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## New Consciousness, New Thinking, and the New Physics

by Arthur Zajonc

Quantum physics is often called the harbinger of a new science and so of a new consciousness. Most such claims are little more than journalistic bravado. Still, one can see quantum physics, along with many other developments in contemporary science, as symptomatic of important changes in the intellectual foundations of modern life. From this vantage point quantum physics is not **causing** a transformation in consciousness, rather its own development reflects the more original changes now underway in thinking generally. Read, therefore, as a symptom, quantum mechanics reveals to us certain important features of a dawning consciousness. In a similar way, the burgeoning area of nonlinear dynamics shows us other significant aspects of the way we will gradually come to see the world.

In the closing chapter of his classic study, **The Metaphysical Foundations of Modern Science**, E. A. Burtt concluded with the observation that "the heart of the new [i.e., post-Newtonian] scientific metaphysics is to be found in the ascription of ultimate reality and causal efficacy to the world of mathematics, which world is identified with the realm of material bodies moving in space and time. (1) Burtt traced the impact of this metaphysics on the prevailing conceptions: 1) of reality, 2) of causality and 3) of the human mind. We may now inquire, How has the "ultimate reality" of material objects in space and time changed over the last one hundred years, and especially in the last two decades? What of causality and the human mind? By focusing on the specific examples of quantum physics and, to a lesser extent, on chaos dynamics, the significant metaphysical changes now taking place become explicitly evident. Many, however, will still deny them.

We should remain modest in our declarations, as only the outline of tomorrow's metaphysics is clear today; much still remains to be filled in. Yet, for all our care and caution, we can fruitfully ask modern physics about the metaphysical foundations of the 21st century. What will be the figure and form of future "reality," the shape of its space and time?

## From Atomism to Entanglement

There is a limit to what a person can handle. A bricklayer lays one brick at a time, its size fitted nicely to the human hand. Even a crane operator places one girder at a time into the structure that will one day be a skyscraper. Things of this world seem to be built up piece by piece. Under such impressions atomism arises.

If the world is constructed brick by brick, understanding it would seem to require a congruent conceptual framework, one that predicates isolated units whose identity is never lost by juxtaposition. From bricks a house may arise, from hydrogen and oxygen may come water, but in both cases we still "see" bricks in the facade and atoms in the molecule. The mortar that binds does not dissolve.

Nevertheless, for all its usefulness and power, unrelenting atomism of the classical vintage is not only **passé,** but simply false. In the embryo it seems that one cell is added to another until a fetus is formed. But isn't it cell division, not addition, that reigns here? First there is the whole, whose intelligent, living lawfulness is sufficient to the unfolding of an infant child. The living world seems to seethe with wholeness, but it is a "soft" kind of wholeness, one whose specific contours are elusive and therefore easy prey to the thrusts of "hard" science critics. Now, however, the hardest evidence against simplistic atomism is found within physics itself in the form of what are broadly called **non-locality** and **entanglement**.

At the turn of the century the brilliant successes of atomic physics seemed to affirm atomism, carrying it even into the atom itself so that today the world is built up from quarks, gluons, and leptons. Light too became atomic, at the hands of Planck and Einstein (1900-1905) with the concept of the photon. Ever smaller and more elementary particles or "quanta" were being discovered. These were the building blocks of nature.

Yet since their inception, one by one, every elementary particle large or small, massive or massless, has shown effects that defy our naive notion of the atom. The Greek root of the word **atom** means "indivisible." With these indivisible, elementary objects we have, since Aristotle, always associated a **place**. One would naturally expect the simplest object to have the simplest



place--a point location. Point by point, atom by atom, a world might then be constructed. The wonderful irony has been that in the struggle for absolute simplicity, physics has had to overturn the classical concept of location, and replace it with "**non-locality.**" (In addition to the loss of simple location, insular atomism has been subtilized to include the concept of quantum "**entanglement**," a term first used by Erwin Schrödinger, and which will be the focus of discussion later in the paper.)

The intellectual current of atomic thinking, of analysis, still runs fast and deep in our time. Contrary notions appear vague and muddled. Yet if quantum theory is any guide, it is only our imagination that is limited. Nature, and even our mathematical descriptions of her, are unambiguous in their indications. Atomism and localism are only impoverished, limiting cases of a far richer and more subtle order to the universe. I would like to describe that order as exactly as possible based on the "simple" facts of quantum phenomena. Behind each statement is an experiment, some of which I will describe. I have done these experiments, as have hundreds of other physicists in laboratories around the globe. To these investigators the experimental results are routine and yield no surprises; but the demands they place on our imaginations are enormous. It is to this aspect that I appeal to the need for a renewal of thinking, the birth of a richer imagination. Like demands are being made on us by developmental biology, ecology, cognitive science, medicine, and myriad other fields. We are at a threshold. In what follows I would like to sketch the precise outline of the new imagination, its logical features, and their wider implications on the evidence of quantum physics.

## Non-locality

As stated above, in classical physics every object has a unique place. In order to connect one such object with another, something must travel from the first object to the second, from one location to the other. If I am here and you are there, it may be the sound of my voice (a wave-form impressed on air that travels at about 700 mph), or light reflected from my face to your eyes (another "form" traveling at 186,000 miles per second). If we sever the links provided by sound, light, etc., then our world would be utterly soundless, black and without the slightest externally induced

sensations. A state of deep sensory deprivation would result. Thus all objects communicate or relate to one another through the passage of signals, be they sound, warmth, light or whatever. Moreover, transmission takes time, and the limiting velocity, from relativity theory, is the speed of light. No communication can travel faster. Everyday experience as well as the phenomena of classical physics support these considerations, but the subtle phenomena of quantum physics do not.

At the quantum level (and this need not be identified only with the microscopic world of atoms and electrons) spatial relationships change fundamentally. A single, "indivisible" quantum such as an electron, neutron, or photon (or even a compound object such as a sodium atom) can be put into a non- classical quantum state, which is "non-local." Let me explain the concept of non-locality by means of a specific example, by reference to a recently performed experiment.

Neutrons are one of the elementary constituents of atoms; they are uncharged and have a mass about 1800 times greater than that of the negatively charged electron. They are produced in large numbers in nuclear reactors, and from there can be directed to experimental areas adjacent to the reactor. Neutrons certainly seem to be substantial objects, particles in the traditional sense. If one directs neutrons onto a thin sheet of crystal silicon, a fraction of them are reflected (by Bragg scattering) and the remainder are transmitted. The silicon sheet acts as a beamsplitter (Fig. 1).

