New Wine in What Kind of Wineskins? Metaphysics in the Twenty-First Century

by Arthur Zajonc

Metaphysics is a hazardous business these days. After all, it purports to reach beyond the evident report of the senses to the ultimate nature or meaning of existence. Yet, all attempts to shun metaphysics are undercut by its universal, if unconscious, presence as the basis for meaning in our lives. In the end, we presume the world and ourselves to be something, and that presumption is metaphysical. The presupposition we live by may view the world as interacting mass points, or a fallen angelic creation, but ultimately life rests now, as in the past, on a metaphysical foundation.

In the closing chapter of his classic study *The Metaphysical Foundations of Modern Science*, E. A. Burtt concluded with the observation that post-Newtonian metaphysics, as embraced by science through the nineteenth century, was characterized by

> 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]

Reality, in this view, was comprised of material bodies moving through an absolute space and time according to mathematical laws. Burtt traced the impact of this metaphysics on the prevailing conceptions: a) of reality, b) of causality and c) of the human mind. We may now inquire, how has the "ultimate reality" of post-Newtonian metaphysics fared over the last one hundred years, and especially in the last two decades? What has become of space, time, causality and the human mind?

We can approach the first two of Burtt's three categories by focusing on the specific examples of quantum physics, and, to lesser extent, on chaos

dynamics. They can show us something of the character and significance of the metaphysical changes now taking place. We should remain modest in our early proclamations, 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 twenty-first century. What will be the figure and form of future "reality", the shape of its space and time?

Following a response to this question, we can turn to still larger issues. Will the new conceptions of time, space and matter urged on us by science be integrated into the dominant material imagination of our universe, or will they find a more congenial home in a thoroughly revised metaphysics? In what kind of wineskins will the new wine be held? If metaphysics is recast, what will it look like, and what will be its implications? In addressing these questions, we will be drawn to examine the thought of Goethe and Rudolf Steiner.

I. 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? One cell becomes two, four and so on. Already in the first cell, the whole physical form is, in some sense, enfolded in a way sufficient to develop the physical form 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 quantum mechanics, 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)[2] 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, the 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".

The intellectual current of atomic thinking, of analysis, still runs fast and deep. 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--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 biology, ecology, cognitive science, medicine, and a myriad other fields. We are at a threshold. In what follows I would like to sketch the outline of the new imagination, its logical features and their wider implications on the evidence of quantum physics. This is part of the "new wine". Once we have sampled it, we will pass on to an examination of the metaphysical wineskins that can contain it.

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 miles per hour), 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. That transmission takes time, and the limiting velocity, relativity theory tells us, 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 an experiment that has been recently performed.[3]

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 (see Figure 1-A,B next page).

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" (that is, 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 it has passed through the beamsplitter can be made apparent very easily and 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

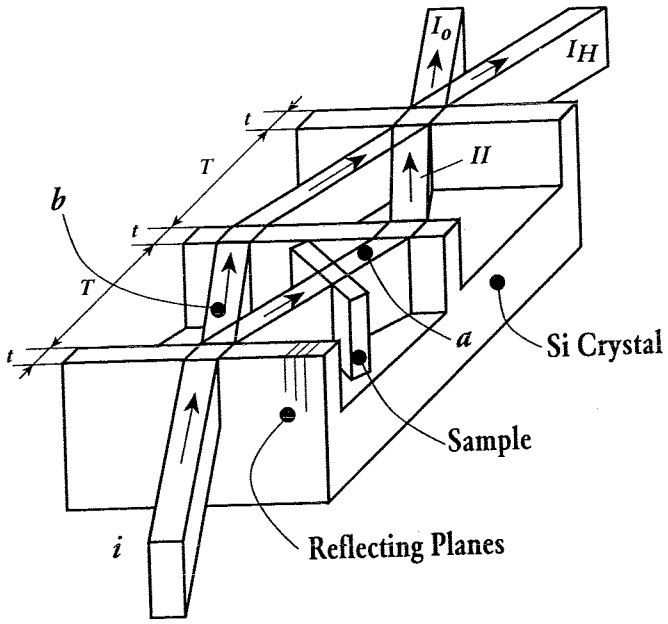

Figure 1-A:

Neutron interferometer.

