circle, as shown in Fig. 2.

Observation is done in the ambiance of a model, the model is created in the context of an observation strategy. The rotation of this cycle evolves the adequacy of the model and the sensitivity of the observation, hence the understanding, of the world around us.

The antithesis of this grok view of the history of science is the dogma of Scientism, in which a particular model becomes identified with its target system in nature. This sin is, ironically, particularly prominent with the fancier mathematical models of physical processes made in the style introduced by Newton in 1685, a Hermeticist throughout his life (Dobbs, 1975). According to grok, mathematical models (although spectacularly elegant and abstract) are just another way of groking, uniquely useful for the most complex dynamical systems.

The conflict between the pragmatic approach of Hermeneutics/Vitalism and the dogmatic stance of Scientism/Logicism/Physicalism is a fundamental force in the history of science (Radnitzky, 1973). What we may learn of its intrinsic action from a study of the Scientific Revolution may be applied in the present time, to help us to surmount our difficulties.

4. Dynamic Models, Cybermimesis and Action Mechanics.

With this introduction to hermeneutics behind us, we may now turn to our main theme: the role of mathematics (and especially *dynamics*) in the evolution of culture and planetary society, as seen from the viewpoint of grok. Please understand that mathematics does not belong to science. Mathematics, in our view, is its own universe. However, some significant part of mathematics lives only to serve. And its main service, according to grok, is to supply models for phenomena and processes observed in nature. Thus some small part of science is extensively involved with mathematical models. *Dynamics* is the part of mathematics used, since Newton, to model processes, while *mechanics*, since ancient Greek science, refers to the model-making art. The word *model* (discussed in a more general setting above) will be specialized, in this paper, to mean *dynamical model.* With the mathematical formalism of a dynamical model, we intend to include a computer program for its simulation. In short, we now mean by a model what is known to contemporary science as a *dynamical model and its computer simulation.* We also refer to this as *cybermimesis,* as it provides a cognitive representation of its target process.

The cybermimesis of mathematics itself may be the grok interpretation of Gödel's famous results on incompleteness, more a problem for logical formalists than for Hermeneuticists (Findlay, 1952). For the representation of mathematics as a logical system, while fundamental to the Logicists, is a secondary aspect (a convenience for groking, a model) of mathematics to the Hermeneuticists.

Consider the grok circle consisting of cybermimesis and observation. The observations must be linked to the model, which means in this context that the data must be machine readable. Thus, experimental data and simulated data may be compared, for example, within the animated computer graphic presentations which have become standard in the simulation profession.

This cybermimetic grok circle is endemic in the sciences today, particularly in biology (Avula and Rodin, 1987; Greco and Kohn, 1986; National Research Council, 1985) and increasingly in social theory as well (Sorenson, 1978). The capability of this strategy to understand large-scale complex, hierarchical systems (holarchies) and chaotic behavior may extend groking to systems which otherwise would be beyond our ken. In combination with the interventions of action research, the cybermimetic grok circle becomes *action mechanics.*

With action mechanics, we may undertake some degree of self-direction in our future evolution. For the intentional and fruitful participation of consciousness (and human society) in the future evolution of our planetary system is impossible without some understanding of its holarchic nature. And action mechanics is a special shortcut to that understanding.