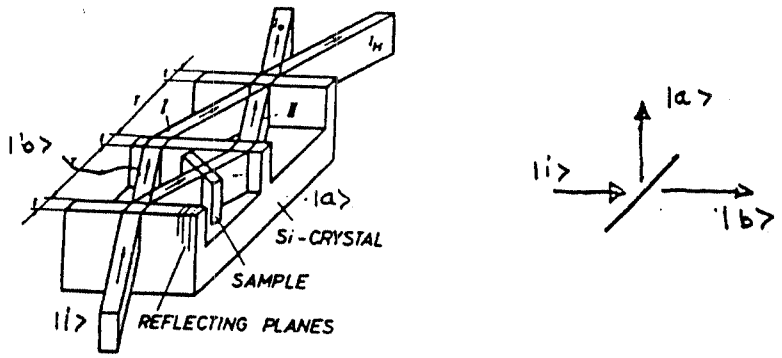


Figure 1 -- Neutron Interferometer and beamsplitter.



One can attempt to follow the trajectory of an individual neutron, at least in thought. Imagine an incoming neutron initially in state | i >. Upon reaching the beamsplitter it can be reflected up (trajectory | a >), or be transmitted (trajectory | b >). In quantum theory these two "modes" (i.e., trajectories) are both possible for each individual neutron, and there is, therefore, a quantum mechanical probability amplitude for each mode. One must be clear at this point. It is not the case that the single neutron somehow splits into "sub-neutrons" with half going one way and half the other. Rather, we should attempt to think of a unitary quantum state where the two modes a and b are both simultaneously occupied. This is a new kind of concept, corresponding to a non-classical situation. The single neutron is in what physicists call a "superposition state." It is still a single neutron, but that single state can only be described as the sum of two quantum mechanical amplitudes, namely the amplitudes for modes a and b. Having encountered the beamsplitter, the neutron is put into a superposition state, which is inherently "non-local."

The non-local nature of the neutron state after the beamsplitter can easily be made apparent in a number of ways. The simplest is to recombine the modes, thereby causing an interference pattern. The mere presence of interference already demonstrates that, in some sense, the neutron "traveled by both paths." We can make this much more dramatic by putting a piece of aluminum foil in one path, say mode a. This slightly delays the neutron in mode a, or equivalently affects the phase of the quantum amplitude for that neutron path and so changes the interference pattern. In other words, doing something in either path (and these can be separated by large distances) affects the single neutron interference pattern. **One neutron interferes with itself in a spatially non-local way.**

Another important feature of such single-quantum interference experiments is that the two quantum amplitudes for modes a and b add "coherently." Usually when ones adds things together they are simply "mixed." Cement, water, and sand make concrete. In the above situation, modes a and b are not added to become a mixture (a so-called "mixed state" in quantum mechanics), but they are added "coherently" and form what is called a "pure state." The ontological status of a single- neutron, coherent superposition state (that is, a pure state) is every bit as solid as the

state of the neutron before encountering the beamsplitter. Although spatially extended, it is one thing.

Therefore, the neutron state after the beamsplitter is consummately strange when viewed from the standpoint of classical physics, but is a perfectly acceptable state in quantum theory, no less (or more) real than the initial neutron state i. Yes, it is non-local in the sense described above, and yes, we are unsure how to picture such a state; but is that anything more than a reflection of the limitations of our thinking, of our powers of imagination?

I have used only two modes in the above discussion in order to keep matters simple, but obviously there could be many more modes involved. A pure state of the neutron would then be a superposition of all these potentially very distant and differently directed modes. Also, experiments exactly analogous to the neutron experiments have been performed using photons, electrons, and most recently, atoms.

One final disconcerting matter. Quantum superposition states of the kind I have been describing can only exist in the absence of measurements. If we were to put detectors in paths a and b, we would always find the neutron either in path a or b, but never in both simultaneously. One only detects whole neutrons, and detects them locally. Here we see the illusive nature of non-locality. When, using physical detectors, one asks directly, "Where is the neutron?" one receives a specific reply. If, however, one probes only by indirection, through interference, then the evidence is compelling for non-locality.

The challenge, therefore, is to conceive of an indivisible object that can show a highly structured and sensitive non-local nature over all conceivable distances. Yet when detected, it always shows its entire self locally, as if instantly collapsing at detection.

## Entanglement

In addition to non-locality, and intimately related to it, is the quantum concept of **"entanglement."** The idea of entanglement was first introduced by Erwin Schrödinger in 1935 as part of his formal discussion of the seminal "EPR" paper by Einstein, Podolsky, and Rosen, which appeared just months before. The concept of entanglement was, for Schrödinger, **the** characteristic



trait of quantum mechanics--"the one that enforces its [quantum mechanics'] entire departure from classical lines of thought." While the single-quantum interferometer discussed above is also formally an instance of entanglement (in that case with the vacuum!), the canonical example of entanglement (and also non-locality) refers to two-particle systems of the type treated in the EPR and Schrödinger papers. We turn, therefore, to them.

Allow two quanta, be they neutrons, electrons or photons, to be produced at distant and unrelated sources ( Fig. 2).

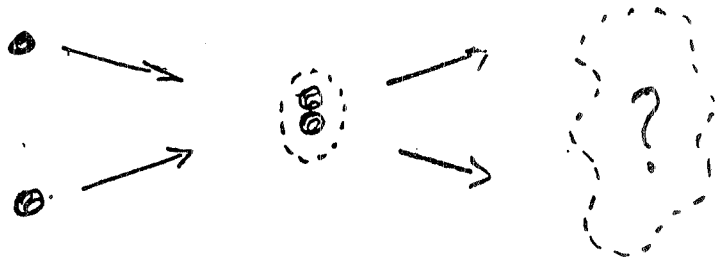


Figure 2 -- EPR entanglement.

Imagine the two quanta as coming together until they interact with each other by some means. After the interaction the two separate, again to large distances from each other. How are we to think of this collision/interaction in quantum mechanical terms? According to classical physics, one would treat the interaction as a microscopic game of billiards. One particle collides with another, the two separate, each going its own way. Following the analysis of Einstein, Podolsky, and Rosen, recent experiments have convincingly shown the billiard-ball model of the collision is completely untenable. In fact, once the two particles interact, they form, according to Schrödinger, an "entangled state," very much like the superposition state of the neutron interferometer. In the entangled state there is no meaning (prior to measurement) to the notion of separate, autonomously moving objects, even long after the collision! The two have become one.