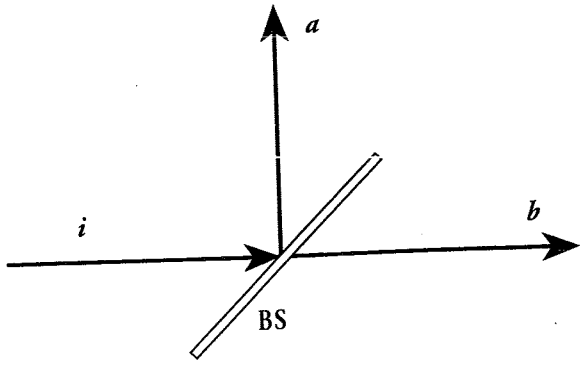

Figure 1-B:

Beamsplitter.

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 one 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 evolution of a coherent state is like the synchronous movements of a military drill team, many soldiers moving rigidly together. The oddity of single quantum interference is that one object can be moving all parts of the drill at once–like a one-man band who is a whole orchestra in himself! 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 really 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 many, potentially very distant and differently directed, modes. Also, experiments exactly analogous to the neutron experiments have been performed using photons, electrons, and, most recently, with atoms.[4]

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 which 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.[5] The concept of entanglement was, for Schrödinger, the characteristic trait of quantum mechanics–"the one that enforces its [that is quantum mechanics'] entire departure from classical lines of thought".[6] 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.

Imagine that two quanta, be they neutrons, electrons or photons, are produced at distant and unrelated sources (see Figure 2 next page). Imagine them 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, then the two separate, each going its own way. But the analysis of Einstein, Podolsky and Rosen, which recent experiments have convincingly confirmed[7], tells us that the billiard-ball model of the collision is completely untenable for quantum systems. 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 go on indefinitely. Unlike the bricks that make up a building, Schrödinger's entanglement asks us to dissolve the concept "brick" as soon as the different elements 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.

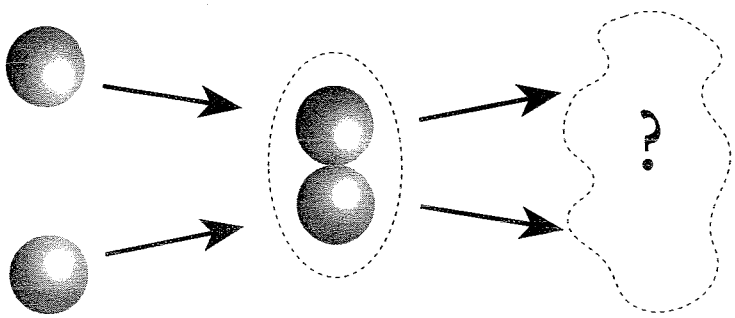

Figure 2:

Two-particle entanglement in EPR experiment.

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. Niels Bohr made much of this fact, burying entangled states under epistemological considerations.[8] 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.[9]

One's immediate reaction might be, but is all this really true? Or is this just another story told by academics (a la Thomas Kuhn, and the sociology of knowledge[10])? In reply, 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, and the recent experiments that use it, have shown that no "local, realistic" theory of physics can account for the experimental facts.[11] 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, which 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 point. 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 now repeating the grand accomplishments of classical physics in their own domains. But a few individuals such as Brian Goodwin (see his chapter in this volume) are able to argue with conviction that while these are powerful paradigms, they leave out 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",[12] of Francisco Varela and Evan Thompson in cognitive science,[13] of Wes Jackson concerning perennial polycultures,[14] of Will Brinton on the soil,[15] 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 spatial order only. 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 Theory, formulated in the early years of this century, deals with time in a way perfectly analogous to the way it deals with space; in fact the three dimensions of space join time to 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 complicating our sense of the relationship between time profoundly.[16]

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.[17]

Let us consider first of all our classical view of time. 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 [that is, 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?[18]

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.

Spacial 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.[19] That is to say, Plato's charge to astronomers was derived from considerations that were beyond physics (that is, "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") so planets must display the most perfect of all motions, namely circular motion. Implicit in this reasoning is a metaphysical basis for time.

Looking at the roots of time invariably led 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 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. 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, whose time-order is not constrained to the relentless regularity of the mechanical timepiece.