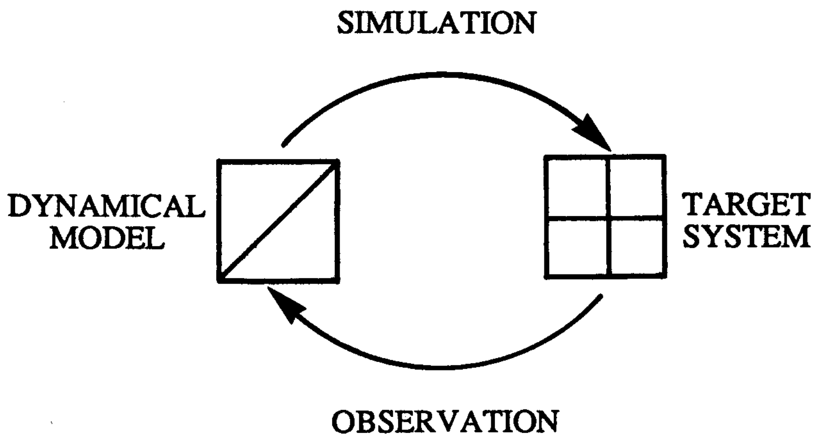

FIGURE 2

5. Conclusion: The Reenchantment of Mechanics.

Through cybermimesis, mechanics may reverse its bad connotation (as in, *mechanistic*) and once again (as in the time of Leonardo) become spirited. What is needed is the reconnection of the models (especially for social and ecological systems) to the people comprising the planetary society. At present, cybermimesis is extensively used by the scientific elite (for cognitive resonance) and by the military establishment (for cognitive dissonance). When home computers attain usable, fast, cybermimetic software and become enmeshed in high-capacity networks, we may see a new direction in cultural evolution. In fact, the roles of the model and its target system may merge, or even reverse, as envisioned in cyberpunk literature (Gibson, 1984). The question is, can we consciously participate in our own evolution through self-resonance, and regain the Garden of Eden?

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I am grateful to Paul Lee for sharing his knowledge of hermeneutics and vitalism, and for his careful reading of the first draft of this paper. Also, it is a pleasure to acknowledge the generosity of Morris Berman, Norman O. Brown, Fritjof Capra, Alan Garfinkel, Donna Haraway, Mara Keller, Ervin Laszlo, Paul Lee, David Loye, Gene Moriarty, and Douglas Wolf in sharing their ideas and resources.

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ESSAY II: THE ANIMATED ATLAS

Dedicated to:
Buckminster Fuller (1895-1984)

Abstract:

Using optical storage media for digital images, reference works with animated illustrations will soon be available for home computers. The translation of familiar cartographic materials, such as an atlas of world history, will soon follow. In this paper, we discuss the possibility of extrapolating such an atlas of world history into an atlas of world futures, using digital simulation of mathematical models for complex social systems. Potential applications to governance, decision making, and education are considered.

1. Introduction:

Hermann Hesse's classic, ***The Glass Bead Game***[1], has long been a great favorite of mathematicians, and many of us have been powerfully influenced by it in childhood. In its story, set in the distant future, humankind has a pet game which serves at once the functions of play, education, and creativity. More recently, Bucky Fuller invented his ***World Game***[2] in which players, gathered during summers since 1969 and supplied with enormous amounts of information about the world, try to project alternative futures and ways to achieve them. The outcome of one such game has been published, and looks much like an illustrated atlas of the world[3]. These works, together with new strategies for the simulation of the future[4], and the advent of optical storage technology for digital images[5], have provided the inspiration for the proposal for a real glass bead game of world futures, presented in this paper and elsewhere[6].

In the next three sections, we describe *an animated atlas of world history*. This is a project which might easily be accomplished with present day technology. In fact, it is very probably already in secret production somewhere in the publishing industry.

In the final three sections, we describe *an animated atlas of world futures*. This is an extrapolation of the animated atlas of world history, based on a technology of the future. We believe this technology, mathematical macrosociology (aka *psychohistory*[7]), is achievable through the extensive application of techniques already known[8].

2. The animated atlas concept.

An encyclopedia is already available for home computers, stored digitally on a single optical disk, or *CD ROM*. Other major reference works will soon follow, as several large software firms have spawned new ROM divisions for this purpose. It is the nature of this medium to easily accomodate graphics and pictorial illustrations, and even brief animated picture sequences, or moving illustrations. Only a small imagination is needed to make an endless list of useful applications of this medium, such as interactive manuals for tuning up the engines of vintage sports cars. Here I wish to single out just one of these potential applications, which will probably be an early one on most lists: the cartographic atlas. This is a favorite of visual people, such as myself.

There are many sorts of cartographic atlas, any of which might be ROMed. Here are some examples.

