Perspective

TOWARDS A PROCESS THEORY OF HEALING: ENERGY, ACTIVITY AND GLOBAL FORM

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ABSTRACT

The paper begins with a discussion of the ideas of subtle energy and its circulation that appear common to many different healing cultures. These ideas are compared to and contrasted with notions of energy from within Western physics and it is suggested that some more subtle views, or paradigms, of energy are required within Western science. In particular, the implications of a process and verb-based world view are briefly explored, together with the possibility of a process-based mathematics. Within such a descriptive system notions of energy-process would be remarkably different.

The paper then explores the extent to which such notions may be present, or have the potential for development within modern physics. These include such approaches as giving subtle forms to available energy, the activities of information and global correlations within systems and the notions of coherence whereby subtle correlations can produce powerful effects. In particular, the idea of non-logical and global correlation is discussed in the context of quantum theory and so-called Chaos Theory. Ideas of Gentle Action are also introduced and it is suggested how, through a field of global meaning (or nonlocal correlations), an active form of energy may circulate through the body and act to renew its functioning and bring the various organs into active balance. In this view, the various healing arts are designed to renew and foster the harmonious functioning of mind and body.

Finally, in an appendix to this paper, a more technical account is presented of the sorts of non-local correlations that exist at the quantum level.

KEYWORDS: Healing, energy, activity, global, physics

PREFACE

Western medicine has become increasingly technological in its approach and its theories of the origin and treatment of disease are very much causally based, relying upon the underpinning of the Western scientific world view. While this approach has lead to some remarkable new knowledge about the body and brain, and to a high degree of technological and scientific skills in such fields as new diagnostic tools, delicate operations and drug therapies, nevertheless there are critics who feel that modern medicine presents an essentially fragmentary view of the person, that it sometimes lacks a human touch and has been unable to address the more basic questions of the nature of wellness and of healing.

By contrast, there are some doctors and institutions who are currently exploring alternatives to mainstream Western medicine. In particular, they are looking at the connection of mind and body, and to the various therapies and procedures and practices that come from other cultures.

The fact that doctors and researchers, trained in Western science are now looking to the healing arts of other cultures is heartening. However, one drawback to this whole enterprise is its lack of cohesion, for it is difficult to integrate these different approaches, and to discover a way of discussing them within our Western scientific language in such a fashion that we do not do violence to their subtleties or to our own way of thinking.

What, I believe, is now called for is a new metaphysics, or way of thinking; one that can act as a bridge between that which is best in Western science and the insights of other healing cultures. This paper by itself is not intended as definitive examinations or proposals but more in the spirit of investigation and speculation.

INTRODUCTION

Throughout the world there are, and there have been, a remarkable series of disciplines, practices, teachings, healings, ceremonies, philosophies and ways of life based upon notions of energy. These include the idea of Kundalini, or the

Serpent Fire, from India in which a subtle energy mounts through the spinal column and circulates through the body. An image that resonates with that of Kundalani is found in the Taoist alchemy of China; here a fire is generated within the lower part of the body and mounts and circulates through various cardinal points. The idea of energy circulation for continued health is also facilitated in practices as diverse as acupuncture and Yoga. A blocking or interference to this energy circulation is believed to give rise to imbalance, disharmony and disease.

The body's internal energy is know in Japan as Ki or Qi and is connected to the respiration. The technology of its employment was perfected in the various Japanese martial arts and its origins can be found, much earlier, in the Chinese notion of Chi. Subtle energy is not, however, confined to the body alone but also circulates through the external landscape. Indeed, it is important in China that landscaping, including the location and contours of roads, buildings and their entrances should take into account the flow of subtle energy. It would be dangerous, for example, to build a road too straight, or to place the entrance of a building directly at the end of a road. But through a careful consideration of the movement of Chi the landscape and the buildings in it can act to canalize and focus this energy for human good. The idea of the proper circulation of energy is therefore extended from the arena of the body to the earth itself. In turn, the Chi has its origins in ancient Taoist philosophy, the true nature of the Tao having no name.

Within the Sufi traditions, there is a process of circulation within the field of matter that is brought about through the various processes of the Great Work or Art (alchemy), in which base matter undergoes a remarkable series of transformations, firstly being reduced to the *materia prima* and then elevated into gold. But this mystical science of the Sufi's is not simply concerned with the level of external material transformation, rather it is a psycho-spiritual-material science in which the purified soul, heart, head and matter are united in a mystical marriage.

It is truly remarkable that the image of the Athanor, be it the alchemist's oven, or Tantric fire within the lower abdomen and of an energy which circulates and transforms, should be found in so many cultures. It causes one to wonder whether we are not perhaps touching upon a universal psycho-spiritual scientific

truth, an observation about matter and body, mind and soul that is common to so many diverse cultures across the world and emerges out of their ancient origins. Titus Burckhardt, the Islamic scholar, for example, even finds the Athanor and its transforming fire within the sacred pipe of the Plains Indians.[1] People have also written and spoken of a connection between the subtle energies of the East, the alchemy of Europe and the Near East, and *Wakan* the Sioux, *Orenda* of the Iroquois (Hudanosannn) the *Manitu* of the various Algonkian speakers, and even to *Num* or boiling energy of the !Kung of the Kalahari.

Could it be, we may speculate at this point, that something very fundamental about health, energy and the nature of the universe has evaded Western Science? Could it be that a profound and highly effective manner of healing, one that has existed in different locations for thousands of years, is only now coming to the attention of Western doctors? Could it be that this subtle energy is basically the same as the subtle energy that is now beginning to be discussed and speculated about by some more adventurous theoretical physicists?

Already physicists speak of the infinite potential of energy within the vacuum or ground state and suggest that our universe is nothing more than a flicker of energy within this immense background. And even that the whole universe came into existence as the result of a minor fluctuation within this energy. One is also drawn to the curious nature of quantum theory with its collapse of the wave function and its non-local correlations, ideas that seem to lie beyond the more conventional and classical notions of force and energy. There is even speculation that information plays an active role similar to that of energy, or that the one can be transformed into the other, or that the one can act to give form to the other. David Bohm, for example, in his Causal Interpretation of quantum theory, speaks of "active information" that will affect the motion and correlation of quantum particles.[2]

PARADIGMS AND PERCEPTIONS

The analogies explored above are indeed persuasive and exciting. They suggest that science should explore what is really meant by energy, transformation, correlation and process; that medicine should open itself to the healing processes

of energy and the wisdom inherent in ancient and diverse teachings. Indeed, within this essay I will attempt to push a little at the limits and speculate upon the connections between such ideas as form, symmetry and nonlocal order as they refer to the processes and circulations of energy-matter.

But before going any further I want to strike a note of caution and guard against a sort of fragmentation that can come about from asserting a false unification, that sort of unauthentic unification that comes about when we force things together that do not belong together—*for fragmentation not only involves breaking apart things that belong together, but also the false perception that different things are identical.*

The question I want to ask is, are all those analogies above really correct? Have we really discovered a single entity "*energy*" that is universally known, but under different names? Or are we perhaps missing some important and subtle differences? In other words, has that word energy, and its various European equivalents, been projected onto something, or some process, or some way of thinking, or some spiritual practice, or some ceremony that may be subtly but significantly different from anything we know? While some ideas of "energy" may correspond quite well to concepts within our own European languages, others are mistranslations or attempts to project the language and thought of one world-view upon another that is quite different.

I believe that this is an important point to make, that subtle and not-so-subtle differences may exist between our own scientific conception of energy and those which we have translated or borrowed from other cultures; particularly when we are dealing with profoundly different languages and world views. Indeed, as we look into this dilemma we begin to see some of the limitations inherent in our own science and world view.

Our current science is based within a world view that sees the universe in terms of objects and substances; for example, Aristotle's division into animal, vegetable and mineral, or the division in high school science of solids, liquids and gases. The universe of Western Science is composed of planets, stars, moons, rocks, crystals, molecules and atoms; each acting on the other by means of the various forces, pushes, pulls, and fields that mediate between objects. This is the perception of object rather than process, the world view within which the word "energy" developed and took on ever more shades of meaning.

PROCESS AND LANGUAGE

This world view, or paradigm, I believe, goes as deep as the European languages we speak and to particular language forms that are over two thousand years old. These languages could all be called noun-based, with nouns being qualified by adjectives and causally connected through verbs. *"The cat chased the mouse," "The doctor cured the patient,"* are expressions which evoke impressions, impressions from a world in which separate, autonomous objects live and move and have their being, and occasionally act on each other. Thus the cat, as object, acts towards the mouse, as object, and we are then directed to a motion that arises out of the transitive action of one object on another. There are, however, many other of the world's cultures that would rather see this as a dance of nature, a game, a play, or a process out of which, for an instant one may choose to abstract that particular pattern of process that we, for the moment, call a cat, or a mouse.