Since antiquity, cosmos (the Greek word for "order") and chaos have been irreconcilable adversaries. Today, however, we are drawn into the marvelous region between these two absolutes. Within the rhythms of pure order the tendrils of chaos can be found, and the path from cosmos to chaos is peopled by magnificent forms displaying the most varied temporal and spatial arrangements, including those of life. Very recent investigations point to yet more intriguing connections between chaos and Plato's periodic motions in the area of "controlled chaos".[20]

If one adjusts the parameters of a driven pendulum, its behavior can be made to run the gamut from perfect regularity to a very un-clocklike chaotic motion. Surprisingly, chaotic motion can be "controlled" by very small periodic perturbations to the pendulum. In this recent series of research papers, physicists have reported on their investigations of the control of chaos from both a theoretical and experimental perspective. The significance of this research is likely to be 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 undermines that idea, and, in these papers, specific means for controlling chaos by subtle forces, periodically applied, are investigated.

This research suggests ways in which subtle period influences can cause dramatic changes in the large scale behavior of systems. Possible applications to biological systems are obvious. Medicine, for instance, 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. Thus, if short-term studies find no effect then, by extrapolation, there should be no long-term effects. But in non-linear regimes, which are the regimes in which we live, one cannot extrapolate; very small perturbations can, under certain circumstances, cause huge effects. Likewise, the approach to therapies has been one of frontal assault. Gentle therapies that work with microdoses, remedies or rhythms have had no theoretical basis on which to stand.

Quantum physics and chaos dynamics are often heralded as harbingers of a new science, and so of a new consciousness. Most such claims are little more than journalistic bravado. Still, one can legitimately see developments in quantum physics, along with many other developments in contemporary science, as symptomatic of important changes in the metaphysical 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 as symptoms, quantum mechanics and chaos dynamics reveal certain important features of a dawning metaphysics. We can look, therefore, at science "symptomatically", reading from it an image of ourselves, and glimpse thereby the nascent forms of a future mentality.

II. The End of the Modern Era

The question still remains: how will the restructuring of space, time and causality be taken up? We probably assume that scientifically, well-informed philosophers will consult among themselves and converge on a single reasonable metaphysics. After all, post-Newtonian metaphysics as described by Burtt appeared to command the field essentially unchallenged. Yet, dissident voices have always existed, and in the first centuries of the modern era, when the scientific revolution dawned during the Renaissance, the battles were real and vociferous. At that time, a spiritual, hermetic metaphysics competed with, and lost to, the rising orthodoxy that became scientific materialism. Today, the burgeoning facts of modern science wonderfully complicate and subvert the complacency of the metaphysical establishment, but as discussions heat up once again, the outcome remains unclear. The reign of the modern era, begun in the Renaissance, seems to be ending without an heir apparent.

The most conservative reaction will likely be the denial of any metaphysical implications to modern science. Like the Aristotelians of the Academy who refused to look through Galileo's telescope, or having looked, refused to reimagine their world, today's traditionalists will reject the promptings of science. Ironically, the role played by reactionary clergy in seventeenth century Padua is now likely to be played by scientists themselves, who could well become the vigilant guardians of an outmoded mentality.

Even among those who acknowledge the facts of a post-modern civilization, a range of responses is probable. At such moments of uncertainty, extreme positions possess a power disproportionate to their merits. We could envisage that at one end of the spectrum, scientific materialism will undergo a modest realignment by incorporating the data of modern science unreflectively into its corpus. Non-locality, entanglement, and the rest, will be co-opted into a slightly retooled materialism that becomes all the more compelling, while at the opposite end, spiritual visionaries will trumpet a New Age and the final overthrow of Matter. Crystal pendants and pyramid power will flourish in the vapid aura of an unthinking spirituality.

But like most dichotomies, this one is false. In order to avoid the excesses of one extreme, it is not necessary to plunge into those of its opposite. Surely there is a middle way that steers clear of the shoals of single vision, whether it be materialism or spiritualism. We can look with both eyes instead of one.

That middle way will not only need to accommodate the facts of new science, but it must also be competent to connect science to the cultural, ethical and spiritual dimensions of human life. In doing so, it will move decisively beyond the strictures of the contemporary metaphysics of science and technology with its hollow pieties about value-neutrality. Recognition of the real links between science and life will be more important than ever, because the enormous powers of the new science, like the old, will be equally open to corruption. Biotechnology and artificial intelligence will be no less vulnerable to greed and the lust for power than the discoveries of Einstein or Cortez. If our new imagination of nature is separated from the ethical and spiritual, then we will have persisted in reducing the most profound entanglement of all–that which entwines material and spiritual existence.