A. Atlases of world history (past):
- political history
- ancient history
- cultural history
- spread of alphabets and languages
- origins of bronze and iron working
- migrations of early cultures
- motions of glaciers
- motions of tectonic plates

B. Atlases of world geography (present):
- physical features (oceans, mountains)
- energy resources (fossil, renewable, solar)
- commercial features (distribution of minerals)
- biogeographic features (biomes)
- population density of important species (medicinal plants)

Many others already exist in libraries, and are found useful for education, research, planning, management, and so on. But these two will serve as models for our present proposal.

The animated atlas of world history would simply be the translation of an existing atlas[9] to ROM, with some interpolation of additional data for the sake of smooth animation. A good idea of an exemplary animated illustrated may be obtained by rapidly flipping the pages of *The Penguin Atlas of Ancient History*[10].

3. Data storage for an animated atlas of world history.

The translation of an existing cartographic atlas to the CD ROM medium would be an enormous burden, comparable to the construction of Cheops pyramid without the aid of levitation (heaven forbid), were it not for the fortunate fact that most of the maps are already stored in digital form in cartographers' offices. Despite this levitation factor, there may be still an extensive translation task required for the reduction of these maps to more compact graphics primitives, to enable the efficient storage of animated sequences Some techniques of data reduction developed for picture phone and satellite video applications might be useful. But it seems reasonable to assume here that an animated atlas of world history is at present a commercially feasible project, at least for an established publisher of an atlas of world history in book form, and may already be secretly underway somewhere in the publishing world.

Further in the future, new data storage techniques may enormously extend the capacity of currently available media. As capacities increase, the volume of information offered for sale by animated atlas publishers will probably increase in proportion, and our collective "intelligence" may increase as well.

Additional compaction of information may be obtained through simulation techniques applied to mathematical models for history, as described in the last three sections.

4. Historical applications.

Of course there are thousands of applications of the many atlases presently existing in book form, mostly unknown to me. And while I might claim that all of these would eventually be subsumed by new animated editions, there is no way to be sure of this. In matter of fact, I am very fond of traditional books, and have a strong prejudice in their favor. Some reference applications may forever be served best by information in traditional book form.

Even so, even more so, the animated atlas might be very useful for its own list of applications. And I would like to head up this list of potential applications with the *publication process for conventional atlases*. The animated atlas, running on the house computer of a conventional atlas publisher, would enable tremendous improvements in the visual representations of information in book form.

Next, I would list the potential application to the *time animation of existing atlases*. That is, if an existing atlas of world history is translated to ROM form for presentation digitally on home computers, the addition of animated sequences would be a very inexpensive improvement. In the context of world history, this means that a historical sequence (such as the motions and migrations listed in Section 2 above) would be presented as a movie, like time-lapse photography, accompanied by a narrative soundtrack in a language chosen from various options.

Finally, I might add to the list any number of *other animation applications* besides the time-lapse movie, such as the sequencing of maps according to temperature, time of year, size of species, and so on. These could be created upon demand by the viewer, by means of sorting maps already in the data base according to the usual algorithms of data base technology.

Any of these potential applications might be employed in the usual contexts, such as entertainment, education, research, writing, planning, management, and so on.

5. The simulation of the future.

Briefly put, the technology of the future needed for the extrapolation of an animated atlas is that of the digital simulation of mathematical models for the geosphere, the biosphere, and the sociosphere. Although the simulation technology exists today, the mathematical models do not.

However, a style of mathematical modeling suitable for creating these models is known[11], and its employment for modeling the geosphere and biosphere is well established. But models adequate for even a low resolution (that is, poorly detailed) animated atlas need to be developed. For the sociosphere, outside of the dynamics of population density, there are few models[12]. The development of these models may comprise the most exciting frontier of the sciences of whole systems.