Language and world view go hand in hand, each supporting the other, each convincing us of the factuality of what we take for reality. For example, during the past few years, there have been, within the West, a variety of new attitudes and insights into the nature of healing, nevertheless, our language still forces us into the trap of seeing healing as something that is "done" to one entity, *the patient,* by another, *the doctor.* Just as the earth acts gravitationally on the moon, so, too, the doctor acts on the patient—both preserving, in a deeper sense, their absolute autonomy and separation, in other words, their fragmentation out of a greater whole. Healing, therefore is taken as the verb that connects one noun to another.

But compare this way of speaking about healing with phrases from an Algonkin language, Montagneais.[3] The term:

HIPISKAPIGOKA IAGUSIT,

was translated in the 1729 *Apprat Francais et Montagneais* as "Le jongler chant un malad," which reflects our notion of the transitive connection between objects as nouns. The first word is a verb to do with singing. A note in the *Apparat* suggests a translation of "I sing he who is sick" (IAGUSIT referring to "he is sick") But, as my colleague Alan Ford, of the Department of

Linguistics, University of Montreal, informs me, this particular verb form can only be used in the third person. The statement about singing could not, in fact, be made by "le jongler," which was Le Pere Lavre's rather insulting description of a Montagneais healer.

The word really refers to an activity, to a process of singing that is going on. The language focuses on the activity itself, the singing, and out of that singing emerge two people "he who is sick" and another who is included within the verb form of the singing. One begins to catch an impression, not of healing being "done" to a sick person, or of the activity of one noun upon another, but rather of pure process, pure verb. Singing is going on, the song is not transitive, not a force that passes between two objects, rather it is the animating power of process, it is like the activity of a fountain, a fountain that takes on a stable form by virtue of the ever changing water that flows through it.

This notion can be seen in another word,

MATUTICHIU—NIKAMU,

which has been translated as "he sings in the sweat tent." But once again one begins with a verb or a pure process. It is only out of this verb that emerges object, one who sings and a sweat tent.

One should also note that, for the Montagneais, there are no nouns to describe the weather—no rain, no snow, no heat and no cold—neither is there morning, or afternoon, or night. Rather there are verbs, processes of time and processes of nature. All is process, all is transformation, all is animation.

This world view appears common to all the Algonkin families of language. My friend Sa'ke'j (James Youngblood Henderson) has explained to me how, for the Mic Maq peoples, all is process and change, all is alliances of the various animators (spirits) of process. The Blackfoot peoples also speak of a world of transformation and renewal (and here I am indebted to my friend Leroy Little Bear for so many rewarding discussions), a world in which any object is only provisionally referred to as an aspect of process. The Haudenosaunee (also called Iroquous) do not speak an Algonkin language, however the spirit of transfor-

mation is vividly inherent in their sacred masks, masks that express the multiplicity of appearance within change (These are sometimes called by non-Native anthropologists False Face Masks).

This process/language vision of the world is not restricted to the Indigenous Americas alone. Some insight into the language of ancient China can be gained from the oldest characters that survive in the Yi Ching, and here I am indebted to the Quang Ngugen for instruction. The characters are not themselves, nouns, verbs, adverbs or other parts of speech but rather they are characters whose form depend upon the context and way in which they are used. Thus *Yi* can act as a noun-form and refer to the changes that occur in the universe, or it could act as a verb and express the process and activity of transformation itself. In alternative contexts it could act in some other grammatical function. Again, form and content complement each other, for the notion of change and transformation is contained both with the world and through the way that it, itself, functions and transforms itself in these functions.

It is with this in mind that I return to the universal nature of that world energy, and to our own Western scientific belief that we are moving ever deeper towards an understanding of its nature. What, I ask, happens when the representatives of a noun and object-based world view come into contact with those who live in a world of process and who speak a verb-based language? What happens when a politically dominant society attempts to "translate," or seeks to render into categories, and concepts, the active meanings of another language; when a world of process, flux, and relationship is translated into a language of nouns, objects, and fixed concepts? What happens, in other words, when "*manitou*" is translated as "energy?" Do we, in fact, discover some deep connection between two world views or do we, perhaps, obscure subtle and significant differences—a whole way of living and being, perhaps? If we are to gain a full understanding of how subtle energy may be involved in healing need we perhaps develop entirely new, process-based, means of description?

ENERGY IN PHYSICS

Bearing in mind the above warnings about the enormous power of European languages to reinforce a particular world view by transforming flux and process

into object and concept, I now want to return to Western science and, in particular, to the word "energy," that noun that we have empowered to carry so much baggage about transformation and change in the universe. Historically, physics began with a study of the regularities of motion and transformation, with objects that move and change their state. Isaac Newton was able to unify the seemingly different conceptions of motion that underlie the fall of an apple, the flight of a cannon ball and the circulation of the moon. Other notions of transformation between various physical and chemical states of matter were also investigated.

It was only later, however, that the concept of energy began to be understood and unified. Through the discipline of thermodynamics, scientists began to realize how such seemingly unrelated manifestations as heat, electricity, the power of chemical reactions, mechanical energy, light and even nuclear and gravitational processes were all aspects of the one underlying, animating principle that is energy.

Energy is what causes a change of state, energy is possessed by objects by virtue of their position and motion, energy is the degree of internal motion within objects. Energy is that which animates, that which gives power to, that which causes to change.

But suppose our science had emerged out of a process-based world view, or that we had spoken a verb-based language. How then would we speak of energy, how would we speak of object? What would be the meaning of Einstein's famous $E = mc^2$ which, in its present form, establishes a metaphor between two noun forms, matter and energy. Would a verb-based Einstein have perhaps created with his $E = mc^2$ a metaphor between two processes, two verbs; or would he paradoxically have created a conjugation between the ultimate noun (matter) and the ultimate verb (energy). Or, from the very first, would a verb-based language have transcended the distinction between object and process, noun and verb and, in this way, have lead to a more holistic physics?

PROCESS AND MATHEMATICS

What we are trying to get at here is some way of discussing energy, within the domain of Western science that can accommodate the idea of energy as a

flowing, transforming and healing force within the body. What I particularly have in mind is the development of a new language whereby process and active transformation can be discussed in science, i.e., a mathematics of process.

Let us be clear, mathematics is not truly a language, in the usual sense of the word rather it is a sub-set or specialized form, of ordinary language. Mathematics, as we know it in the west, is something that has evolved out of certain refinements within Indo-European languages, refinements that have made clarity and logical connectivity explicit, that deal in the quantitative and in formal relationship. Mathematics has specifically developed to avoid ambiguity, confusion and multiplicity of meaning. Yet, these are both its strengths and weaknesses, for while our mathematics is well adapted to make calculations and express abstract relationships it cannot deal with quality, ambiguity, and feeling. In particular, it could be argued, our mathematics, and by implication, our physics may not readily be adapted to deal with process and with the activities of healing.

Our mathematics is a refinement of noun-based languages and has its origins in categories of thought. Take, for example, number which emerges out of ideas of category and set. Numbers are the "nouns" of mathematics, subject to such operations as addition and multiplication. In other words, the various transformations and operations of arithmetic and group theory are analogous to the operations of verbs on nouns. Likewise, algebra is an exploration of the relationships of noun-categories.

The evolution of modern geometry is another case in point. It began with empirical rules of measurement which were generalized, collected together and, being freed from any particular practical referent, became the abstract and logical relationships of the properties of a few regular shapes called Euclidian Geometry. A further degree of abstraction led to Projective Geometry and then to Topology, in which shape is fluid and only the relationships such as intersection, inside of and outside of, are retained. Today, a modern physicist deals in cohomology theory where geometric relationships have been freed from even reference to an underlying spatial manifold. So mathematics has moved progressively towards increasing abstraction and increasing study of the relationships of relationships. Nevertheless, our mathematics remains rooted in the idea of noun-categories.

This can clearly be seen in the paradigm attempt of mathematics to come to terms with process and change. The calculus deals with rates of change and transformation, with changes in position and velocity, with the way rivers flow, flames burn and things decay. But, in attempting to come to grips with the very nature of change Newton employed his "method of fluxions" in which the elements of change are made progressively smaller and smaller until, in the infinitesimally smallest limit, one reaches the static. In essence, therefore, change within the calculus emerges out of the static, out of a noun world of frozen elements. The calculus stands as the compliment to Zeno's paradox, for rather than motion paradoxically being reduced to the static, the moving is itself to be *represented* by means of the static. Even within its modern twentieth century dressing, calculus still attempts to come to change, to engage the verb, by means of noun-based relationships.

While modern mathematics has moved towards ever increasing abstraction it, nevertheless, leans upon notions of category and the static. There are, however, hints of attempts to go beyond this—for example, the French philosopher Stephen Lupasco's "logic of antagonism" in which opposites are supposed to be held within a constant dynamical tension. In addition, the quantum theory appears to demand a process-based mathematics which has yet to be fully developed.

I wonder what would be the mathematics of a verb-based language and a process-based world view? Would it be a language of change, in which form and content are perfectly matched? Indeed, would we even recognize this formalism as being mathematics or, rather, would we only project from it that part that appeared to deal in what we already understand as being mathematics—categories and the static?

PROCESS MATHEMATICS?