For entanglement can 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. The distinction has been useful, but the division of one from the other is a dangerous illusion. From the twelfth to the eighteenth centuries, science struggled for its intellectual freedom, to be unfettered from the shackles of religious ideology. But now that we are, by and large, free of them, we are also free to recognize the entwined nature of our world: body, soul and spirit.

I am advocating, therefore, a metaphysics that embraces not only a holism of space and time, but also a holism of the sensory and the moral. One of my influences in this is the poet-scientist, Johann Wolfgang von Goethe (1749-1832), who rightly saw the danger of separating these two. Best known for his *Faust*, Goethe valued his scientific accomplishments even more highly than his literary ones–a fact which few people realize. He worked in the areas of color science, botany, biology and geology to name a few of his many interests. In each of these fields he combined serious empirical research with the desire to see the unity within nature, a unity that reached into the artistic and ethical as well as the mathematical and abstract.

Goethe refused to leave the phenomenal for the abstract, and his scientific writings are therefore more a poetic re-enactment of the phenomenal than an abstraction of them. He always 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 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.

This gulf still characterizes even those areas of science which I have outlined as potentially revolutionary. 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, showing itself best in the lovely fractal geometries of Mandelbrot sets. One stands, therefore, as the contemporary physicist always has, apart from nature, an onlooker.

I would maintain, therefore, that in addition to a metaphysics that allows values and holism, science also needs a methodology that includes qualities as well as quantities. Goethe and, after him, Rudolf Steiner (1861-1925) offer a promising framework for developing such a science, which is always aware of its vertical as well as its horizontal entanglements. As a poet-scientist, Goethe was ever mindful of the vast range of realities reflected in each phenomenon, and proceeded accordingly. Following his lead, Rudolf Steiner sought to perceive the occurrences of life in the spiritual context that would illumine them most fully. He viewed the spiritual as inherently intelligible, and therefore susceptible to objective inquiry. Both Goethe and Steiner, however, recognized that in order to include cultural, ethical, and spiritual aspects, the methods and scope of science requires change.

From Image to Archetype

Goethe viewed research as taking place in three steps which are depicted in Figure 3.[21] The first moment of scientific encounter is best characterized by wonder. Plato wrote that all true philosophy begins with wonder, and in the intervening 2000 years little has happened to change this opinion. We pass by countless phenomena without "wondering" about them. If we pause before them to marvel, we have taken the first tentative step toward scientific engagement. Phenomena studied at this level Goethe termed "empirical phenomena". No understanding of them is required, merely an openness, an ability to wonder. This naturally leads one to focus one's attention.

The act of attending is a powerful factor in human development. Without it, conscious learning is impossible. In attending to a phenomenon, a transformation occurs within the observer; a realignment or growth takes place. This fact was central to Goethe's understanding of research, for one is forever blind to that for which one has no eye. Through wonder, one is brought into a lively,

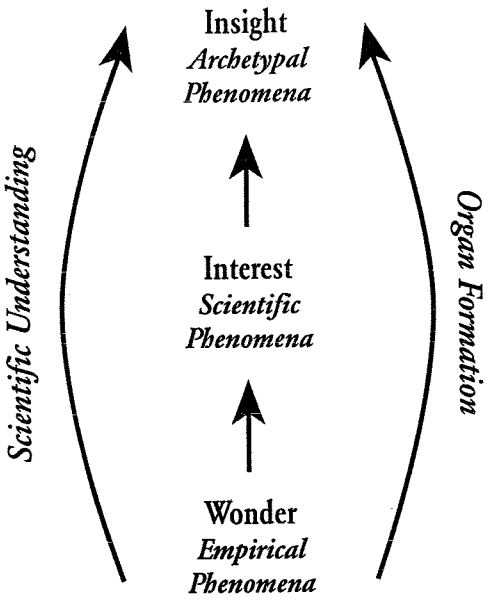

Figure 3:

Research and cognitive development, according to Goethe.

focused relationship to a phenomenon. That engagement is formative. As Goethe wrote:

> Every object, well-contemplated, creates an organ for its perception.[22]

At the heart of Goethe's worldview, and certainly of his science, was the conviction that human beings undergo real development throughout their lives, spiritual as well as physical. Lively engagement with a phenomenon is essential for its understanding because, in Goethe's view, we are changed in the process; we develop faculties adequate to comprehending what is before us.