6. Technical considerations.

The animated atlas of the past, conceived in today's technology, might best be based on optical disk memory media. But tomorrow, as models for the simulation of holarchic systems such as the biosphere become available on the research frontier, we may be able to use these models to create much richer atlases. For digital simulation is capable of generating an essentially infinite amount of information from a very compact dynamical model. The technology for the digital simulation of complex dynamical systems, at present, is substantially more expensive than the technology of digital memory. But by the day after tomorrow, this situation may be reversed.

As this technology is not widely known outside of the simulation profession, we give here a brief picture. The models envisaged are arrays, or complex networks, of dynamical schemes. A dynamical scheme is a system of ordinary or partial differential equations containing control parameters. These schemes (representing model holons, or nodes of the network) are coupled into a model holarchy (representing the complex system being modeled) through mappings from the dynamic states at one node into the control parameters of another. The digital simulation of such a model holarchy is accomplished by algorithms from computational dynamics called iterative, or relaxation methods. These require a great deal of arithmetic computation, which is slow and expensive. Special purpose computer hardware has been developed for accelerating these computations economically, such as *array processors* and *cytocomputers*. These are extensively used in the signal processing and image processing fields, where the same algorithms are used for related problems of computational mathematics. They are available in the form of add-on boards for computers of the engineering workstation class.

Thus, an animated atlas of world futures needs a more advanced computer system than one for memories of past histories. Nevertheless, this technology may soon reach the home computer market. The popularity of video games has created very sophisticated graphics computers for this market already.

A related technology which may find application in the area of future simulation is artificial intelligence. Properly combined with dynamical system simulation, further economy in the atlas may be obtained.

7. Future applications.

All the applications listed in Section 4 may be enhanced by the addition of future simulation. But this capability will be particularly relevant in applications in the planning and management category. Here, we list just a few typical applications.

C. Atlas of the world (future)
- political conflicts
- religious strife
- international terrorism
- greenhouse gas distribution
- climatic warming
- nuclear winter
- loss of topsoil
- depletion of fossil fuel reserves
- population explosion and movements
- stock market indices
- business forecasting
- distribution of wealth
- production of food
- marketing appraisal
- crop prediction
- spread of epidemics

Some of these areas already have good models, which have been developed recently by specialized scientists, and run on large supercomputers. Others must be developed from scratch by extensive scientific effort. But all are feasible, and require the same modeling style (complex dynamical systems) and simulation technology (highly parallel cytocomputers).

In conclusion, an animated atlas is feasible right now, on desktop computers of the engineering workstation class, costing about $35,000. The number of areas where adequate models are already available is small, but increasing at a good rate. Meanwhile, the technology is becoming less expensive, and may soon reach the home computer level.

We will probably get to experience adult video games, such as an interactive, animated atlas of world futures, in theme parks and science museums, in the near future. Soon thereafter, we will find them in our own homes. Possibly, they will be more interesting to many people than fiction films and documentaries on the same subjects. Questions arise as to the effects this will have on the evolution of society, and on the future of the entertainment and telecommunications industries. My own expectations are high that these developments will help justify the computer revolution, and enhance the future of humankind, and of our biosphere.

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ESSAY III: POLITICAL WEATHER REPORTS

Dedicated to:
Lewis Fry Richardson (1881-1953)

Abstract:

According to the hermeneutical theory of the evolution of consciousness, the development of a new relationship between our species and the biosphere may be encouraged by monitoring political and ecological variables or indicators, and feeding them back into society through broadcasting media. This possibility was foreseen by Richardson in 1919, as a means for avoiding wars. In this paper we describe a practical implementation of this program, based on the animated atlas technique.

1. Introduction: the Richardson Program.

Many people are comfortable in the present world situation, in spite of global crises, because of local optimism. A common mechanism may be the denial or repression of awareness of global problems, due to the lack of any strategy (beyond prayer) to interact with the world situation. Mathematically based strategies for global interaction have been discussed generally in a companion paper [1]. Here we are going to present a specific proposal for an experimental program. Based on the ideas of Lewis Fry Richardson, it aims at an intentional increase of global awareness by means of a subtle but sustained intervention.