One clue as to the mathematics of process may be gained, perhaps, from the ancient mathematics inherent in the Yi Ching. It is sometimes said that the I Ching is a binary mathematics, but really things go much deeper than this, for the characters and symbols of change are themselves not fixed but subject to change. (i.e., the moving lines take one hexagram into another). While in our

algebra the value of x may change we do not expect the symbol itself to transform. However, within the Chinese mathematics of change, both content and form are equally matched and participate in a constant dynamical transformation.

Another clue to this mathematics of process and change, of a mathematics that may be better adapted to talk of energy circulation and the various processes of health, may be gained from a consideration of Sacred Number. It seems that, for Indigenous people all over the world, when one speaks of mathematics one begins with a consideration of Sacred Number. This idea of number is not something abstract or concerned purely with calculation. Rather it is an expression of harmony and balance within the cosmos, within ceremonies, within architecture and, moreover, within the human body itself.

As was mentioned above, our notion of number comes from the concept of categories and sets. We first learn about numbers in school in terms of, for example, collections of apples and pears and, taken to its sophisticated limit, this same sort of thought process is at work when modern mathematicians and philosophers attempt to come to terms with numbers.

$$1 + 1 = 2$$

The verb of addition acts on the noun, 1, which retains its object-like quantity as it combines to form 2. But how does this apparently simple process work in our work of experience. Do two rain drops running down a windowpane perhaps merge into one? Does not an egg and a sperm merge into a dividing multiplicity? Does a thought preserve its categorical uniqueness or is it the generative force that entrains a whole symphony of mental activity? In other words, must 1 and 1 always equal 2?

It seems to me that Sacred Numbers are not of this static, categorical nature. Rather they represent stages of process, points of dynamical equilibrium, aspects of change and alliances of different powers and influences. A typical alchemical axiom runs *"Out of the One comes Two, out of the Two comes Three, and from the Third comes One as the Fourth."* Numbers here are not static objects of thought but aspects of a dynamical process; an idea that is echoed in

everything from the Quabhalla, to the calenders of Meso-America and the ancient mathematics of China.

Within such systems a number is a nexus, a point of arrival and departure, a stage in an eternal cyclic process of renewal. A number represents a point of harmony and equilibrium, or a new generative force of change. It is for this reason that number is reflected in ceremony, architecture and the human body. The movement of the subtle energy of the Qi or the Serpent Fire must pass through the proper numerical sequence as it circulates through the body. Each number is a point of arrival and departure and, with this cycle of energy, each number must be renewed. Similarly, the passage of time (for the Mayans) is a great cycle, having proper times for renewal.

We now see the deeper meaning of order within Sacred Mathematics, for order does not refer to something static and fixed. Rather, counting is itself a sacred act, something that takes us through the sequence of processes that will allow us to arrive back at our point of renewal. Sacred ceremonies in their sequence are themselves aspects of counting, a counting that causes us to remain in harmony with the movement of the seasons and the cosmos. Counting is also an expression of the proper circulation of subtle energy, or healing, through the body. So disorder becomes a disruption of this circulation, disorder is disharmony and sickness, a denial or a disruption of the processes of life and the circulation of the cosmos.

Sacred Mathematics appears to be the key that lies at the heart of so many healing systems. It is also the key to sacred architecture, to the ceremonies of renewal throughout the year, to the great cycles of the ages, and to the proper functioning of the body. It could be that if we are to make an integration between our own scientific world view and that inherent in the healing arts of other cultures then we must be willing to deal not only with the static but also with process and with the dynamic aspects of order, form, pattern and unfolding. In the sections that follow, we shall attempt to touch upon related notions within modern physics, albeit sometimes tangentially. In the sections that follow, we shall attempt to touch upon related notions within modern physics, albeit sometimes tangentially.

SUBTLE ENERGY IN MODERN PHYSICS

As we have pointed out, physics has tended to use energy as a noun form. Energy can be measured, so that one can have a given quantity of, say electrical energy, and convert it into another quality of heat energy, or chemical energy. The science of thermodynamics was an attempt to get to grips with this circulation of energy in a somewhat similar way to the fashion in which currency circulates from country to country, via different rates of exchange. The second law of thermodynamics, for example, explains how, in this circulation, a price must always be paid, for some of this energy is converted into a form less available for direct work. This loss of useful energy was, in turn, tied to the notion of increasing entropy and the idea of molecular chaos. Natural processes, we are told, move spontaneously in the direction of increased molecular chaos and the break down of correlations. Correlations can only be restored at the expense of energy.

This approach to the circulation of energy is doubly defective. Firstly because it still views energy as a more-or-less noun-like form and, in addition, it is based upon notions of ultimate decay and dissipation. Systems with simple regular orders must ultimately give way to disorder and entropy increase. Indeed, the end of the universe lies in its final "heat death" and absolute molecular chaos. Life and the unfolding of new orders are, therefore, exceptions within this world view, curious accidents of nature and isolated islands within the march of chaos.

More recently, however, there have been speculations on what is called subtle energy, something that is not really included within the above thermodynamic balance sheet. Subtle energy *is more to do with the notion of a form, or of a dynamical pattern that is imposed on energy, with the unfolding of subtle dynamical orders and new forms out of chaos, and with circulation of these subtle forms.*

David Bohm, for example, has given the example of how the very small but information-packed energy picked up by the antenna of a television set acts to give form to the more "gross" energy that is picked up by the power plug. In this instance a subtle energy acts to direct a less formed, but more powerful energy.

Another example is of an ocean liner that approaches land. In this case, the subtle energy of its radar system and computers is used to direct the immense energy of its engines and cause the boat to head for a particular harbor and dock. One could also think of examples in which a subtle activity acts to give form to processes involving the flow of both energy and matter. In this way, through the operation of something subtle, dynamical forms can unfold out of an apparently random background.

In these examples, the idea of subtle energy is being used in the sense of some sort of activity of information. Normally information is considered as something passive, like a book or computer memory. But in these cases we realize that information has the power to direct and give form to raw energy.

A similar idea is present in David Bohm's Causal Interpretation of the Quantum Theory. Here what is known as the Quantum Potential acts to direct the particular motion of individual electrons. Conventional potentials, forces and fields act on an electron in terms of pushes and pulls. In other words, in a mechanical way, so that the greater the force, the bigger will be its effect, and the further away the source of a field, the weaker will be its effect. Not so with Bohm's Quantum Potential, for here it is the form and not the size of the potential that matters, so that even tiny disturbances located some great distance away can exercise a marked effect on the motion of the electron. In Bohm's approach it is this subtle form, packed with information about the surrounding environment and experimental set-up, that acts to direct the "un-formed" kinetic and potential energy of the electron. In this fashion, for example, an electron that passes through one slit of a double slit experiment is "in-formed" in its motion about the location of the other slit. Therefore, without ever being in the region of the second slit, the electron has received information about some distant part of the apparatus in a "non-local" way.

It is important not to get tied up in debates about the interpretations of quantum theory or whether David Bohm's is better or worse than some other interpretation. What I feel is important as far as the present discussion is concerned is that Bohm, and his colleague Basil Hiley, have clearly shown the existence of a new and very curious sort of potential, or active information, that could possibly exist in our world. They have demonstrated the way in which information can exist as activity, and how that activity can impress itself upon raw energy.[2]

HEALING ENERGY

It is here that a connection can be made with some of the ideas in the first sections of the paper. For, rather than theories of healing involving the search for some new form of physical energy in the universe, or some new force, one could perhaps focus attention on a way of coordinating existing energies at highly subtle and sophisticated levels. Is it that the Chi or Qi energy, Kundalini, the burning fire of the !Kung, and so on represent forms of physical energy that are totally unknown to Western physics? Are they, perhaps, spiritual forms of energy that cannot be measured in the laboratory? Or could it be that they are the manifestations of something extremely subtle and active which correlates and directs the processes of the various natural energies of the body? Could it be that breath, metabolism of food, and so on are all at the service of something that is transcendent to them, some active information, or even intelligence, that causes the continual harmonious circulation of healing, transforming energy through the body?

Health would then lie in this harmonious and orderly circulation, while illness would represent a blockage, or a misalliance, something that interferes and perverts the normal form of energy, something, for example, that draws upon the body's energy to support it and therefore syphons off energy from more vital functions. This circulation could be variously described as a flow of meaning through the body, the animation by spirit, or the coming into harmony of the body with the entire natural order. Healing, therefore, would not be so much directed, in a causal way, to various malfunctions or defects, but to the renewal of this activity of harmonious circulation. The various ceremonies, practices and disciplines that exist across the world can, I believe, be seen in this light as *something that acknowledges and celebrates the movement of spirit, or subtle energy, through the body.*

Healing may be done by song, dance, drumming, touch or by entering into some mandala, painting, medicine wheel that is a matrix of energy balance. In their different ways all these forms of healing are designed to produce a dynamical harmony within the body-mind, mind-body and to restore balance. But one must always remember that this balance is not static but dynamic, a matter of process and circulation, and that the body and mind are themselves the particular manifestations of this more subtle level of reality.