While the whole process begins in wonder, it is interest that animates the central period of organ formation. We take the naively given phenomena and begin to reproduce them for ourselves, changing the conditions to see which are required for its appearance, and which are minor factors. We distinguish the essential from the unessential. Goethe termed these "scientific phenomena". On them we train ourselves, and forge new faculties.

At this point it is important to note that Goethe remains with the phenomena throughout. He does not replace them with abstract concepts (point masses, postulated forces, unseen mechanisms . . .). Goethe's "scientific

phenomena" retain their full range of associations, which meant for Goethe a moral-spiritual aspect intimately related to the purely sensory. The glow of oranges and reds in the evening sky is a moral-spiritual phenomenon as much as a physical one, and while the two might be distinguished, they cannot be divided.

The final step is the most difficult, but also the most important. It is the move from interest to insight, from scientific phenomena to what Goethe termed "pure or archetypal phenomena". Once again Goethe holds to the epithet: phenomena. Yet, at this point one moves beyond the concrete occasions of individual phenomena to exemplary or archetypal instances. In their purest form, such phenomena do not really exist outside the mind, but they can be seen within or through the most refined phenomena characteristic of an area of study. One never really sees, for example, the parabolic trajectory of a thrown stone, but under certain circumstances one comes close; and so one learns to see in the particular, the universal. Insight into the universal is a sublime moment, a "eureka" experience treasured by every discoverer. In order to apprehend the universal in this way, one must have labored long with "scientific phenomena", fashioning organs for insight.

The insight, once gained, needs to be communicated. But how? The only true way is to lead others to the same insight, which they must earn for themselves by traveling, like you, along the path of scientific experience, for they cannot see through your new-won faculties but must fashion their own. The alternative, almost unanimously adopted by the modern scientific method, is to reduce the experience to an equation, a mathematical relationship. Gone from it are the rich layers of meaning and association inseparable from real insight, but it retains the raw physical power of the original insight. Then, like a machine invented by some modern day Daedalus, the formula can be used without fully appreciating its moral import. Goethe foresaw the dangers of this approach, which are now, in the face of ecological disasters, the ethical implications of biotechnology, and our nuclear arsenal, becoming evident to us all. Like young Icarus, we fly on wings not of our manufacture, insufficiently aware of the hazards of flight and forgetting Blake's injunction: "No bird soars too high if he soars with his own wings".

Goethe sought inventors and discoverers, not technicians. He wanted an original, Daedalean relationship to scientific and technical knowledge, not an inherited relationship like that of Icarus, and he persisted in a unified view of knowing, including both the physical and the spiritual. An archetypal phenomenon, for all its purity, is woven of two worlds, one sensory and the other "moral". By attending to one face alone, we may forget, or lose sight of the other. The sentimental poet may lose the physical force of insight, while the scientist, embarrassed by the sublime, may rush to strip insight of her glory. Goethe

steadfastly refused to sunder one world from the other; he insisted on vertical entanglement at every moment and in every instance.

One of Goethe's most careful students, Rudolf Steiner, sought to extend and apply Goethe's method of inquiry. Trained in the sciences and philosophy, but also an individual with singular spiritual gifts, Steiner saw Goethe's understanding of science as one capacious enough to hold an objective inquiry into the ethical and spiritual, as well as physical aspects of life. The archetypal phenomena were, as Hegel termed them, windows opening out onto a phenomenology of mind or spirit. Rudolf Steiner published his epistemology and spiritual philosophy in numerous books.[23]

Like Goethe, Steiner held that through disciplined inquiry faculties are developed, but he held that these could include faculties suited particularly for spiritual as well as conventional scientific research. The phenomena of nature and of life can be approached in a way that leads through archetypal phenomena to genuine spiritual experiences. The fruits of his own spiritual investigations led Steiner to a complex spiritual conception of the world in all its aspects. Of particular significance for our considerations is his understanding of human evolution. If we live in a period of metaphysical change, what light can Rudolf Steiner throw on its origins, character or relationship to a re-conceived space-time?