Richardson was a physicist before World War I. He worked for the Meteorological Office in England, and was responsible for one of the first mathematical models for simulation and forecasting of the weather. It is said that the best current model has been derived from his work [2]. As a Quaker, he volunteered for service in the War as an ambulance driver. He saw the great destruction of life and limb in France, and resolved to devote the rest of his life to the amelioration of social problems. His first effort was a simple two-dimensional dynamical model for the arms race, in 1919. He hoped that another war could be avoided. But his paper was rejected by publications three times in a row, missing the opportunity to influence the course of world events leading up to World War II. It finally appeared in 1939. With each rejection his theory grew, and the whole story was published only several years after his death [3,4].

This affair is a classic example of the dictum: *the disease consists of the rejection of its cure.* Also, it is an epic of personal heroism and courage, in that Richardson never gave up. He was one of the first to realize that a circular process of positive feedback (called a *Richardsonian process*, or *schismogenesis*, by Gregory Bateson) leads to runaway behavior. And in his attempts to justify his theory of the arms race and reply to his critics, he amassed an amazing amount of data from historical records, giving birth to the field of *politicometrics.*

Our idea in this proposal is to replace the process of publication in scientific journals, as pursued unsuccessfully by Richardson between the World Wars, by a direct presentation of the data on public television. Our hopes for interacting with the world future in this way is based on the *hermeneutic theory of the evolution of consciousness.*

2. The hermeneutic circle.

The full background of this theory may be found elsewhere [5, 6, 7]. Here we give just the basic idea. Hermeneutics originally meant the exegesis of sacred texts. Later, it was extended to the exegesis of literary works, and became a branch of philosophy devoted to the theory of *understanding*. In 1808, the *hermeneutic circle* emerged in the writings of Friedrich Ast. Here, and in the later work of Schleiermacher, it refered to a referential cycle: parts, whole, parts, etc. Still later, Dilthey generalized the hermeneutic circle in his attempts to found the human studies on hermeneutics, and literary criticism became an integral part of the cyclical process of the evolution of culture: the cycle of creation, criticism, creation, etc. With Heidegger, this cycle was enlarged still further, to a basic mechanism for the evolution of consciousness.

This prepared the ground for cybernetics in 1945, which began with this mechanical metaphor (cycle, as feedback loop). Cybernetics then looked on the history of science as a cycle: model, experiment, model, etc. From this point of view, a branch of science evolves through the revolution of its hermeneutic circle. This led to a hermeneutical branch of the philosophy of science, which dominates the subject today [7].

When the revolution of the hermeneutic circle is blocked by the refusal to model or to observe, or by the dogmatic identification of the model with the target system, evolution halts. Similarly, the evolution of consciousness may stall through the lack of referential feedback, or adequate models, or both. Thus, the rejection of Richardson's work by short-sighted editors diminished the evolution of public consciousness of the alternatives to war [8].

We propose to revive this hermeneutic circle with new models, new observations, and a new strategy for closing the feedback loop, based on *daily political weather reports.* The actual circle for this program consists of the biosphere and planetary society as target system (GAIA), and a complex dynamical model (CHAOS), connected in a hermeneutic circle through the incorporation of politicometric observation from GAIA into CHAOS, and through feedback from CHAOS to GAIA by television broadcasting, as shown in Fig. 1.

3. Politicometric modeling and broadcasting.

Since Richardson's time, politicometric theory has evolved. Econometrics is particularly advanced, and at present there is an enormous amount of econometric data already recorded on computer tapes, suitable for our needs. Non-econometrical data on past and present political weather is also available, to a lesser extent, in computer tapes of newpapers, and organizations devoted to monitoring, such as the Worldwatch Institute, Amnesty International, the World Wildlife Fund, and others. To select among these data some indicators to present in a computer graphic display of the world situation requires a model. That is the teaching of the hermeneutic circle. For example, in ***World Dynamics***, Jay Forrester selected five parameters (population, capital investment, natural resources, agriculture, and pollution) [9].