It is also significant to note that so many healing ceremonies take place within the presence, and with the active involvement, of the whole group. Again in these cultures healing is not something that is "done" to the patient by the doctor, rather the healing is a process of activity, generation and renewal of energy, that emerges out of the activity of everyone present. It is therefore an expression of wholeness of the group, their place within the movements of nature and the cosmos, their alliances with various powers and spirits, and the particular relationship to a person we in the West would call "the patient."

THE ORDER OF ENERGY CIRCULATION

The question we now face is how the various processes within the body, breathing, local metabolism, functioning of cells, and organs, circulation of blood, nerve impulses and so on, are brought together within a dynamical correlation that circulates throughout the body in a healing process. We can inquire, for example, if Kundalini is a process of circulation involving a very subtle correlating energy that moves through the body and brings into focus the body's various natural energies and metabolic processes and focuses and amplifies them to a very high degree. That is, rather than having a variety of different uncoordinated processes within the body they all become joined within a single, global flow of meaning that circulates through the whole system, gaining in power as it does so.

The analogy would involve the difference between an ordinary light bulb and a laser. In a light bulb atoms are excited by the passage of electricity, each one giving off a flash of photon-energy. The whole process, however, lacks any global correlation or coherence, for each atom emits its energy without reference to the others. In other words, release of light energy is essentially chaotic. In a laser, however, a subtle process acts to link each atom and cause them to emit their photons of energy, each at exactly the same time. One way of thinking about this would be to imagine a sort of circulation of virtual energy through the laser, building up in intensity until the energy in every atom is simultaneously released. The result is a coordinated emission of energy, a process that, by being correlated globally, results in a beam of extraordinary intensity.

Imagine an analogous process within the body, in which the circulation of a subtle correlating energy, i.e., a form of active information or meaning, could act to coordinate all the different processes within the organism. In this way the metabolic processes of the body could be focused and would give rise to the circulation and amplification of energy far beyond its normal range.

The key to this process, as with the laser, is a global correlation or circulation operating at an extremely subtle level through the operation of what could be called, metaphorically, a highly intelligent application, or highly sophisticated, active information. The key to this healing would therefore be a circulation of some sort of global, non-local correlation that operates throughout the body, a circulation that may even extend into the group, nature and the cosmos.

Let me give another example: When an electric current passes through a normal metal the moving electrons scatter off the various obstacles in their path. This has the overall effect of dissipating some of their energy, the lost energy turning up as heat. (An electrical current passing through a wire produces heat). In a superconductor, however, a very subtle form of correlation acts globally to coordinate the motion of all the electrons. This has quite remarkable consequences, for while an individual electron, as it approaches an obstacle, still does not have sufficient energy of its own to get out of the way, nevertheless, the electron family as a whole acts to guide the electron around the obstacle. By means of a very subtle form of global correlation, a vast number of electrons is able to behave collectively and to move past obstructions without any scattering or dissipation of energy. An electron current set up in a superconducting ring will therefore circulate forever without loss.

Again, we see how a very subtle form of correlation is able to coordinate the motions of a vast number of separate objects and cause them to circulate in a collective way. The physicist H. Froehlich[4] has proposed that collective states are entirely characteristic of all living systems and that coherent correlations act to coordinate flows of energy and matter within cells. One could even speculate that correlated and non-local processes are also of key importance within the brain.

WAVE FUNCTION, FORM, AND CORRELATION

At another level of explanation we can see how this global correlation of energy and system are related to the overall form of the quantum mechanical wave-function. In many quantum systems it is generally believed that the wave-function can, to a good approximation, be made up out of a number of separate contributions. In other words, distant parts of the quantum system, while still connected to each other, do not exhibit that coherent correlation that is characteristic of the laser or the superconductor and their wave function does not, in consequence, have an overall global correlation. In the superconductor, superfluid and plasma, however, the wave function has a particular global form. Rather than being, to a good approximation, built out of separate contributions, it is an integral whole, a global form, in which each electron, or part, is subservient to the whole. In this way the motion of a single electron within a superconductor is entirely determined by the motion of the whole.

The way in which the motion of the whole system determines or guides each of its parts is the essential feature of quantum systems. Indeed, expressed in terms of the quantum mechanical wave function this is what distinguishes quantum systems from the "classical" systems described by earlier physics. The way in which the overall form of the wave function can establish a non-local correlation through the whole system can be seen even in the following simple case.

In classical physics it is always possible to distinguish or pick out any one particle and follow its trajectory through space. Not so within the quantum domain, for it is held that electrons, or photons, or neutrons, are indistinguishable. This means that if we were to interchange two such particles, one for the other, then the resulting system would be physically identical to the former, i.e., there is no measurement or observation that could ever distinguish between the two cases. This is yet another case of how a quantum system differs from a classical one.

It turns out that the results of any physical measurement or observation within the quantum domain always involves not the wave function Ψ itself, but its square $|\Psi(1,2)|^2$, where 1 and 2 respectively refer to the positions of particle 1 and particle 2. Therefore the physical indistinguishability of two different situations can now be expressed as an equivalence:

$$| \Psi (1,2)|^2 = | \Psi (2,1)|^2 \qquad (1)$$

That is, there is no way of determining the difference between one electron being in position 1, and the second in position 2, from the case in which the first is in position 2 and the second in position 1.

Now equations of the form

$$y^2 = x^2 \qquad (2)$$

have two solutions

$$y = x \quad \text{and} \quad y = -x. \qquad (3)$$

This means that two possibilities also exist for elementary particles, either:

$$\Psi (1,2) = \Psi (2,1) \qquad \text{Symmetry} \qquad (4)$$

or

$$\Psi (1,2) = -\Psi (2,1) \qquad \text{Antisymmetry.} \qquad (5)$$

Therefore, when two particles are interchanged the wave function either remains unchanged or its sign is changed, from plus to minus. It turns out that the former property (symmetry) is the case for the *elementary particles that carry the forces of nature*, like photons, gravitons and certain mesons (called Bosons, or Bose-Einstein particles), while the latter (antisymmetry) is the case for the *particles that make up the structure of matter*, such as electrons, protons and neutrons (Fermions, or Fermi-Dirac particles).

The idea that the wave function for electrons must have an overall antisymmetry under interchange of particles produces curious results. It means, in effect, that there is a global symmetry operating within the whole wave function, so that two electrons, no matter how far apart they may be, are in a certain way correlated. It is important to note that this form of correlation is not produced by any physical force or causal link, indeed there is no energy or force that passes between the two electrons to ensure the antisymmetry, rather

it is the non-local form of the whole wave function that is important. In this sense, rather than a local connection via force, one has a sort of acausal connection between quantum particles. It is remarkable that a notion of acausal connection should have been quite independently posed by Carl Jung with his idea of Synchronicity, and that later his colleague in the investigation of synchronicity should have been Wolfgang Pauli whose Nobel Prize was awarded for the discovery of this very fact of antisymmetry, and its implications, at the quantum level.

One can call this principle by different terms, antisymmetry, synchronicity, non-local connectivity, global form, dynamical order, yet all point in the direction of a correlation that transcends anything known in the classical world. And, as the physicist John Bell, has demonstrated, this antisymmetry is not simply some abstract mathematical result but leads to real effects in nature. Because of this antisymmetry it is not possible to write down the wave function as a product of two different contributions, one from each electron, as would be the case in a classical system. Rather the wave function has a non-local symmetry which means that it is inherently non-separable.

Now suppose that each of a pair of electrons shoot off in opposite directions and measurements are then made on each of them. Because of the overall asymmetry of their wave function there will always exist a particular degree of correlation between the two measurements made at opposite ends of the laboratory, a degree of correlation that exceeds anything conceivable within the "classical" world. This non-classical correlation was predicted by John Bell and has since been confirmed in different experiments. In other word, the quantum system behaves in an holistic way and, in its motions and process, the system is correlated globally. Moreover, this correlation is not the result of any physical force or interaction, it exists in an acausal way, it is a non-local or acausal correlation.

Now this form of non-local correlation is inherent in all quantum systems and, I want to suggest here, that its effects extend right into living systems. In other words, what could be taken as the criterion of life is this ability to sustain coherence, or correlation over long distances, that is, for processes to be integrated together in a non-local way.

In earlier sections I have suggested that a deeper understanding of healing energies, within the Western scientific framework, may require a new mathematics and a new process-oriented science. What has being explored in this section are simply hints that the quantum world is forcing us to face—that global coherence and non-local correlations play a key role at the quantum level and may also be an important basis for life. In turn, this sort of non-local correlation may have connections to the circulation of subtle or active information. While the full mathematical forms needed to deal with process remain to be developed, some implications of the quantum correlations and non-local symmetry are developed in the technical appendix to the paper.

CHAOS THEORY

The idea of an overall form that guides or correlates processes of matter and energy at a subtle level is also present in what has generally been called "Chaos Theory." But this title is, I feel, something of a misnomer, for Chaos Theory is really dealing with systems of extraordinary sensitivity and complexity.

Such systems are truly holistic in that their behavior is determined by the totality of their surroundings (their boundary conditions). The famous "butterfly effect," for example, tells how tomorrow's weather in New York could be affected by a butterfly's wings flapping today in Chicago. In other words the very delicate dynamics of such a system are determined by a myriad of global effects.

