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SYNCHRONICITY

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Sometime during the year 1961, I visited the Museum of Science and Industry in Chicago. In the center of the museum there is a display which aims to illustrate the nature of statistical procedures. Large steel balls are dropped from a vaulted ceiling some three stories high. They end up in a Gaussian heap with an almost deafening clatter. The description of the display prepared by the Museum for its visitors points out the impossibility of predicting the path of any of the balls and then goes on to emphasize that the outcome of the fall of so many of them is always the predictable Gaussian distribution. This, the Museum's description waxes, is the mystery of probabilities which it is the office of statistics to manage for us.

A decade later, Jacques Monod, in his fascinating little volume, Chance and Necessity, detailed his own puzzlement regarding the same mystery as it appears in biology. How is it, he asked, that so many chance events come to comprise the recognizably stable forms of which organism are constructed?

For me the puzzle in Chicago and in Monod's book was a different one. Having recently written Plans and the Structure of Behavior (1960) with George Miller and Eugene Galanter, I was impressed in Chicago by what the Museum had left out of its description: the fact that the metal balls fall through a very large plastic symmetrical maze! In reviewing (1972) Monod's book, I used this experience to suggest that there is a universal reciprocity between constraint as it becomes manifest in biological and physical structure and the randomness of the events constrained by that structure. The Gaussian is as much a reflection of the symmetry of the structure through which the balls pass as it is of the unpredictability of the path of each ball through that structure. Reciprocity does not dispel the mystery but it does describe it more accurately.

Today I want to carry this idea of reciprocity to help penetrate another mystery, the mystery of synchronicity. Once again, there seem to occur chance events which nevertheless describe some meaningful pattern.

Carl Jung is responsible for the concept "synchronicity." A behaviorist friend once remarked that he was certain Jung had been insane, that surely such a concept as synchronicity could not be of interest to someone sane. Careful reading of Jung's precise operational definitions of every concept he employs should quickly disabuse even the staunchest behaviorist of the idea that there was anything wrong with Jung's mentality. In fact, Jung made certain observations, similar to those which others have also reported, and was extremely puzzled by the apparent connections between the observations. He thought that the then current discoveries in quantum physics held clues which would solve the puzzle.

In quantum and nuclear physics, as in Jung's observations there appear events which seem to be related but the relationship defies explanation in ordinary terms. Thus in the Einstein-Podolsky-Rosen "Gedanken" experiment and in the observations subsumed by Bell's theorem, pertubations of an elementary particle can momentarily influence another at a distance when the only connection between the particles is historical. Within the nucleus, the appearance of quarks can be described mathematically but the descriptions involve the occasional reversal of the time arrow or of causality.

What are described in both physics and in Jung's observations are correlations. In fact, all observation begins by noting correlations. What causes trouble is the attempt to determine a direction of causality within the correlations. David Hume's famous example of the correlation between a cock crowing and the sun rising is typical. The cock crows then the sun rises. Ordinarily we expect the antecedent event to be causal to the subsequent one. In the cock and sun example the causality appears to extend in the reverse direction. Closer examination, however, reveals that the circadian rhythms of the cock become entrained by the rising of the sun and that his crowing can therefore anticipate the sun's rising. The circadian rhythms constitute an order, an arrangement of events that lies behind the observed correlation.

Observations of relationships between chance and necessity are also correlations. If it is believed that the constraints of necessity must evolve from chance events--that the chance events anticipate their own constraining-- problems arise which are difficult not only to answer but to frame as reasonable questions. If, on the other hand, we chose to believe that the constraints are prior, we are pushed to asking as well: How do the constraints arise? Thus it seems better to ask, as in the case of the cock and the sun: Can we discern an order which lies behind the observed correlation? With respect to to quantum physics, this is the direction which Bohr and Heisenberg took when they emphasized the importance of the observer and the apparatus he chooses. Following their lead, the cock/sun example would suggest we examine the brains of scientists (and brains in general) to see if there is any mechanism (such as there was in the case of the entrainment of circadian rhythms) which would account for the observed correlations. I believe there is and that it leads us back to both physics and synchronicity.

As almost everyone knows, there is a correspondence between the sensory surfaces and muscles of the body and their projections onto the surface of the cortex. The famous homunculus drawn on maps of the cerebral hemispheres represents these correspondences. The homunculus forms a coarse-grain map of the spatial relationships between the organism and his environment. Less well known is the fine-grain relationship encoded within the receptive field properties of the cortical neurons. Each receptive field has been shown to respond selectively to several sensory qualities. In the visual system, for instance, a cortical cell will respond selectively to a colour, say red, a direction of movement, say from right to left, the velocity of the movement, and something called spatial frequency.

Spatial frequency is of special relevance to the synchronicity problem. Initially, the discovery was made by David Hubel and Torsten Wiesel that many visual cortical cells would respond especially well when a cat or monkey was shown a line of a particular orientation. A decade later, even greater selectivity was elicited in several laboratories when multiple lines (gratings) rather than single lines were presented at the preferred orientation. The gratings varied in the width and spacings of the component lines. Thus when various gratings are scanned at some constant speed, the frequencies with which light and dark alternate, differ. Since these frequencies are determined by spatial rather than by temporal differences, they are called spatial frequencies.

Each receptive field of a cortical cell was found to be tuned to approximately an octave of spatial frequency. Tuning curves of adjacent receptive fields overlap. The sensory-cortical mechanism can be conceived to operate something like a piano. When a stimulus strikes a sensory receptor (e.g. in the retina), the receptor functions much as does a key on the piano keyboard. The excitation is relayed to the receptive field (the string) to which it is connected in the cortical sounding board, inducing a resonance. However, the receptor does not function as if its keys were independent. Because of connections among neighboring receptors, the entire receptor surface acts more like a stringed than a percussion instrument.