If a third quantum object were to interact with the already entangled two-quantum system, then a more complex entanglement would occur. Once again the individual identity of the

quanta disappears and the three are now one. Clearly this process can continue indefinitely. Unlike the bricks that make up a building, Schrödinger's entanglement asks us to dissolve the concept "brick" as soon as the two are brought together. The entangled system is an **emergent** reality. Through the interaction, a novel ontic entity or relationship arises, one whose entire meaning is dependent on a loss of reality of the original quanta. Yet what has been entangled can be disentangled. Quanta are entangled by interactions; they are disentangled by measurement. With our normal sense apparatus, or with the physical instruments of the laboratory, we detect only classical disentangled objects. Neils Bohr made much of this fact, burying entangled states under epistemological considerations. Others have attended more closely to the implications of entanglement. The puzzle of how entangled states become disentangled has been with quantum theory from the beginning, and is known as the "measurement problem." No acceptable solution has been found, although David Bohm's "quantum potential" theory goes some distance toward an answer.(2)

We can return briefly to the first example of a non-local, single particle state and ask in what way is it related to entanglement. Several recent experiments have emphasized the importance of considering even the single-particle superposition state as entangled. But with what is it entangled? The surprising answer is the vacuum. The beamsplitter used to create the state actually has not one but two inputs ( Fig. 3).The beamsplitter not

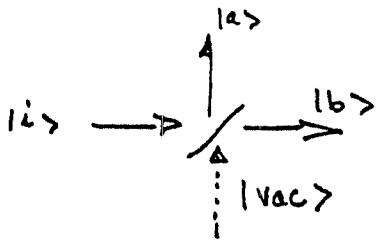


Figure 3



only superposes states a and b but adds a coherent vacuum contribution to both. In certain experiments this vacuum contribution is critical to our theoretical understanding. Thus, one now speaks of single-quantum states that are entangled with the vacuum. The idea is intriguing. Objects can become entangled with emptiness (which is a very rich object in quantum theory), as well as with other objects.

One's immediate reaction might be, Is all this **really** true? Or is this just another story told by academics (a la Thomas Kuhn, and the sociology of knowledge)? First, one can say that quantum theory, together with its features of non-locality and entanglement, really does work where all classical theories fail. The powerful theorem of John Bell(3), and the recent experiments that use it, have shown that no "local, realistic" theory of physics can account for the experimental facts. However, at another level, I think the interesting question is not whether the new physics is **more** true than the old physics, but rather to first acknowledge that it is radically different, and second, to see the new physics as indicative of a new consciousness, one that will gain dominance over the next two hundred years in much the same way that the Copernican and atomic views did. From this vantage point, the absolute truth of these views is not the essential aspect. Rather, **the move from old physics to new physics is indicative of a shift in Western consciousness toward a non-local and entangled imagination of our world.**

Nor is the shift only taking place in physics. Within the life sciences, molecular biology and neo-Darwinian evolutionary theory are repeating the grand accomplishments of classical physics now in their own domains. But a few individuals such as biologist Brian Goodwin are able to argue with conviction that while these are powerful paradigms, they omit much that is essential to the understanding of developing organisms. The mechanical imagination of molecular biology must reside within the more capacious imagination schooled on morphogenesis. Likewise, I see the work of John Todd on "living machines," of Francisco Varela and Evan Thompson in cognitive science, of Wes Jackson concerning perennial polycultures, of Will Brinton on the soil, and many others, as the vanguard of a new imagination or paradigm constructed on "post-modern" metaphysical foundations. Nor by any means is the new imagination ineffectual. It has already given rise to technologies

in waste treatment, agriculture, and medicine. In the face of ecological and social disasters, this burgeoning imagination will be critical to our well-being and the well-being of the planet.

## Toward a Modern Conception of Time

The reconfiguration discussed above treats only spatial order. In most presentations of the new physics, the impact of recent developments on our conception of time is treated little or not at all. Yet here too, profound structural changes have occurred. Relativity deals with time in a way perfectly analogous to space; in fact the three dimensions of space and time form an inextricable foursome. The ideas of relativity, therefore, affect time and space in equal measure. Moreover, recent explorations in quantum theory have upset the usual, well-ordered time sequence associated with causality, profoundly complicating our sense of temporal relationships. Still, as Roger Penrose has recently written: "Our present picture of physical reality, particularly in relation to the nature of time, is due for a grand shake-up, even greater, perhaps, than that which has already been provided by present-day relativity and quantum mechanics."(4) One force in the shake-up is likely to be chaos dynamics.

In his **Timaeus**, Plato put forward a geometrical atomism in which all five elements were conceived in terms of primordial triangles. In the hands of physically-minded atomists, Plato's abstract geometrical atomism of pure forms became the substantial material atomism with which we are all familiar. In a less obvious but equally influential way, Plato can be seen as the father of modern temporal atomism. The relevant discussion is treated by Simplicius in his **Commentary** concerning Plato's dictum to astronomers. Simplicius writes:

**Plato lays down the principle that the heavenly bodies' motion is circular, uniform, and constantly regular [i.e., always in the same direction]. Thereupon he sets the mathematicians the following problem: What circular motions, uniform and perfectly regular, are to be admitted as hypotheses so that it might be possible to save the appearances presented by the planets?**(5)



The complex observed motions of the planets were to be reduced to a set of uniform, circular motions, a task brilliantly performed by Ptolemy and generations of ancient astronomers.

Spatial atomism decomposes static objects into elementary particles. Astronomers, by contrast, treat objects in **motion**. Following Plato's demand, these motions were also decomposed. What we see as the irregular motion of planets is thought of as the sum of many different, but perfectly periodic, motions. The description of motion thus entails time as well as space, and the cycles demanded by Plato provided the absolutely regular basis for the mathematization of that temporal dimension. Planetary cycles are but the ticking of an astronomical clock.

In his analysis of this development, Pierre Duhem made clear that the reasons for choosing this particular solution were explicitly metaphysical.(6) That is to say, Plato's charge to astronomers was derived from considerations that were outside physics or astronomy (i.e., "meta"-physical). Planetary motion should be thought of as fundamentally circular because, on theological grounds, planetary substance was known to be perfect (of the "quintessence"), and so planets must display the most perfect of all motions, namely circular motion. Implicit in this reasoning is a metaphysical basis for time.

The roots of time invariably lead one to the rhythms of sun moon, planets, and stars. In the ancient world, time was given primarily through them, whether the division be into years, seasons, months, days, or parts of days. Yet the observed motions of the heavens are complex. Plato, and astronomers after him, regularized that motion according to the dictates of circular motion. What atomism has been to space, the relentless cycles of the heavens, and later the mechanical ticking of the clock, have been to time. Over the centuries we have divided and sub-divided time into smaller and smaller bits, ever more accurately regulated. We organize our lives according to this fragmented image of time.