Mathematically this can be seen in such things as the famous Strange Attractor—this is a region (within what is known as Phase Space, a sort of behavior space for the system if you like) which has a Fractal Dimension and exerts an overall attraction for the system. The Strange Attractor could be thought of as a global form within this "behavior space" which acts to guide the overall motion of the system.

Chaotic systems can also be thought of as systems which constantly refer back to, or enfold, themselves. In a sense they reenter or revisit themselves. They are like stories that stretch back in time and for which the overall meaning of

the story is of key importance. Systems with simple order, the sorts of systems discussed in the classical physics texts, are more mechanical, they could be compared with an individual who is obsessed, single minded and insensitive to everything else that is going on. Such a person may behave in a rigid, mechanical way, carrying out repetitive tasks and reacting in quite predictable ways. Indeed, to continue to apply this metaphor to a human, one would generally say that such a person was unbalanced and mentally unhealthy; indeed behavior of this kind would probably also lead to physical illness. The chaotic systems, however, could be compared with a person who moves in a highly open and sensitive way through a rich landscape, a person, moreover, rich in memory who is always seeking to integrate meaning. Such a person is open to new meanings and relationships and would generally said to be healthy.

To return to physics, technically speaking, the path of a chaotic particle is determined in an extraordinarily sensitive way by a whole series of coefficients that represent its successive enfoldments in time. To change only one of these coefficients in even the smallest way would be to cause the system to move in an entirely new direction. But if we were to do the same thing with a "classical system" we would hardly notice the difference.

So "Chaotic," or rather holistic and sensitive systems, also share something in common with quantum systems. Their behavior is determined by overall global forms or symmetries. Again we touch on the idea of a system that, by means of very delicate coordination of all its parts, should engage in a correlated, cohesive and coordinated movement—a circulation of healing energy, perhaps.

GENTLE ACTION

The idea introduced above can also be discussed in terms of what I have called Gentle Action. Take, for example, the case of the sort of sensitive system discussed in the previous section. By very carefully arranging all the coefficients of the system—the global meaning of its life story, you could say—it is possible to direct that system in a very powerful way.

In the case of a "classical system" large effects can only be brought about through large causes. Such systems are linear in nature and are generally controlled

through local intervention, the bigger the intervention the more the system is moved in a new direction. By contrast, a sensitive or chaotic system is extremely responsive to the slightest influence and, by a very precise and global coordination of a multiplicity of tiny influences, it becomes possible to cause such systems to move very powerfully under their own internal energies.

Coherent correlation, recall, is what happens within a superconductor, and superfluid, when that system moves as a whole; in this way a very small "intelligent" non-local intervention has produced a result of extraordinary power. Another image is of the minimal yet global coordination of very tiny ripples around the edge of a pond. Normally such coordination would be very rapidly lost in the general random motions of the wavelets. But by coordinating things globally, that is non-locally, it becomes possible for all these wavelets to cooperatively assist each other (via constructive interference) and grow in size as they move inward. The result, therefore, of a minimal but non-locally correlated intervention around the edge of the pond would be a very large surge of energy at the center.

Again we begin to see connections to subtle energy flow in healing, to the way in which marked effects can be brought about through the non-local coordination of very tiny fluctuations on a global scale. One could imagine, perhaps, some highly "intelligent" and sensitive coordination that operates within the entire body, a global sense of meaning perhaps, or the operation of spirit. This would have the effect of coordinating all the tiny individual metabolic processes, energy-producing reactions, flows of various substances, and natural circulations within each cell, organ and region. The result would be analogous to the exampled globally coordinated ripples in the pond, or to the action of the laser or superconductor, in that a great flow of something extremely powerful would be generated and would then move through the body. In this way a circulation of active meaning and energy may act to bring an energy of reanimation, or a spirit of renewal, into each organ. Or, to put it another way, this highly intelligent energy flow moves throughout the body, bathing each organ, each region, in a field of meaning, or spirit, or animation. The flow would act to reaffirm and reanimate the correct and harmonious working of the body/mind. And, similar to the way coherent energy builds up in a laser, it may be possible through a continued circulation of healing energy to create effects, body processes and transformations of extraordinary intensity.

One could also imagine this sort of circulation operating within a social group, and even extending out into the environment. One can imagine something that resists this flow, or which attempts to fragment its order. This would be the nature of disease, for disease and disorder would now be seen as an essential break down of harmony and subtle global order within the flow. Disease could also act as an obstruction to flow, something that dissipates energy, or creates vortices in the energy of circulation.

The way to healing would therefore lie in some practice, ceremony or process that causes the restoration of harmony and balance throughout the body-mind. It would involve engaging the disordered and disharmonious part, that which had been fragmented off, and working gently with it. Gentle action would work at the level of meaning, of active information, of correlating flows and engaging coherence in metabolic processes.

It would be interesting to explore some of the healing traditions in terms of certain of the concepts discussed above. Always bearing in mind, of course, their strictly limited and provisional nature. By exploring ideas back and forth across different world-views it may be possible to discover new ways of opening up Western medicine to some of the deep insights of other traditions.

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For the interested reader, the author has elaborated on theoretical underpinnings from quantum physics in support of his thesis. [Ed.]:

TECHNICAL APPENDIX

SUBTLE CONNECTION: NON-LOCALITY, BELL'S THEOREM, COHERENT STATES AND THE FORM OF THE WAVE FUNCTION

ABSTRACT

Non-locality in quantum theory is discussed in terms of the global form of the wave function, and as subtle set of necessary and sufficient conditions on the 2-matrix or reduced density matrix. In addition to manifesting itself through the well known Bell's inequalities non-locality also appears as a macroscopic coherence length in condensed and coherent systems. By examining the structure of the 2-matrix, a connection between these two forms of non-locality is made. It is suggested that subtle enfolded orders and non-local forms may have a wider implication and be relevant for a variety of living systems.

INTRODUCTION

A distinguishing aspect of the quantum mechanical description of nature is its non-locality. Bohr, for example, stressed the undivided wholeness inherent in the quantum mechanical description of nature. The essential feature of the double slit experiment is a sort of wholeness in which changes made at one slit, located a macroscopic distance from the other, result in overall changes to the interference pattern.

The non-locality inherent in a pair of initially correlated particles that become separated by a macroscopic distance has been investigared by Bell[1] and in a variety of experiments.[2] These experiments demonstrate a non-local correlation that cannot be explained with reference to any "local" theory in classical physics.

This non-classical aspect of quantum theory, its essential wholeness, is also connected to what could be called the "form" of the wave function. In classical systems it is generally possible to separate the system's description into that of various spatially separate subsystems in interaction. In quantum theory, however, the wave function is not spatially separable in this way, into a product of subsystems, and so the special form of the wave function plays a significant role.

While a quantum mechanical wave function is not truly separable into a simple product of different contributions it is, to a good approximation, possible to treat a system of, for example, two alpha particles and four electrons, as being more or less reducible to a description of two helium atoms with a weak interaction between them. However, in certain other circumstances a collection of helium atoms—alpha particles and electrons—will act in a markedly different way, as a single collective or coherent state—a superfluid. Likewise, under certain conditions, a gas of electrons will also act as a single coherent whole.

The nature of these coherent and condensed states is reflected in the very special forms of their wave functions and the fact that they preserve their internal correlations over macroscopic distances. This feature is totally novel to the quantum theory and does not occur in any classical system. Thus *form* of the wave function exercises a sort of dynamical holism over the system, ensuring the active, dynamical correlation of every particle within the coherent system, no matter how far apart they may be from each other.

This novel dynamical order will be discussed using a formalism known as density matrices, which make certain quantum mechanical implications quite explicit. It will also be used to explore the relationship between dynamical forms and non-locality, or what could be called the "acausal connectivity" inherent in quantum theory.

QUANTUM INSEPARABILITY

Think of two "classical" particles 1 and 2 located at some great distance from each other. The first particle is in state A, say, while the other is in another state B. As the particles slowly approach each other they begin to experience each other's interaction. This is extremely weak at first, since the strength of a force falls off with the inverse square of the distance.

If we ask for the total state S of this weakly interacting system then it is a simple matter to write it as

$$S(1,2) = A(1) \times B(2).$$

This illustrates the essential mechanical nature of classical systems, that they are composed of interacting parts and, in consequence, can be broken down into components again.

Now let us contrast the above description to that of a quantum system where two electrons 1 and 2 are separated by a great distance. By analogy, we would say that the first electron is in state $\emptyset$ and the second in state χ. Suppose that they are so far apart that the electromagnetic interaction between them is extremely weak. One would

assume that the total state of the system $\bar{\Psi}$ (1,2) could be written, by analogy, as

$$\bar{\Psi}\ (1,2) = \emptyset(1) \times \chi(2).$$

But this turns out to be entirely incorrect, for the wave function of a quantum system is never separable in this way; it is never reducible to a simple product of states. Indeed, as Neils Bohr so often stressed, quantum systems must always be considered as undivided wholes.