At this point it is neccessary to emphasize that the model behind this selection does not have to be a good model, in the sense of predictive science. Any model will do for a start. For if it is not dogmatically fixed, the timely revolutions of the circle will create the evolution of the model, the world perceived through it, and the consciousness enveloping the entire process. Of course, modelers do their best to choose a suitable initial model (or models, as it furthers to have a spectrum of them on hand).

Having chosen some model for the global political situation in terms of available observations

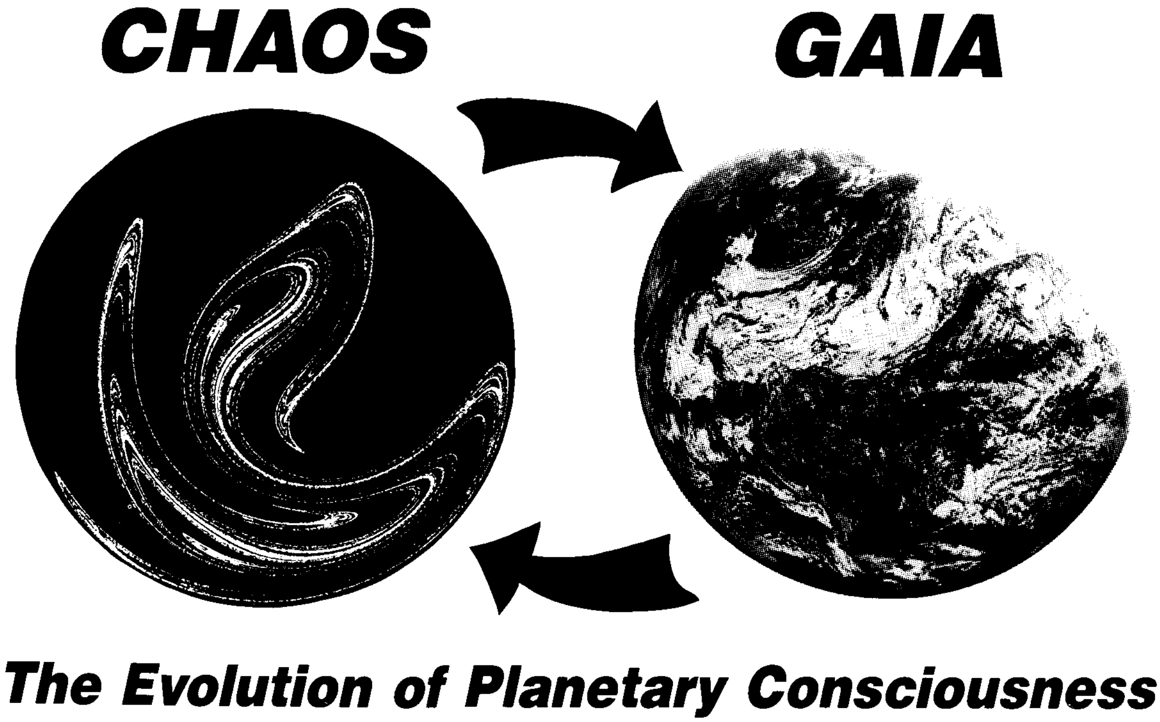

FIGURE 1

and existing data, we propose to present it with the technology of the *animated atlas* [10]. The paradigm for this technique is the *daily weather report* broadcast by local television stations. In these programs, available data is shown as a graphic overlay on the local geographic map. A short time series of this data may even be presented as a time-lapse movie. This type of animated atlas may be seen already in the airports of Europe, on the monitors of the Siemens *Meteo Display* system. Our proposed displays would follow this example exactly, but would emphasize the global scale.

In our plan, the *political weather report*, created in this way on a daily basis, would be broadcast (like the atmospheric weather report) within the daily news broadcasts of the television and newspaper networks. Presumably, different realizations of this scheme would employ differing models. Some might emphasize pollution, others international terrorism, arms traffic, or military spending. Dangerous trends might be readily perceived by viewers, leading to gradual changes in attitude.