Are there any indications that Penrose is right, that physics may provide for as great a shake-up in time as with space? One youthful area of research that seems to point in that direction is chaos dynamics. By far the greater part of nature, in fact one could argue all nature, shows rhythms that are not reducible to the periodicity of the clock (at least in anything more than a formal way.) (7) They show their own peculiar kinds of "chaotic" rhythms. When

seen from the standpoint of classical regularity, such motions appear chaotic and have been rejected by scientists for centuries. Yet once one enters into the mindset appropriate to such phenomena, a rich, patterned world opens up, one whose time-order is not constrained to the relentless regularity of the mechanical timepiece. One can illustrate this with a simple example.

Consider a driven mechanical pendulum of the kind seen in a grandfather clock. The equation describing its periodic motion can be given as:

$$x'' + 0.05x' + \sin(x) = A \sin(w\,t).$$

The primes indicate time derivatives, the second term on the left is a damping term, and the sin(x) term gives the restoring force due to gravity. The term on the right-hand-side of the equation is the sinusoidal driving term whose amplitude A, and frequency w, can be adjusted. For small amplitudes and certain values of the drive frequency, the pendulum motion is perfectly periodic. This can be seen in the graph of sin(x) vs time (Fig. 4), and the "phase space" representation of the system's evolution (a plot of angular velocity vs angle x), which is an ellipse. As the pendulum swings back and forth, it traces out and retraces the orbit shown in Fig. 5. Slightly increasing the amplitude of the driving force causes a distortion of the periodic motion. When plotted as before, these changes show up clearly, especially in the phase space representation (Figs. 6 & 7). The path traced out is no longer a simple ellipse. The phase point (v,x) still repetitively traces out a figure, but it is now considerably more complex.(8) Increasing the drive amplitude further leads to chaotic motion, whose phase space portrait is shown in Fig. 8. The test for true chaos in the technical sense is to begin the pendulum at two neighboring points in phase space (i.e., two slightly different values of velocity and position) and watch them evolve. If the phase-space trajectories parallel each other, then the transition to chaos has not been reached; but if their trajectories in phase space diverge exponentially, then the motion is truly chaotic. The phase-space plot of Fig. 8 is that associated with chaotic motion; however, notice that not all parts of phase space are filled in. If the initial conditions of the pendulum had been such that the trajectory started in the upper right-hand corner of the phase-space plot, before long the trajectory would have moved into the shaded



region. Such behavior is characteristic of a "chaotic attractor."

With each increase in drive amplitude we have left the perfection of Platonic epicycles further and further behind. Cosmos (which means "order") has been replaced by chaos. Yet within the chaos we have detected subtle forms of order. The chaotic attractor is one hint, but I would like to mention a very recent set of investigations that point to beautiful connections between chaos and Plato's periodic motions; it is the area of "controlled chaos."

If one adjusts the parameters of the driven pendulum such that its behavior is chaotic, that chaotic motion can be "controlled" by very small periodic perturbations to the pendulum. In a recent series of research papers, physicists have reported on their investigations of the control of chaos from both a theoretical and experimental perspective.(9) The significance of this research is likely to be very great. In traditional physics it has always been thought that the strength of an effect is in direct proportion to the size of the driving force. The harder you push, the faster you go. The so-called "butterfly effect" from chaos dynamics has undermined that idea, but in these papers the specific means for controlling chaos by very subtle forces, periodically applied, are investigated.

This research suggests ways in which subtle periodic influences can cause dramatic changes in the large-scale behavior of systems. Possible applications to biological systems are obvious. Medicine has been dominated by the ideas of traditional mechanics. According to this way of thinking, the effects of long-term exposure to toxins, electromagnetic fields, etc. should scale linearly, and thus if short-term studies find no effect then, by extrapolation, there should be no long-term effects. In non-linear regimes, which are the regimes in which we live, one cannot extrapolate. Very small perturbations can cause huge effects, under certain circumstances. Likewise, the approach to therapies has been one of frontal assault. Gentle therapies that work with microdoses of remedies or rhythms have had no theoretical basis on which to stand. The metaphysics of science constrained the accepted range of thought not only within physics, but also in medicine, agriculture, developmental biology, ecology, indeed in every technical field (and often invaded non-technical thinking as well). Linear dynamics and an atomism of space and time have dominated the imagination of science and society. Within physics itself, this is slowly changing, and a new

thinking needs to develop along with it.

The novelty of the new imagination is no guarantee of positive change. The fall of classical mechanics at the turn of the century, the rise of modern art and **Lebensphilosophie** did not usher in an age of enlightenment. The tragedy of two world wars is ample testimony to that. Too often, the ideologues of the new living philosophy fell prey to the corruption of power under Hitler. Revolutions provide an environment of anarchy into which the darkest sides of human nature may insert themselves.

## Vertical Entanglement

The new imagination of which I have been writing is not immune to corruption. It too can be co-opted by the old motives of greed and the lust for power. It will be no less vulnerable to human failings than the discoveries of Galileo or Cortez. If the new imagination is separated from the ethical and spiritual dimensions of our world, then we have reduced the most profound entanglement of all.

Entanglement should be thought of as vertical as well as horizontal. Technical problems are also moral and spiritual problems. They are wedded like two interacting quanta into a coherent state. Science has sought for centuries to disentangle body from soul, subject from object, scientific knowledge from spiritual values. From the 12th to the 18th centuries, science struggled for its intellectual freedom, to be unfettered by the shackles of religious ideology. Now that we are by and large free of them, we are also free to recognize the entwined nature of our world--body and spirit.

The logic of non-locality and entanglement as evidenced in quantum physics has the strength of hard experimental facts and mathematical clarity. However, it lacks other equally essential, if softer, aspects. Goethe knew this danger well, and so refused to leave the phenomenal for the abstract. Even his scientific writings are more a poetic re-enactment of the phenomenal than an abstraction of them. His reluctance was well grounded in that he rightly saw the sensory as inseparable from the "moral" or spiritual. As long as the sunset itself was in view, as long as the rainbow arched majestically overhead, the dangers of abstraction were mitigated, and the voice of the qualitative could be readily



heard. When such phenomena, however, are reduced to schema or the equations of optics, (even if quantum mechanical or non-linear) then quantitative reasoning dominates, and a gulf widens between the objective and subjective, between quantity and quality.