One reason for this essential quantum mechanical non-separability was discovered by Wolfgang Pauli in terms of a special non-local symmetry that must be obeyed by all quantum mechanical wave functions. In essence, for an N-particle system:

$$\bar{\Psi}(1,\ 2...i,j...N) = \bar{\Psi}(1,2...j,i...N)$$

or

$$\bar{\Psi}(1,2...i,j...N) = -\bar{\Psi}(1,2...j,i...N)$$

That is, under the interchange of any pair of particles the wave function is either symmetric, or antisymmetric. The former case refers to Bose particles (force carriers like photons, gravitons, some mesons, etc.) while the latter refers to Fermions (matter particles like electrons, protons, neutrons, etc.) [More generally, if spin and other internal coordinates are separated out of the wave function then its spatial form must conform to a particular Young Tableau.]

It turns out that, as a result of this requirement of symmetry or antisymmetry, the wave function of a system can never have a separable form, a fact which has a profound theoretical outcome as Bell's Theorem.

BELL'S THEOREM

The spectrum of ideas leading to Bell's Theorem began with Einstein's attempt to find an objective meaning to the local properties of a quantum system. While Einstein was willing to admit that it may never be empirically possible to specify exactly both the position and momentum of a particle, he nevertheless maintained that such a concept retains an objective meaning. The electron has a path, argued Einstein, even if we are forbidden from ever determining its parameters.

To support this concept of local reality Einstein, along with Podolski and Rosen (EPR), proposed a special type of non-destructive experiment.[4] In essence, an initially correlated system is separated into two correlated parts. Since the overall momentum of the system is conserved it should be possible, by measuring the momentum of one particle to

deduce the momentum of the other. Likewise, a measurement of the position of one particle enables us to deduce the position of the other. Thus, Einstein believed, it is meaningful to describe the undisturbed electron as having well-defined properties—position and momentum. By never observing the particle directly and only making measurements on its correlated partner the election's independent reality was never disturbed.

Bohr,[5] however, countered the EPR argument by stressing the holistic nature of quantum systems and suggesting that the very disposition to measure one of a pair of non-commuting observables changes the whole context of an experiment and renders the meaning of the second observable ambiguous.

A further step came with Bohm[6] who focussed the argument on the antisymmetry of the wave function. A pair of particles in an eigenfunction of a antisymmetry operator, and will continue to remain in such a state no matter how far apart they separate. The overall antisymmetry of the wave function for the two electrons has nothing to do with any physical interaction between them. Indeed, this non-local property is essentially non-classical in nature. Such non-locality is incompatible with a theory based on the notion of a local reality or any local hidden-variable theory.

It remained to John Bell to demonstrate how non-classical correlations between pairs of particles, arising out of the (non-local) antisymmetry of the overall wave function, can be experimentally and definitively distinguished from the predictions of a local reality theory. Such experiments have been repeated many times and come down firmly in favor of non-local, quantum mechanical reality.

The special dynamical form of the wave function, called antisymmetry, is the essential feature leading to non-separability and the sort of "acausal" connection described by John Bell. The implications of Bell's Theorem have led to all manner of speculation. What, some people have speculated, would be the effects of non-local correlations within living systems and, in particular, the brain? There have even been attempts to explain such things as telepathy and the paranormal in terms of Bell correlations, i.e., through correlations that do not fall off with distance. However, these discussions generally miss the important point that the *Bell correlations are not mechanical in nature, they do not involve, for example, some new sort of instantaneous force.* It is no use attempting to construct a new sort of long range transmitter, or telepathic device, that would make use of Bell correlations to transmit information from one location to the next. What Bell's Theorem demonstrates is an essential wholeness within the quantum system and a correlation of its total state that can only be understood in non-local terms.

Now cautioning us to avoid seeing the Bell correlations in terms of forces and mechanical connections does not mean that non-locality may not have important implications

elsewhere. Indeed, as we shall see, the global nature of the wave function plays a key role in all coherent systems. Bell's famous theorem, and the active discussion that still surrounds it, has always been concerned with the non-classical correlation of only two particles. But, as this appendix paper shows, this dynamical, non-local correlation is generally true of all quantum states. In the discussion of subtle energy processes the whole notion of global *form* was emphasized. Now we see how one such example of a global and non-local form arises out of the antisymmetry of the wave function. This antisymmetry, and the significance of the form and the wave function is an essential feature of quantum theory. In the sections below, some of the implications of these quantum connections will be demonstrated using a particular formalism, called the Density Matrix, to render them explicit.

THE DENSITY MATRIX

The wave function is the usual descriptive form for quantum theory. However, the so-called reduced density matrix, although less well known, can also be used as a quantum mechanical description and, moreover, contains the Pauli antisymmetry (or symmetry) conditions in a particularly interesting enfolded form. Using the 2-matrix, therefore, non-local correlations and antisymmetry can be displayed in a new formalism. The reason for employing the density matrix formalism in this paper is simply to express the notion of "form" in a new way, one that may suggest novel approaches.

The formalism that is relevant for considering these correlations is called the second order reduced density matrix, or 2-matrix. It is obtained by integrating over an N-particle wave function

$$D^{(2)}\ (12:1'2') = \int_{3..N} \Psi^*\ (123..N)\ \Psi\ (1'2'3..N) \qquad (1)$$

In a sense, a certain degree of information is lost within this process of integration. However, valuable information remains, in an enfolded form, within the 2-matrix and therefore knowledge of this matrix alone is sufficient to allow any expectation value of the N-particle system to be calculated exactly. What is of particular interest is how the Pauli conditions are reflected in the form of the matrix.

First let us see how critical information about the quantum system has been enfolded into the 2-matrix. One would normally calculate the energy of an N electron quantum system in the following way

$$E = \int_{1..N} \Psi^*\ (1..N)\ \hat{H}(1..N)\ \Psi(1..N) \qquad (2)$$

where $\hat{H}(1,2....N)$ is the Hamiltonian of the system

$$\hat{H}(1..N) = \sum_{i=1}^{N} \hat{H}(i) + \sum_{i<j}^{N} \hat{V}(ij) \tag{3}$$

In terms of the 2-matrix this energy can now be written exactly as

$$E = \frac{N}{2} \text{Trace } \hat{h}(12)\, D^{(2)}(12:1'2') \tag{4}$$

where $\hat{h}(12)$ is called the reduced Hamiltonian

$$\hat{h}(12) = \hat{H}(1) + \hat{H}(2) + (N-1)\,\hat{V}(12) \tag{5}$$

And, let me stress, that (4) is not an approximation but an exact result.

This reduced Hamiltonian has a spectrum of eigenvalues and eigenfunctions

$$\hat{h}(12)\, \phi_n(12) = e_n\, \phi_n(12) \tag{6}$$

We can expand the 2-matrix in this complete set of eigenfunctions

$$D^{(2)}(12:1'2') = \sum_{n,m}^{\infty} B_{nm}\, \phi_n^*(12)\, \phi_m(1'2') \tag{7}$$

This enables expression (4) for the energy to be written as

$$E = \sum_{n}^{\infty} B_{nn}\, e_n \tag{8}$$

which means that in order to calculate the total energy of the N-electron system all we need to know is the complete solution to a corresponding 2-electron problem (the eigenvalues to the reduced Hamiltonian) together with the coefficients $\{B_{nn}\}$. This is a very interesting conclusion, for it tells us that all the complexity of the many body problem is enfolded within the solution of a corresponding 2-body problem (using the reduced Hamiltonian) plus a set of the numerical coefficients. It turns out however that the $\{B_{nm}\}$ contain, in an enfolded way, all the subtle information about the various global correlations within the quantum many body system.

This result holds for any observable or measurement within the system. All one needs to know are a set of eigenvalues to the reduced two-body operator and the corresponding numerical coefficients in the 2-matrix.

It seems that the many body problem has been partitioned into two parts, one of which deals with a paradigm two body problem and the other (the $\{B_{nm}\}$) of which contains information about different sorts of correlations between electron pairs within the system, including those non-local correlations that are the direct result of Pauli's principle. (This is not to say, however, that the quantum system has been physically

partitioned; rather, the mathematical formalism for representing the various correlations within the system.)

It turns out that what is physically really interesting about a many electron system, or other many body problem, is present in this second part, that is in the complex and subtle interrelationships amongst the $\{B_{nm}\}$, for it is here that the implications of the non-local form of the wave function have hidden themselves.

As an example, suppose we wish to determine the energy of a large atom. The first step would be to calculate the complete set of two body energies and eigenfunctions to the reduced Hamiltonian $\hat{h}(1,2)$. This can be done in a fairly straightforward fashion to a high degree of approximation.

Already a great deal of information is contained within this complete set of eigenvalues so one may perhaps be excused for believing that the difficult work of calculating the total energy had already been done. One would assume that these values would be inserted into equation (8) along with some reasonable assumptions for the values of each of the $\{B_{nn}\}$. Very quickly, however, one learns that this approach gives disastrous results.