An Evolutionary Perspective

The revolutions of science, the rise of novel artistic achievements, or social and economic change are usually 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,[24] 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 that 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 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,

whereas there is perhaps no area where an organic or entangled notion of time is of greater importance than here. We need 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 mechanics, chaos dynamics, ecology, etc.

If, as I have suggested, a form of thinking is emerging that is newly sensitive to holistic and ethical entanglements 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.[25] Constraints of length will force me to be schematic.

Based on his spiritual experiences, Rudolf Steiner considered the human being to have a four-fold nature.[26] 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 by the name "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 spatio-temporal 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 by the names "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. Details of the four-fold nature of the human being can be found in many of Steiner's books.[27]

Although in a certain sense all four of these aspects of the human being have been present for many thousands of years, the relationship of thinking to them has changed fundamentally over that time. In order to understand this, one needs to allow the activity of thinking to have a reality which is not brain-bound. That is to say, in its essence, thinking is not a product of physical or bio-chemical 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 evidenced in an epoch 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 which 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 ninth and fifteenth 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.[28]

Materialism climaxed in the mid-nineteenth 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 "Life philosophy"–*Lebensphilosophie,* as it was called.[29] 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 which were 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 of consciousness, one that would move the basis for thinking back from the physical body to the life body, or etheric body, of the human being. As this occurs, the "thought-shadows" of physical thinking will once again acquire life. According to Steiner, thinking will gradually come to reflect, in form and function, the character of the etheric which is inherently holistic. Individuals will be drawn toward new "living" thoughts as they lift their thinking itself to the level of life.

Stated frankly, I think that 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 living things. 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", that is at once moral and intellectual. Much hangs on our self-awareness of this fact, and on our efforts to promote it not only in ourselves but also in others.

We have to come to understand that every phenomenon is an opportunity for an engagement that is qualitative as well as quantitative–that considers wholes as well as parts, chaos as well as order. These are but different aspects of the same unitary reality, which 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[30] understood modern technology to be the touchstone or insignia of our contemporary world. Whitehead wrote: "What is peculiar and new to the [twentieth] century, differentiating it from all its predecessors, is its technology".[31] 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,[32] those who reject modern science and technology are no less chained to it, even intellectually, than those who enthusiastically embrace it. 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 on *The Question Concerning Technology,*[33] Martin Heidegger quotes the German poet Hölderlin:

> But where danger is, grows
>
> The saving power also

and comments: "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 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 three 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 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, medicine, agriculture or waste treatment, by staying with them, or to put it figuratively, by dying within them? I believe that the answer is "Yes". The thinking such technologies require will have the figure and form of entanglement and the rhythmical dynamics of life. We can find instances of them already about us. In agriculture, the organic and biodynamic movements are proving that caring for the Earth is not incommensurate with growing health-giving food. In medicine, the significance of mind, so long belittled in Western medicine, is now reasserting itself, as thousands of practicing physicians diagnose and treat their patients as soul-spiritual beings, as well as physical bodies. Even the wastes we produce in such prodigious quantities are being penetrated and transformed by a new kind of technology—the waste water work of John Todd, and the composting projects of Will Brinton, mentioned above, being but two examples with enormous potential.[34] All of these are predicated on an understanding of nature and human life as an integrated whole; they are based in a nexus of values that reach beyond profit and power to a recognition of the entwined order, moral and physical, in which we live.

In his February 4, 1992, speech to the World Economic Forum, Vaclav Havel recognized the fall of communism not as the victory of capitalism, but as the end of the modern era. According to Havel, the post-Newtonian metaphysics described by Burtt is crumbling. A truly fresh metaphysics, one amply exemplified by Goethe and Steiner, remains in the wings vying for attention. When Havel writes, it could be Goethe speaking:

> We must try harder to understand than to explain. The way forward is not in the mere construction of universal systematic solutions, to be applied to

reality from the outside; it is also seeking to get to the heart of reality through personal experience. In a word, human uniqueness, human action and the human spirit must be rehabilitated.[35]

That same revitalized spirit must come to shine through every human enterprise, and nowhere more brightly than in science and technology. Then will the new wine, vintage 2000, be borne in fitting wineskins.

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