Research in quantum physics rests firmly in the quantitative, a strength when speaking with those who will listen to nothing else, but it has no phenomenal or qualitative component. One cannot "see" the entanglement of neutrons, one can only deduce it from the response of detection electronics. Chaos dynamics is, by and large, a phenomenon of high-speed computing. It shows itself best in the lovely fractal geometries of Mandelbrot sets. One stands, therefore, as the contemporary physicist always has, apart from nature, an onlooker.

Yet the dawning consciousness is urging something else, a closer relationship, a fuller participation in the phenomenal, which is very difficult in quantum physics, but less difficult in chaos research. One can ask, How can one participate? Where does one see entanglement and the subtle new orders of chaos dynamics in nature? Goethe looked to the plant, animal, and human kingdoms. Here the non-mechanical acts in potent and often miraculous ways both in space and in time. But every phenomenon is an opportunity for a fuller engagement, qualitative as well as quantitative, whole as well as parts, chaos as well as order. These are but different aspects of the same unitary reality, one we should be careful to cultivate as well as investigate.

The metaphysical foundations of science for the next millennium should be broad and deep enough to see science as a spiritual endeavor, as an aspiration of the human soul and an inseparable companion to art and religion. If we succeed in this, even if only modestly, then the transformations of culture and society will reach far beyond the provinces of academic science. Technology itself will change, becoming the hopeful basis for a sustainable future.

## Technological Implications

Both Alfred North Whitehead and Martin Heidegger understood modern technology to be the touchstone or insignia of our contemporary world. Its particular features, which differ from those of antiquity, both represent our culture and continue to define

it. The transformations wrought by science and technology have brought unparalleled mastery of physical forces and substances, and inseparable from that mastery, the potential for hitherto inconceivable destruction. What deep and essential changes within the practice of technology and science might lead us through this dangerous time of passage?

Rejection of technology and science is not only infeasible, but an illusion. As Heidegger writes, those who reject modern science and technology are no less chained to it, even intellectually, than those who enthusiastically embrace it.(10) Aversion is as compelling as lust. To establish a **free** relationship to science and technology is of utmost importance. Otherwise we are held hostage by them, whether as enthusiasts or neo-Luddites. How does one establish a free relationship to science and technology? Bluntly put, only by standing fully within the field of danger, and finding a way to the essence of each. In his seminal essay, "The Question Concerning Technology," Martin Heidegger quotes the German poet Hölderlin:

**But where danger is, grows**
**The saving power also.**

Heidegger writes that "precisely the essence of technology must harbor in itself the growth of the saving power." Thus, knowledge of the essence carries with it the possibility of establishing a truly free relationship to science and technology. But one needs to go on, freely developing the saving power from out of the essential itself, surrounded by danger.

The danger now is great. Sensing that danger, some will turn away from their routine lives in science and engineering in search of a genuinely free relationship to their craft, seeking for that saving power they feel must lie at its heart. The old Masonic legend of Hiram, who was master builder to King Solomon, contains a powerful image of the saving power within the danger. As the crowning ornament to the Temple, Hiram undertook to forge a huge brazen sea. As the molten bronze was poured, the mold failed because of sabotage by four jealous apprentices. In the moment of disaster, Hiram called out to his long line of spiritual ancestors for guidance; the voice of Tubal-Cain (the first artificer of bronze) arose, urging him into the fiery molten sea itself. In response, Hiram threw



himself directly into the flaming metal. By doing so he was granted the magical means (by his ancestor Tubal-Cain) to save the casting. By dying into one's craft, one can bring it new life.

Is it possible to transfigure the crafts, be they physics, cognitive science, computer technologies, biology, agriculture or waste treatment, by staying with them, or to put it figuratively, by dying within them? In my view, yes. And what is the shape of the thinking these new technologies will require? They will have the figure and form of entanglement and new rhythms. We can find instances of them already about us in new forms of agriculture (e.g., biodynamics), medicine, and waste treatment (e.g., Brinton or Todd).

In his book **The Technological Society**, Jaques Ellul argues that every aspect of our life has been recreated in the image of the machine by what he terms "technique." Technique is the "totality of methods rationally arrived at and having absolute efficiency" as their goal.(11) Following Lewis Mumford, we can take the mechanical clock as the paradigmatic machine. Its invention in the 14th century marks the dawn of a new way of seeing, as well as ordering our individual and collective lives. The clarity of the clockwork, its transparent logic, was to the concrete imagination of craftsman what the pristine logic of scholastic philosophy was for the cleric. It took two centuries for the technique embodied by the mechanical clock to become part of the intellectual life of Europe, but by the 17th century, it was firmly ensconced.

Never before had such values dominated thinking. Time had always been connected to the planets and stars. Why are there twelve hours, an hour hand, and minute hand? These are remnants of the starry constellations, sun, and moon. The sun (as hour hand) moves against the background or the zodiac (the twelve hours), while the moon (as minute hand) makes its rounds twelve times faster. One need only recall the imaginal universe inhabited by the early metallurgist with his alchemical conceptions of the embryology of metals. The metallurgist was fully participant in a sacred world order where his actions were spiritually as well as physically significant. In fact, the two were never seen as separate. Physical actions were also moral- spiritual actions, in an eminently practical way. It is perfectly natural, therefore, that the mechanical clock would first be integrated into the moral world of the 14th and 15th centuries. As Lynn White has beautifully documented, the

mechanical clock was taken in the 15th century as the symbol par excellence for the cardinal Virtue of Temperance. Everything worked in the most balanced and rational manner in a clock, and the human soul should aspire to a similar regularity. It was then but a short leap to an image of man and universe as a clock- like machine, body and soul, as was so often repeated during the 18th century by Enlightenment philosophes.

The rise of the clockwork universe paralleled the loss of vital spiritual conceptions of world and person. For the first time in history, technology and science were gradually but steadily separated from matters of spirit. Within their own domain, rationality and efficiency reigned supreme, and were challenged only by Romantics and the various counter-cultural stirrings of the last two hundred years. As the scientific and technical paradigm became more and more powerful, it is not surprising that its "technique" came to invade the provinces once set aside for humane or spiritual treatment: the organization of society and the economy. Taylor's "scientific management" and the rationalization of social structures (e.g., institutions for the ill, the dying, death itself, the rise of the city, and suburbs...) come to mind. The extraordinary bounty these developments brought made them invincible. This was Progress.

Today, spiritual values are increasingly in the foreground, and they are **not** experienced as disjunct from science and technology. Occasionally one hears strains of neo-Romantic longing for a pre-Industrial society, but far more often one senses a yearning for noble values and actions that move forward, reaping the best fruits of traditional science and technology, but recognizing the need for change, absolutely fundamental change in the imagination and metaphysics of future science. Many ask, Is it not possible to enact a complete penetration and transformation of the "technique" of modern culture such that spiritual values and insights will join the physical mastery of nature? Might there not be one integrated realm in which to live instead of two warring ones? The answer is surely, yes. And we have already begun, if we would but look around us.