Similarly, interconnections among receptive fields make the cortical resonance more like that of a wind instrument. Or, taking a more complex analogy, the sensory surface scans the environmental changes to which it is sensitive somewhat as a television camera scans a scene. The results of the scan are transmitted and then picked up in those locations within reach, which are fashioned with the appropriate receivers. Note that any of these devices are capable of mediating a practically infinite number of complex patterns composed from the action of a relatively few distinct elements.

From the congerie of receptive fields, each tuned to a fairly limited bandwidth of spatial frequency, the complexities of spatial vision are constructed. The mathematics which decribes the the relationship between the spatial configuration of the grating used to examine the receptive field, and the spatial frequency tuning curve of that field, is the Fourier transform. The Fourier theorem states that any pattern, no matter how complex, can be analyzed into components consisting of regular wave forms of different frequencies and amplitudes. Further, the pattern can be reconstructed from the components provided track is kept of the phase relationships between the components. The Fourier transform does the analysis into components in a fairly straightforward fashion, and the same transform accomplishes the inverse. Dennis Gabor realized this characteristic of the Fourier theorem in the invention of the hologram. The holgram stores the Fourier transform of a pattern which can subsequently be reconstructed by applying the inverse procedure.

The hologram displays a most peculiar and interesting organization. David Bohm refers to it as an "implicate order" (1981) because all form and pattern, including space and time, become enfolded within it. As well, the hologram is a distributed order. These non-local characteristics are just those which pose the problem in quantum physics. We might say that the implicate order in physics "entrains" the Fourier process in the physicist's brain. However, "entails" would be a more appropriate description of the relationship in this instance.

The parallel to the cock/sun example is thus complete: There is a mechanism in the brain which can be taken as an order which lies behind the observed correlations in quantum physics. This order is the Fourier transform of spatial pattern. Just as an understanding of the process of entrainment of circadian rhythms makes possible an understanding of the causal relationships involved in the observed correlation between the cock's crowing and the rising of the sun, so, an understanding of the Fourier process in the brain makes possible an understanding of the causal relationships involved in the observed correlations which constitute quantum physics.

Let us review the issue. The cock's crowing precedes the sun's rising. Ordinarily, we attribute proximate causality to operate in the same direction as the time arrow. This doesn't make sense in the cock/sun example, so we search for an explanation and find it in the entrainment of the cock's innate circadian rhythm. In quantum physics similar problems arise in attributing proximate causality: The caused appears to precede the causing or else there is no understood basis for the observed correlation whatever. This doesn't make sense so we search for an explanation. Following the lead that it is the intrusion of the observer into the observation which may account for the difficulty, we examine the brain of the observer and find the Fourier process by which patterns are transformed into a holographic-like order from which they can be reconstructed. We now ask whether the realization of the Fourier brain process has explanitory power in physics.

The answer to this question lies with the power of the Fourier theorem and all the mathematical procedures which stem from it to transform from the ordinary space/time world of proximate causality to an enfolded, distributed non-local order in which correlations and only correlations exist. This power of the tranform is used in computer and statistical sciences in the form of FFTs, fast Fourier transforms, whenever correlations must be computed to any depth. The procedure is also the basis of CAT and PET scans which form images by correlating in the transform domain the results of restricted individual recordings.

Once the non-local nature of the transform domain is clearly recognized its presence helps understanding at many levels. This ubiquity is perhaps best demonstrated in Einstein's very basic formulation regarding the relationship between energy and mass: E=mc2. In quantum physics E, the energy term is measured as momentum; m the mass term in gravitons appearing in certain locations; with c, the speed of light determining the time arrow. (At the speed of light time stands still.) Thus the right side of the Einstein equation represents space/time as we ordinarily perceive it. The left side of the equation represents momentum, the potential of energy available at any moment. E is therefore a non-local term which is, in fact, related to space/time via a Fourier transform!

The brain, as we saw above, has the capacity for both space/time and non-local processing. Why then, in quantum physics are we limited to observing one or the other? Why cannot we observe both the momentum and location simultaneously? The answer is complementarity, introduced by the techniques and apparatus used to make the observations. However, in keeping with Bohr's conception, complementarity is a fundamental property of both the observed and the observer, and not just an artifact introduced by the procedure. The Fourier theorem expresses this basic complementarity.

Recognizing the existance of a non-local transform domain in which correlations and only correlations can occur, places the observations which are summarized under the concept synchronicity into a framework with other observations of non-locality. Syncnronicity appears bizarre because our senses and brains are programmed to seek proximate causality even when only correlations are observed. In the case of synchronicity, as in the case of the cock and sun and in quantum physics, proximate causal relationsnips can be introduced only by reference to the observer who stands behind the observations. The brain of the observer is endowed with transform capabilities which allow a non-local ordering as well as a space/time ordering of events.

Several difficult problems remain. Why is the space/time order so much easier to access than the non-local order? Are the space/time and non-local complementary orders exhaustive or are there many other, as yet unrealized orders? (This is the many possible worlds problem.) By what mechanisms are mystical experiences which often display non-local properties generated? And finally, are the space/time, non-local and other possible orders completely the construction of our senses and brains or do they reflect a universal cosmology of which the senses and the brain partake? (This is the same question as asking whether mathematics is an invention or a discovery.)

From the direction taken in this essay, an important aspect of the search for the answers to these questions is to learn more about the brain which is asking the questions. At this point in history, it appears important once more to join efforts in the life sciences to those in the physical sciences. Only a century ago, a quantitative sensory psychophysics was construced from such a joining. Now, the need is to develop a brain based science which can encompass both the new physics and the spiritual nature of mankind.