In fact, even by imposing some very reasonable constraints upon the $\{B_{nn}\}$ the calculated energy falls far below the true ground state energy for the atom. This indicates that the Variation Principle has been violated—in other words, that one must have been working with a 2-matrix that is not derivable from an antisymmetric wave function. (The Variation Principle states that energies calculated with any trial or approximate wave function will always lie above the true energy of the system. One normally proceeds by making constant adjustments to this trial wave function until the energy falls as low as possible—i.e., approaches the true energy asymptotically from above. It is only possible to violate this principle if the wave function does not possess the correct antisymmetric form.)

We are therefore faced with the following quandary. The 2-matrix allows us to calculate, in a very compact form, the expectation value of all quantum mechanical observables for a particular system. All we have to ensure is that a trial 2-matrix should be derivable from a wave function that has the correct antisymmetric form. The conditions that would correspond to this restriction are called the N-representability conditions and, it turns out, that they are extremely subtle for they express what could be called an enfolded relationship between the complete set of coefficients $\{B_{nm}\}$ and the eigenfunctions $\{\phi_n\}$ to the reduced Hamiltonian $\hat{h}(1,2)$.

Despite considerable research activity these conditions are not know in an explicit, or what for a better would could be called a compact, form. Rather one must always first

go to a full N-particle wave function in order to impose conditions on the 2-matrix. The goal of N-Representability conditions would be to discover some new conditions for dynamical non-locality, upon the 2-matrix. Clearly this must occur in nature in a very interesting and subtle way. Indeed, the full import of the special form, or non-locality of the wave function can only be appreciated when one goes to the 2-matrix. While Bell's Theorem was specifically formulated to deal with the non-classical correlation of only two electrons one can see within the 2-matrix a more general set of conditions that express the non-classical correlations of a many body system.

ATOMIC CORRELATIONS

Let us look at a simple example, an atom which contains four electrons. Since physical systems seek the lowest possible energy one would assume that, to a good approximation, one would simply inset the lowest eigenvalues e_n in equation

$$E = N/2 \ \Sigma \ B_{nn}e_n \tag{9}$$

with appropriate bounds upon the B_{nn}. It can be shown that these bounds are of the form

$$0 \leq B_{nn} \leq 1/(N-1) \qquad N \text{ even} \tag{10}$$

where N in this case is 4, i.e., the B_{nn} must all be less than or equal to 1/3. So as a first guess one would approximate the total energy of the system using the first three 2-electron energy levels, i.e., $1s^2$, 1s2s ^1S and 1s2s ^3S with equal weights of 1/3. However, as we have hinted above, this gives an absurdly low and physically unacceptable result. In fact, the antisymmetric form of the wave function demands that an additional $2s^2$ energy level be included in (9). What is striking about this energy level is that it lies within the 1sns continuum—i.e., there are an infinite number of 2-particle energy levels lying below it. Nevertheless what could be called the antisymmetric form of the wave function, or its non-local correlations, are enfolded within the 2-matrix in such a way that the B_{nn} are not independent of each other but are all related through a set of conditions enfolded within the eigenfunctions $\{\phi_n\}$. Specifically at this first level of approximation:

$$\begin{aligned} &B_{11} = 1/6 && {}^1S \\ &B_{22} = 1/6 && {}^1S \\ &B_{33}\text{-}B_{55} = 1/6 && {}^3S \text{ (triply degenerate states)} \\ &B_{66} = 1/6 && {}^2S \end{aligned} \tag{11}$$

I cannot stress too much the importance of this result, that a $2s^2$ level should be included. It demonstrates that antisymmetry—the non-local form of the wave

function—makes an unusual and non-classical demand upon the 2-matrix, a demand that forces upon it an enfolded order.

Why do we call this a non-local effect? Because the special form of the wave function, its antisymmetry, has a profound effect not only upon the dynamics of each electron but upon the way in which the electrons interact with each other. Let me illustrate this in the following way. Suppose, in the above example, one were to switch off the electromagnetic interactions between electrons, retaining only the attractive force between each electron and the atomic nucleus.

The Pauli principle dictates that rather than electron pairs all occupying the lowest energy 1s state, they must arrange themselves according to expression (11), i.e., pairs of electrons also occupy the 1s2s and $2s^2$ states.

In itself this is a non-classical result. Now look what happens when the electron-electron interaction is switched on in a progressive way. Suppose at a first approximation we allow each electron, in turn, to experience the electron density of all the others, i.e., to move in the electrostatic field produced when the other electrons are held in place. By repeating this process successively with each electron, one can investigate the average effect of how each electron adjusts to the interaction of all the others. This is what is known as the Hartree-Fock approximation and, using the wave function approach, it involves writing the wave function as a single Slater determinant and varying each electron orbital until the total energy is minimized.

What is the equivalent approach in the 2-matrix picture? The Hartree-Fock approximation is exactly the same as switching on the full electron-electron interaction within the reduced Hamiltonian $\hat{h}$ (12) and determining its exact energy eigenvalues. That is, the Hartree-Fock energy is equivalent to solving the interactive 2-electron problem exactly. However, in writing down the expression (9) for the total energy one still retains the same set of first approximation $\{B_{nn}\}$ given by expression (11). In other words, the particularly weighting factors associated with each energy eigenvalue are those calculated in the absence of electron-electron interaction. That is, while they include the Pauli requirements at what could be called the first level of approximation, they do not take into account the very fine details of an electron pair's dynamics as it responds to the detailed interaction of all other electrons.

In a sense, however, nothing truly unexpected has happened. The real crunch, the truly exciting physics, happens when the final amount of the electron-electron interaction is fully switched on and one is forced to move beyond the Hartree-Fock approximation. In the Hartree-Fock approximation each electron was allowed to adjust to the average motion of all the others. Or, in terms of the 2-matrix, while the exact energy eigenvalues for the 2-body problem were used the weighting factors $\{B_{nn}\}$ did not take into account the detailed changes within dynamics of all the electrons.

It turns out that under the full electron-electron interaction one must take into account the full nature of the eigenfunctions to $\hat{h}(12)$ (also called geminals). This is how the special form of the many body wave function is enfolded within the 2-matrix, for the effect of making a change to any one of the $\{\phi_n\}$ would affect the entire 2-matrix. In other words, each weight factor B_{nn} is linked in an enfolded way to all the other $\{B_{nm}\}$ and to the complete set of $\{\phi_n\}$. So an interaction that makes even a small change to one particular geminal will effect the whole 2-matrix by changing all the weighting factors $\{B_{nm}\}$. Or, to put it another way, the dynamics of every pair of electrons is correlated in an enfolded or non-local way to every other pair. Earlier it was suggested that, within the Density matrix formalism, the many body problem had been partitioned into two parts–one dealing with a paradigm two body problem and the other giving the $\{B_{nm}\}$. But now we see that a subtle relationship exists between the $\{\phi_n\}$ and the $\{B_{nm}\}$. This relationship is related to the overall global form of the wave function. Or, to put it another way, the subtle internal order of the density matrix arises out of the essential non-local form of the entire quantum system.

To transform from a full wave function into a 2-matrix involves a process of mathematical integration, which is really a sort of enfoldment. In this way, the special form of the wave function is enfolded into a subtle set of mutually dependent conditions that link together all the pair functions and weight factors. What this means, in effect, is that each electron pair is correlated in a very subtle way with every other electron pair. And this correlation, moreover, is not simply the result of the physical force of electromagnetism but a sort of enfoldment of two effects—electromagnetic interaction and N-representability (i.e., the requirement of antisymmetry for the total wave function).

This, I believe, is the full importance of what was only implicit within Bell's result. Because of the non-separability of the general N-electron wave functions, the motion of each electron is related to the whole, not simply through a physical force but through non-local correlations.[9] And so the fine details of the physical interactions between electrons is experienced within the whole system. To borrow David Bohm's phrase, the antisymmetry principle really manifests itself within the implicate order, for it enfolds in a subtle fashion restrictions and correlations upon the electron dynamics.

In this way, I believe, one can establish a metaphoric connection between non-locality, dynamical form and discussions of subtle energy. With the Bell correlations and the N-representability conditions on the 2-matrix we have a subtle form of non-locality that exerts a correlating effect on all parts of the quantum system. One may, perhaps, wish to speak of a correlated dynamics within the system. However, these very conditions caution us that the system is an indivisible whole and should not be treated as composed of even correlated parts. This non-local holism may indeed have significance for a consideration of subtle energy within living systems; it certainly does so for coherent and condensed matter.

But this is not to say that one would necessarily use the 2-matrix language in order to discuss subtle energy. Indeed the drawback of this form of description is its somewhat static nature. Rather the purpose of this appendix is to explore the implications of "enfolded non-locality" and "global form" within a particular formal language. By showing the particular subtle way in which this dynamical order operates one may perhaps gain a new respect for subtle process and of the need for a new formal language in which to discuss non-local correlations and the circulation of subtle energy.[9]

SUPERCONDUCTIVITY

A novel feature of quantum theory is that the wave function must have a special overall form and, as we have shown above, one can also see this in an equivalent way as the enfolded order of the 2-matrix. It turns out that the effects of this enfolded order are even more remarkable when it comes to superconductivity and correlated systems. Indeed, it becomes apparent that the very phenomena are a direct result of this enfolded order, i.e., that such coherence and global order is not possible for classical systems.