## An Evolutionary Perspective

Usually the revolutions of science, the rise of novel artistic achievements or social and economic change are treated exclusively within the framework of external historical realities,



perhaps including a modest psychological dimension. What I would like to suggest, and in this I follow Rudolf Steiner and Owen Barfield, (12) is that such developments are best understood as reflections not of external forces primarily, but of profound, if subtle, shifts in our consciousness, a shift that occurs very widely and so becomes of cultural as well as individual importance. Moreover, Steiner and Barfield suggest the basis for such changes in consciousness is to be found in the changing soul-spiritual configuration of the human being. The driving forces that determine these changes in the human soul are as much inward as outward in nature. Although not a widely held position, I find their view of real value, and would therefore like to apply this understanding to our previous considerations.

One can approach the evolution of consciousness in many ways, and it is a complex subject open to misconceptions and over-simplifications. Specifically I am not speaking about "progress," nor about a linear time-development in which the past is harvested for the future. A linear, mechanical conception of time can all too easily dominate our thinking in treatments of evolution. Perhaps nowhere is an organic or entangled notion of time of greater importance than here. It should be a conception in which the past is resurrected in the present and anticipates the future, where the future, as it were, works back into the present. With these cautions expressed, I would like, nonetheless, to venture an interpretation of the events we see being played out in quantum physics, chaos dynamics, ecology, etc.

If, as I have suggested, we are at the beginning of a form of thinking newly sensitive to non-local and entangled aspects of our world, we may rightly ask, What has changed in us that brings these aspects newly to the fore? Why have we missed these features of our world for so long? How could we have been so blind? Rudolf Steiner maintained that such developments (or the lack thereof) are the reflection of inner, soul-spiritual changes. What are the specifics of such soul-spiritual changes and how do they occur? In order to answer this question, I will need to briefly present Steiner's understanding of the "spiritual anatomy" of the human being. Constraints of length will force me to be schematic.

Based on his supersensible experience, Rudolf Steiner considered the human being to have a four-fold nature.(13) The aspect evident to us all is that which presents itself as the

physical body, which includes that in us which is solid, liquid, aeriform, and warm. The mineral, plant, and animal kingdoms obviously also possess a physical nature. To this Steiner adds, however, three other "bodies" or dimensions to the human being. The one most proximate to the physical he calls "etheric" or life body. It is a body of formative forces, responsible for the form and life of the human being. Plants and animals, but not minerals, also possess such a body. The spatiotemporal order of the etheric is quite different from that of the physical, and will be of particular concern to us in understanding non- locality, entanglement, and the rhythms of a new dynamics. To physical and etheric bodies are added two others, called the "astral" body and the "Ego." With the astral body there arises the inner world of simple, sentient consciousness, which we share with the animal world. Finally, Steiner sees the human being as possessing an Ego responsible for self-consciousness.(14) Details of the four-fold nature of the human being can be found in many of Steiner's books.(15)

Although in a certain sense all four of these aspects to the human being have been present for many thousands of years, their relationship to thinking has changed fundamentally over that time. In order to understand this, one needs to allow the activity of thinking to have a reality that is not brain-bound. That is to say, in its essence, thinking is not a product of physical or biochemical processes of the body. Thinking, rightly understood, is a spiritual activity. However, according to Steiner, that activity can be realized or imaged in one or another of the four bodies. Over the long course of time, thinking has been realized first by the Ego, then by the astral, the etheric and, since the fifteenth century, by the physical body. The kind of thinking an epoch evidences reflects the relationship of thinking to one or another member of the soul-spiritual nature of the human being. For example, Greece at its height lived in a form of consciousness that brought thought to consciousness in the etheric body. The vital, living quality of art and philosophy during that period is a reflection of the etheric basis for thinking in the Greek soul.

In the time between the 9th and 15th centuries, a significant change took place, and thinking "fell," as it were, further down into the physical body. On the one hand, in Steiner's view, this form of consciousness led to the possibility for true freedom (an essential gain), but on the other it led to the modern, materialistic



conception of nature. In a 1924 "Letter to the Members" he described his view as follows:

**The reason materialism arose, is not that only material things and processes are to be seen in the outer world of Nature; it is because human beings, in the course of evolution, had to go through a stage which brought them to a form of consciousness that is at first only capable of seeing material revelations. The one-sided development of this requirement in human evolution has resulted in the modern view of the natural world.**(16)

Materialism climaxed in the mid-19th century. By the turn of the century, many forces--artistic, religious, and political, as well as scientific--were shaking the bastions of complacent materialism and advocating other aspects as both real and significant in life. During the first two decades of the century, Germany was swept by a **Lebensphilosophie**, as it was called. The Blue Rider School, and many prominent literary and scientific figures threw themselves into the movement. After the tragic intervention of two world wars, which capitalized on the neo-Romantic excesses sometime a part of the movement, we find ourselves in a situation once again where a philosophy of life as opposed to matter, of ecology as opposed to atomism, seems in the air. Why? In his letter of 1924, Steiner stated that the present time marked the beginning of another shift, one that would move the basis for thinking back from the physical body to the life body, or etheric body, of the human being. Then the "thought-shadows" of physical thinking would once again acquire life. This would be undertaken freely by aspiring human souls who were deeply discontent with the achievements of modern physical science. They would begin to think new "living" thoughts because they had begun to lift their thinking itself to the level of life within them.

Stated bluntly, I think this is what is occurring in our time. By honest, forthright efforts, and with a heartfelt concern for others and for the planet, our thinking is being lifted into a realm of life. The laws of that realm are inherently non-local and entangled, and its rhythms are those of life. The new ventures in quantum physics, chaos dynamics, agriculture, medicine, cognitive science,

and biology are at root a reflection of a dawning cultural shift toward "living thinking." Much hangs on our self-awareness of this fact and on our efforts to promote it, not only in ourselves, but also in others.

## Notes

1. E. A. Burtt, **The Metaphysical Foundations of Modern Science**, (Garden City, New York: Doubleday Anchor, 1954), p. 302.

2. Bohm's theory is attractive in many respects. Massive particles retain their autonomous atomic character throughout, and the mysteries of non-locality and entanglement are carried by a ghostlike quantum potential unique to his theory.