4. Global modeling and simulation.

In the case of the *atmospheric weather report*, an important feature is the short term prediction, or *atmospheric weather forecast*. These predictions are much prized, in spite of the fact that their reliability is not great. As we have explained above, the (short term) forecast is based upon computer simulation of a highly sophisticated mathematical model derived from Richardson's early work. Without the forecast the weather report might be interesting, yet not compelling.

We also wish to enhance the appeal and the effect of the *political weather report* with short term predictions, that is, with a *political weather forecast*. This will require a model not only for the indicators, but also for their dynamics. Richardson's arms race model is a dynamical system, and so is Forrester's global model. More sophisticated models have appeared since these pioneering works. Although the evolution of a satisfactory predictive model is probably far in the future, forecasts based on simple models may admirably serve the needs of the hermeneutic circle.

The evolution of better models may emerge in the competitive arena of television broadcasting, as well as in government bureaus such as the meteorological or politicometric offices, and within the financial forecasting profession. Considering the magnitude of the global crises on the horizon, it would be well to give ample support to any hopeful strategy. Therefore, we propose, in the next essay, a research institute for the accelerated implementation of this strategy.

5. Conclusion: three steps to the future.

In short, we have proposed a strategy for reviving the spiral of cultural evolution in the context of the *world problematique*, while simultaneously accelerating the growth of the social sciences. The strategy involves the radical idea of *social intervention*, championed by Kurt Lewin under the name *action research* [12; p. 203]. This is a hermeneutic strategy, and was associated to the hermeneutical circle by Lewin himself [10; p. 206]. The proposed program might be actualized in three steps.

Step 1. The Politico. Create (as a commercial or government service) a computerized service for data. This service would be analogous to the *meteo*, or meteorological office. Some universities are already trying to accomplish this, for the support of research in the social sciences. This service would make politicometric data (updated daily) available to news media in a format compatible with the computer technology currently used by them for the creation of their atmospheric weather reports, including the splendid color video *animated atlas* displays found in most video broadcasts. These displays are already used for political data by some broadcasters (especially, the *Weather Channel* in the United States).

Step 2. RIMS. Create a Research Institute for Mathematics and Society, which would centralize mathematical models and computer simulations created by social scientists, and evaluate them by comparison of simulated data with politicometric observations from the politico. One archetype for this institution is the U.S. National Center for Atmospheric Research. Another is the GAIA project of the Soviet Academy of Science [11]. A more detailed proposal for RIMS is given in the next Essay.

Step 3. Forecasting. Present the results of future simulations (by the best models for global social and political systems from RIMS) as tentative predictions, and *what if* games, within the reports established in Step 1. One model for these interventions is the dissemination of the *Nuclear Winter Scenario* by the Academies of Science of various countries in recent years. The interventions proposed here, however, would be sustained, small-scale, and (relatively) unfrightening. One strategy for these interventions would be the extension of the political weather reports of the news media from past and present data into the near future, within the animated atlas format. Another would be fancy animated atlas machines located in theme parks, or in *Social Exploratoria* associated with local museums or schools. These would provide for mini- experiments by any interested individuals. Eventually, interactive computer-graphic programs could be provided to individuals having access to sophisticated workstations, for use with data obtainable from online politico services on the information networks.

The ascent of these three steps creates for us not a goal, but a process: the hermeneutic circle, as shown in Fig. 1. Thus: from observation into model, to improvement of model, broadcast of implications of current policies and trends, changes of attitudes and policies, observation of effects of these changes, transformation of the model, new ways to observe, and so on.

Computers, mathematics, social theories, individual knowledge and understanding, and planetary society itself: evolving together. *The means are here today. Will we make use of them?*

Acknowledgments:
It is a pleasure to thank The City of Firenze and the organizers of the Physis Conference for their invitation and support. In addition, Gene Moriarty is responsible for my discovery of Lewis Richardson and hermeneutics, and Dave Loye introduced me to Kurt Lewin and action research. Yoshisuke Ueda supplied the 1984 reproduction of his original chaotic attractor discovered in 1961, appearing in Fig. 1. Andra Akers kindly sent a copy of Moiseyev [11]. To these people, and many others who egged me on, my heartfelt thanks.