Consider the case of a BCS superconductor. (We will leave aside the mysterious details of the new High Temperature superconductors.) The conventional BCS theory has it that a phonon-mediated[10] interaction causes a coupling between electrons in momentum space—the Cooper pairs. In most accounts of superconductivity it is held that the entire electron gas condenses into these Cooper pairs, i.e., that the pairs behave as Bosons and an actual Bose-Einstein condensation occurs. It is this supposed condensation which is then held responsible for the phenomenon of superconductivity.

This, in fact, is not correct and the actual collective state is the result of a much more subtle tension, or enfoldment, between these electron pairs and the overall antisymmetric form of the wave function or, in the case of the 2-matrix, the N-Representability conditions. As we shall see, within this tension of N-Representability, it is possible for the 2-matrix to take on a special form in which off-diagonal long range order (ODLRO) is present so that correlations persist across macroscopic distances. These macroscopic correlations are in fact common to all coherent systems and are particular feature of quantum theory with its curious non-locality.

Again we only begin to see the true nature of the constraints of overall dynamical form when we come to work within the 2-matrix formalism. Normally a discussion of superconductivity would take place within a second quantized formalism, and while this may be convenient for numerical calculations it obscures other details and leads, for example, to the erroneous conclusion that Bose-Einstein condensation is possible within an electron gas.

For the purpose of the present discussion let us work with diagonal form for the 2-matrix

$$D^{(2)}(12:1'2') = \Sigma\lambda_n \Psi_n^*(12) \Psi_n(1'2') \tag{12}$$

Since

$$\hat{D}^{(2)}(12:1'2') \Psi_n(12) = \lambda_n \Psi_n(12) \tag{13}$$

the $\{\lambda_n\}$ are eigenvalues to $\hat{D}^{(2)}$, with the $\{\Psi_n(12)\}$ as corresponding eigenfunctions. In general, for electrons in an atom, molecule or metal the λ_n are of the order of $1/N^2$ with, as was shown in the previous section, a subtle enfolded relationship between the $\{\Psi_n\}$ and the eigenvalues $\{\lambda_n\}$.

However, a general result that follows from the basic requirement that a 2-matrix should be N-Representable (i.e., a necessary but not sufficient condition that it should be derivable from any general sort of antisymmetric wave function) is that

$$0 \leq \lambda_n \leq 1/N \tag{14}$$

As was said before, this upper bound is never normally approached. However, in the case of a superconductor it turns out that

$$\lambda_1 \sim 1/N \tag{15}$$

along with of the order of N^2 additional states, each with very small eigenvalue of the order of $1/N^2$.

The occupation number of the lowest state, the Cooper Pair, is therefore not 1, as is normally believed, but of the order of 1/N. Condition (15) is a unavoidable restriction, a limit that nature places upon the internal dynamics of all fermion systems, no matter how they chose to pair themselves up. We therefore see that, thanks to condition (15) which is a particular expression of the Pauli Principle, the expectation value of the Cooper pair can never exceed 1/N.

Not only are the statistics of electron pairs not Bose-Einstein, neither are they what are called "intermediate statistics". It is sometimes incorrectly held that, through the action of certain attractive forces, electron pairs obey a form of statistics that lies midway between Fermi-Dirac and Bose-Einstein. In such a case the $\{\lambda_n\}$ would be represented as a set of variables whose bounds lie between the occupation numbers corresponding to Bose and Fermion pairs and each of which is a simple function of the others. However, the true statistics of these occupation numbers is far more complicated than this because each is dependent, in a complicated way upon all the other occupation numbers and eigenfunctions of the 2-matrix.

These considerations show us that the statistics of electron pairs within a condensed system are indeed far more complex than Bose-Einstein or Intermediate statistics. Indeed, it is the overall form of the wave function, or the subtle N-Representability conditions, that give rise to the coherent behavior within a superconductor whereby the dynamics of the electrons are interconnected in a very complex fashion.

In particular, C.N. Yang[8] has shown that, despite the fact that λ_1 is vanishingly small, there will still be off-diagonal long range order within the 2-matrix. In other words, thanks to the subtly enfolded order of the 2-matrix, *the correlation between different regions of the superconducting electron gas does not vanish at macroscopic distances.*

SUPERFLUIDITY

A discussion of superfluidity in terms of the reduced density matrix is far more complicated than in the case of a superconducting electron gas. Most texts treat the helium atoms in a superfluid as pure Bose particles and the phenomenon itself as a case of Bose condensation. At a certain level of understanding this may be helpful. However, the simple fact of Bose condensation is not sufficient to produce a superfluid. What is required is a coherent wave function in which scattering into higher momentum states is prevented. Without this additional requirement, a condensed state would not exhibit flow without resistance.

The coherence of the superfluid's wave function arises in the attractive interaction between helium atoms as a result of their polarization. A proper treatment of a superfluid must therefore include virtual excitations of the electronic wave functions around each helium atom, a fact that immediately leads to an extremely complicated statistics for the helium atoms themselves—a statistics which does not simply deviate from pure Bose statistics into "intermediate statistics" but involves the sorts of enfolded conditions met in the case of superconductivity.

A deeper insight into this problem would involve detailed analysis of the reduced density matrix as a function of both the nuclear center of mass and electronic coordinates. The N-Representability conditions on such a matrix would then arise from symmetry in nuclear center of mass coordinates and antisymmetry in electronic coordinates. This analysis is beyond the scope of the present appendix. However, it is sufficient to note that macroscopic coherence and off-diagonal long range order in the 1-matrix (expressed in terms of nuclear coordinates) follows directly from subtle and complicated interrelationships arising in the higher order density matrix, expressed in both electronic and nuclear coordinates. Again long range order, global symmetry and antisymmetry requirements on the wave function are interrelated.

CONCLUSIONS

The global symmetry or antisymmetry of the wave function is a feature unique to quantum theory. Information enfolded within the form of the wave function plays an important role in both the sort of non-local correlations discussed by John Bell and in the detailed behavior of condensed and coherent systems such as superconductors and superfluids.

What is of particular significance is that coherent states may play a key role in all living systems. Indeed, there may be something essentially quantum mechanical about life. This special feature seems to involve a sort of enfolded order of dynamics, a subtle correlation that enfolds and unfolds within the different movements of the system. Such an order is not inherent within "classical systems" in which such non-local, or global, symmetry requirements are not available.

The importance of the reduced density matrix representation in understanding this is that non-locality in the wave function becomes explicitly translated into a set of enfolded interrelationships between states and occupation numbers. In a condensed state, for example, these correlations ensure off-diagonal long range order which corresponds directly to macroscopic coherence within the physical system. The density matrix approach was therefore used in this appendix in order to illustrate how non-locality can appear us an enfolded or implicate order form. However, in the light of the previous discussions of verbal languages and process mathematics we must acknowledge that, as presented here, the density matrix remains static and does not form to the content of description.

The unique feature of quantum theory, its rejection of local reality, has been emphatically demonstrated by Bell in the particular case of a correlated pair of electrons that are then separated by a macroscopic distance. We have now seen how manifestations of non-locality can also be found within condensed systems and may well be the key to living systems. Subtle correlated changes to the boundary conditions of sensitive systems can produce large, coordinated changes. The mechanism of memory in the brain, for example, while it remains obscure, may well be non-local in nature and it is possible that global correlations of boundary conditions could play a role in the nervous system. *Such notions as the circulation of energy, information and subtle correlations throughout the body may well have some connection to some of the ideas discussed in this appendix.*

REFERENCES AND NOTES

1. J.S. Bell, *Physics* 1 (1964), p. 195.
2. For example see A. Aspect, A. Dalibard and G. Roger, *Physics Review Letters* 49 (1982), p. 1804.

3. A review which contains references to the various properties of reduced density matrices discussed in this article can be found in F. David Peat, *Physical Chemistry, An Advanced Treatise* (H. Eyring, D. Henderson & W. Jost, Eds. (Academic Press, New York, NY, 1975), p. 429.
4. A. Einstein, B. Podolsky & N. Rosen, *Physics Review* 47 (1935), p. 777. See also Quantum Theory and Measurement. J. S. Wheeler and W. H. Zurek, Eds. (Princeton University Press, Princeton, NJ, 1983).
5. N. Bohr, *Physics Review* 48 (1935), p. 696.
6. D. Bohm, *Quantum Theory* (Prentice-Hall, Englewood Cliffs, NJ, 1951).
7. A. J. Coleman, *Review Modern Physics* 35 (1963), p. 668.
8. C. N. Yang, *Review Modern Physics* 34 (1962), p. 694.
9. A note of caution about that word "correlation": properly speaking it means the connections within a system. However, theoreticians who make calculations of atomic and molecular energies have come to use the word in a more restrictive form, i.e., as " correlation energy," meaning a set of detailed corrections that go beyond the Hartree-Fock approximation. In the present paper, however, the world "correlation" is being used in its more general sense.
10. Phonon (a quantized vibration of the metal lattice).