3. John Bell, **Speakable and Unspeakable in Quantum Mechanics**, (New York: Cambridge University Press, 1987).

4. Roger Penrose, **The Emperor's New Mind.**

5. Simplicius, quoted by Pierre Duhem in **To Save the Phenomena**, (Chicago: University of Chicago Press, 1969), p. 3.

6. ibid.

7. In a sense, Fourier's theorem guarantees that all motion can, in principle, be decomposed into a suitable sum of periodic motions. The utility of that theorem, however, does not force us to make the ontological leap that maintains the existence in fact of those periodic motions. They are there only as an artifact of our method of analysis. Another form of analysis (e.g., another expansion in terms of a different complete set of orthonormal functions) would produce a very different set of artifacts.

8. This is an instance of "subharmonic oscillation." The Poincaré map shows a finite number of points.



9. See for example E. R. Hunt, **Physical Review Letters**, vol 67, pp. 1953-55, October 7, 1991, and references therein.

10. Martin Heidegger, **The Question Concerning Technology**, (included in many collections).

11. Jaques Ellul, **The Technological Society**, translated by John Wilkinson, (New York: Vintage, 1967), p. xxv.

12. Owen Barfield, **History, Guilt, and Habit**, (Middletown, Connecticut: Wesylan University Press) or **Saving the Appearances**, (New York: Harcourt, Brace & World, nd).

13. In other instances, Steiner writes of a three- and nine-fold way of understanding the human being.

14. The exact nature of the Ego as Steiner presents it, and its relationship to the Buddhist understanding of the Ego, or the lack thereof, would take us beyond the scope of this paper. A Buddhist friend has made the following identifications: physical body--**rupa**; etheric body--**prana**; astral body--**citta**; and Ego-- **Buddha-dhatu.**