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ESSAY IV. RIMS: a proposed institute

Dedicated to:
Ludwig von Bertalanffy (1901-1972)

Abstract:

A proposal for a novel research institute, The Research Institute for Mathematics and Society, and The RIMS Social Exploratorium, capable of supplying a *political weather bureau* with adequate data in computer-readable form suitable for graphic presentation on video broadcasts, together with a public display center based on the *animated atlas*.

1. Aims.

This proposed new research institute and public exposition would be devoted to:

* the acceleration of the development of the social sciences through the extensive application of the techniques of mathematical modeling (especially by the strategy of complex dynamical systems theory) and computer simulation (especially by the techniques of interactive graphics),

* the application of new models for the social sciences to forecasting, planning, and management of global resources, amelioration of world problems (famine, epidemic, climate, population, terrorism, wars, etc.), and

* international education on problems and possible strategies to achieve a better world, especially through planetary broadcasting of alternative world futures.

Research in pure mathematics or social theory would be accomodated only to create new models.

2. Structure.

The structure of the research activities would be based on partnerships between mathematicians and social scientists. One mathematician might work with three scientists separately, or in joint projects. A working group (or *unit*) in the institute might be comprised of four permanent members: one mathematician and three scientists, and a computing facility. There may also be some number of temporary members, depending upon outside grant support. Permanent members would have endowed chairs, as at the Institute for Advanced Studies (Princeton) or at a European university. Two or more such units would comprise a medium-sized version of the proposed institute.

3. Scope.

The areas of research would be selected from the social sciences, from planetary ecology, and from general evolution theory:

* psychology, psychiatry
* sociology, anthropology, mythology
* economics, politics, history
* biology, geography, biospherics, ecology
* evolution, morphogenesis, systems theory

and so on. The emphasis would be upon models of immediate relevance to world problems.

4. Communication.

In addition to research aimed at the creation and study of dynamic models for social systems, there would be a strong emphasis upon rapid presentation of working models to the public at large, through:

* publications
* films, video programs, news releases
* displays at theme parks and science museums

and so on.

Another means of communication would be through the sponsorship of conferences for the exchange of ideas, models, theories, and strategies for their application to global problems.

5. Exploratorium.

Another mechanism for the essential communication between the institute and the outside world would be a *social exploratorium* attached to the institute. Here the latest social models would be available to the public, members of the press and broadcasting media, and visiting scholars, political dignitaries, and the like. These models would be animated computer graphic color displays with interactive voice and sound.

Further, efforts would be made to record feedback from visitors, for consideration by the resarch teams in revising their models. The institute members would make regular appearances at the exploratorium to facilitate this interaction. Lectures, film shows, and live teleconferencing events would also be offered.

6. Proliferation.

The institute could expand unit by unit, but beyond three units it might be preferable to divert support to the creation of similar institutes in different locations. The seed function of the first institute, in spawning nucleation centers for the paradigm shift to a systems/cybernetic/evolution consciousness needed for the creation of an intentional stable future for planetary society, might be its most important function. As similar institutes appear in different locations throughout the world, they may be connected by a satellite based computer network, so that massive cooperative simulations with composite models may be accomplished.

7. Funding.

A first guess at the institute endowment would be eight million dollars *per unit*. This represents an endowment of 12 times the annual budget, plus capital (primarily computing) equipment.

The exploratorium would require its own endowment of at least the same amount, and may be considered as a separate unit.

A complete institution, comprising four research units and an exploratorium, would thus need an endowment of about $40M.

As a first step, a small grant (*ca* $150,000) will be sought for a model project within the university environment. With it, we will try to produce some exemplary models, and to locate further support.

The next step would be the creation of a single research unit. This might be associated with a university, or independent but near a university. Later, funds would be sought for the exploratorium. This could be located adjacent to the research institute, or in a nearby metropolitan area.