15. See for example **Theosophy** or **Occult Science--an Outline.**

16. Rudolf Steiner, **The Michael Mystery**, (London: Anthroposophical Publishing Co., 1956), p. 20.

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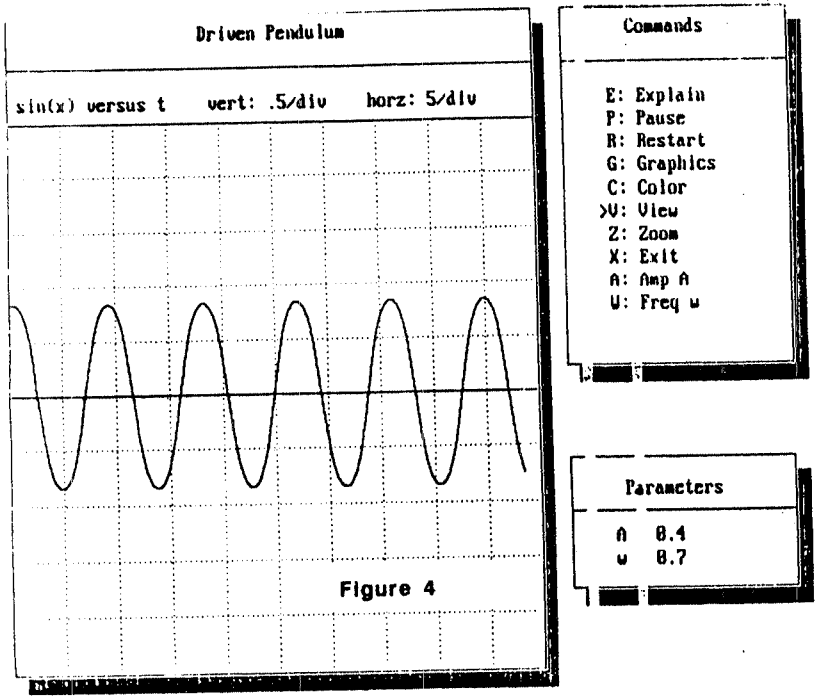
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Figure 4
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P: Pause
R: Restart
G: Graphics
C: Color
>V: View
Z: Zoom
X: Exit
A: Amp A
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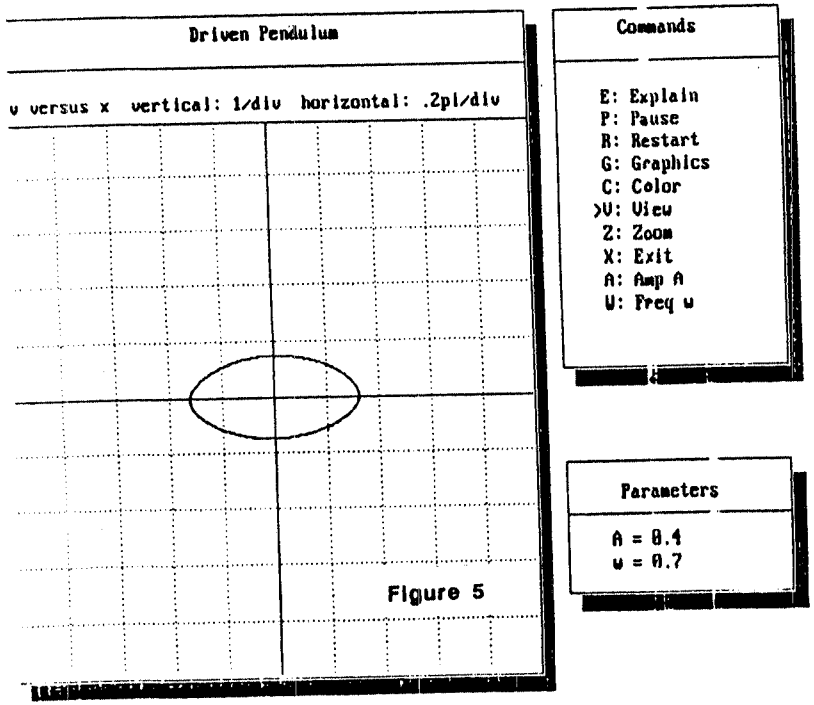
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Figure 5
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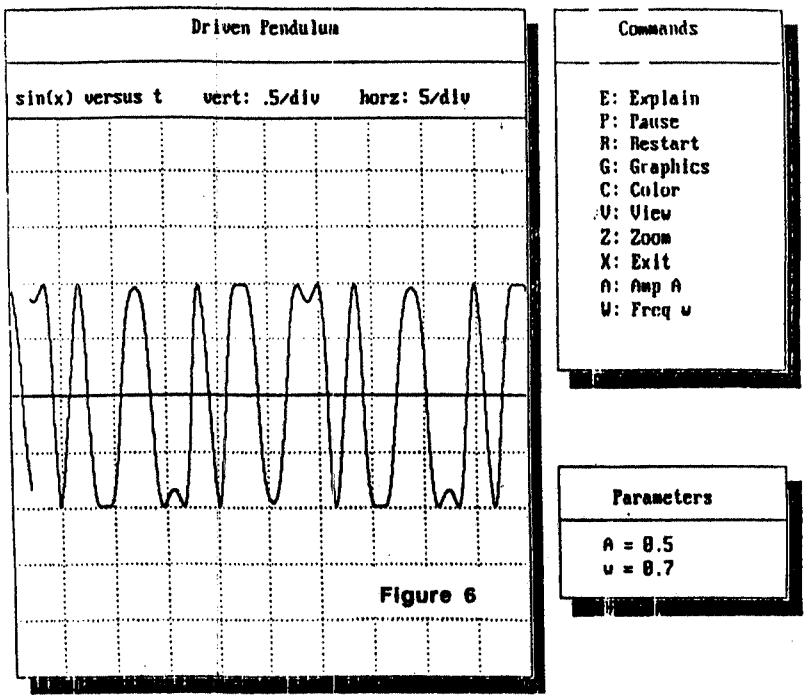
Driven Pendulum
sin(x) versus t vert: .5/div horz: 5/div
Figure 6
Commands
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P: Pause
R: Restart
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C: Color
V: View
Z: Zoom
X: Exit
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W: Freq w
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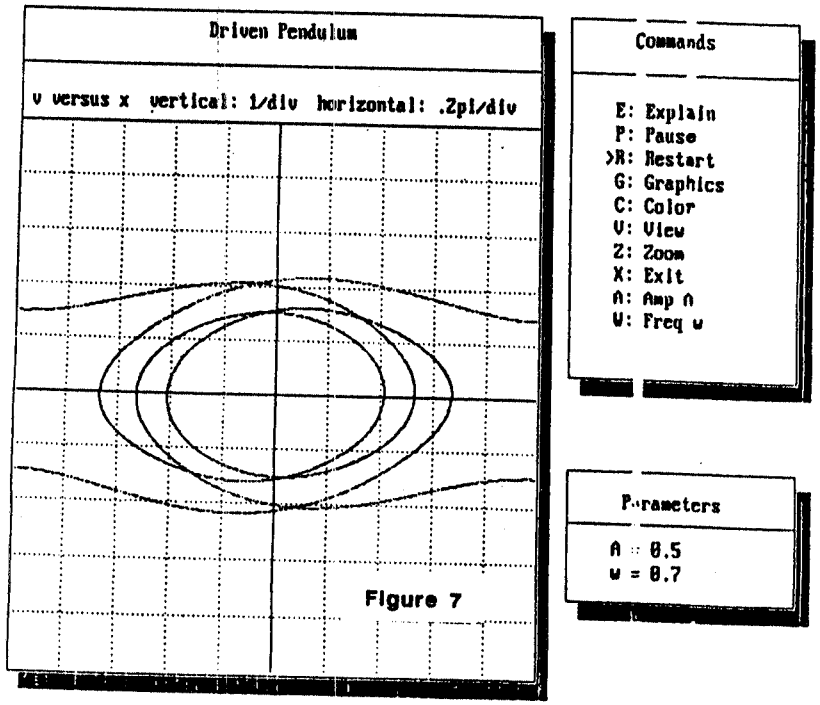
Driven Pendulum
v versus x vertical: 1/div horizontal: .2pi/div
Figure 7
Commands
E: Explain
P: Pause
>R: Restart
G: Graphics
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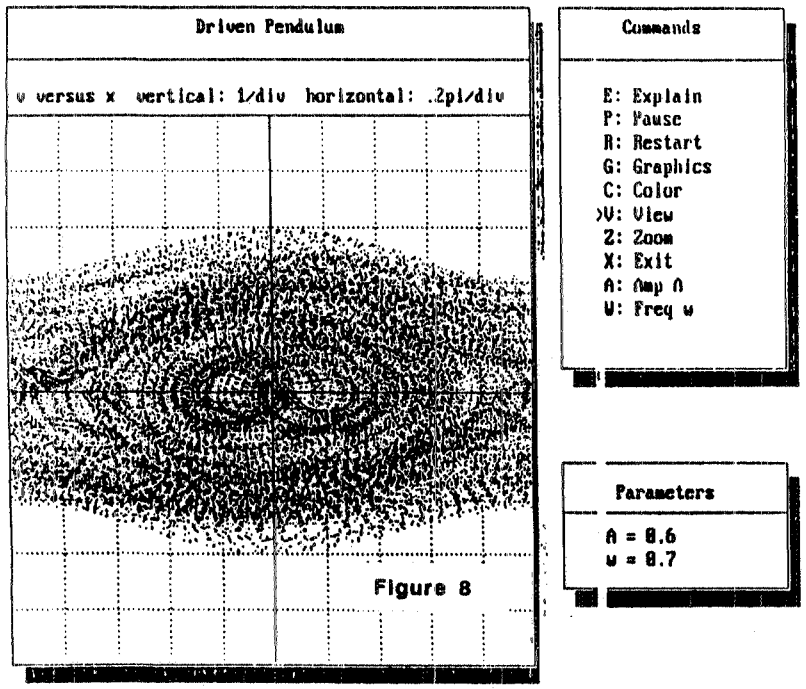


Figure 8



# The Rhythm in the Embryonic Period of Development in Birds

by Friedrich Kipp

(translated by Malcolm Gardner)

**This article first appeared in 1951 in the annual anthroposophical "Star Calendar" (Sternkalendar). Although only a preliminary study, it represents an intriguing attempt to demonstrate the biological reality of the rhythm of the week. Unlike the day, the month, and the year, the week does not correspond to any obvious astronomical rhythm and hence is often regarded as an arbitrary human invention. Yet already the names of the days of the week point to the planets and suggest that the sevenfold week is somehow a synthesis of the individual planetary rhythms. In the postscript following this article, I have extended Dr. Kipp's analysis of his data.--M.G.**

It may already have struck some readers that the duration of the period of embryonic development in our domestic animals corresponds in a remarkable way with the rhythm of the week. Thus, for example, the hen broods for exactly three weeks until the chicks emerge, the goose for four weeks. The gestational periods of horses, cattle, and pigs, etc. can also be expressed rather exactly in terms of weeks.

However, since domestic animals make up only a vanishingly small percentage of the animal world, this relationship between the duration of the embryonic period and the rhythm of the week could be a coincidence. We must test this question in a larger animal group. The birds are especially appropriate here because the incubation time of most bird species is well known today, whereas with the gestational period of wild mammals there are still many unclarities.

The incubation periods of 197 Central European bird