6

Vibrations and the Realization of Form

Ralph Abraham

Universal Form and Harmony
were born of Cosmic Will,
and thence was Night born, and thence
the billowy ocean of Space;
and from the billowy ocean of space
was born Time—the year
ordaining days and nights,
the ruler of every movement.

Rigveda X 190

1. INTRODUCTION TO MACRODYNAMICS

Macrodynamics is a synonym for kymatics. My preference for Anthony's (1969) nomenclature over Jenny's (1967) is just personal taste. If any of this part seems too technical, skip directly to Section 2.

Morphogenesis, the evolution of form from chaos, has a high priority in the philosophical literature of many cultures: the *Rigveda*, *I Ching*, Heraclitus, Cabala, and others. Up to this very volume, phenomenological descriptions of morphogenesis in various spheres abound in our literature. On the other hand, *morphodynamics*—the study of the mechanics of morphogenetic processes in the context of hard science—is just beginning. It has been born of two recent developments: a suitable mathematical foundation, the *theory of catastrophes* of René Thom (1973); and an adequate observational tool, the *macroscope* of Hans Jenny (1967; 1972). Here, then, is a very concise introduction to *experimental morphodynamics*, including a preliminary report on our own macron observations through the first color macroscope. This chapter is dedicated to Neemkaroli Baba, late of Uttar Pradesh.

ISBN 0-201-03438-7/0-201-03439-5pbk.

Erich Jantsch and Conrad H. Waddington (eds.), *Evolution and Consciousness: Human Systems in Transition*.
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Simple Macrons

Macrodynamic processes in nature take place in hierarchical systems of compound (heterogeneous) macron organisms. To understand these processes, we try to dissect them into fictitious categories of simple (homogeneous) macrons. The three basic categories are physical (P); chemical (C); and electrical (E). The physical macrons are further subdivided according to the material state of the macron medium: solid (PS), isotropic liquid (PL), liquid crystal (PX), and gas (PG). Here we discuss examples of these six types.

Physical Solid (PS): A flat plate is vibrated transversally by an external force, usually electromechanical transducers coupled either directly or through an intermediate fluid. A stable aspect of the system is a spiderweb of motionless curves, the Chladni nodal lines, originally observed by sprinkling sand on the plate. The complete vibration pattern of the plate is best revealed by laser interferometry. This pattern is the *macron* in this example. It depends upon control parameters of two types: *intrinsic controls*, such as dimensions and elasticity of the medium; and *extrinsic controls*, such as frequency and amplitude of the driving force. Of course, this example is very special, as the medium is more or less two dimensional. For a generic example in this category, consider a rubber ball in place of the thin plate. Stable modes of vibration are characterized by symmetric distortions of shape, separated by motionless nodal surfaces. If the medium is magnetic or piezoelectric, driving forces may be applied directly with electromagnetic fields.

Physical Isotropic Liquid (PL): Beginning once again with a two-dimensional approximation, suppose a round dish is filled with a thin layer of isotropic liquid, and the bottom of the dish is heated. Soon the liquid will begin to *simmer.* Careful observation will reveal a spiderweb of nodal lines (actually, parallel lines—*rolls* and packed hexagons called *Bénard cells*—are combined in patterns), within which the liquid convects toroidally (up at the boundary of the cell, down in the center). This *Bénard phenomenon* is a macron. Another type is observed by vibrating the bottom of the dish in a (PL) macron. As the amplitude is gradually increased, the liquid layer first behaves as a solid—the *elastic macron;* then, after a certain critical amplitude is reached, the *simmering point*, a convection or Bénard-type simmering fluid flow begins—the *hydrodynamic macron.* The macrons, or stable modes, depend on intrinsic controls such as shape, compressibility, and viscosity; and external controls such as frequency and amplitude of the driving force. In the general case of a thick layer of liquid, the elastic and hydrodynamic macrons are three-dimensional generalizations of these effects. But

ISBN 0-201-03438-7/0-201-03439-5pbk.

there occurs at least one effect of a different type. If the dish is rotated or the liquid is stirred, there may arise toroidal partitions, within which a ring of fluid—a *Taylor cell*—flows spirally. These rings are also seen when a drop of fluid enters another mass of fluid, as in smoke rings. Hierarchical repetition of Taylor cells may be observed by dripping ink into a glass of very still water. The *von Karman vortex street* also belongs to this class.

Finally, we include in this category *isotropic powder*, that is, dust made of spherical solid particles of identical size. Jenny (1967; 1972) has produced Bénard cells in powders of moss spores.

Physical Liquid Crystal (PX): If the medium is in a liquid crystal metaphase, any macrons of elastic or hydrodynamical type may be induced in it. But two additional phenomena have been observed which are peculiar to this phase, and other simple macrons will undoubtedly be discovered which belong especially to this category. If a thin layer of fluid is exposed to a transverse electrostatic field, simmering is induced in approximately hexagonal cells—the *Williams effect.* Presumably, an elastic macron is induced below the simmer point. In an oscillating electromagnetic field, piezoelectric waves are induced—the *flexoelectric effect.* In this category we might also include *anisotropic powder*—dust of identical aspheric solid particles.

Physical Gaseous (PG): In gases, we observe the macrons of isotropic liquid, as well as (presumably) additional pattern mechanisms belonging specifically to this category. Perhaps these gaseous macrons are unique combinations of elastic and hydrodynamical macrons of the (PL) category, possible in this context because of the high compressibility and low viscosity of the usual gases. The enormous dimensions of these macrons make them hard to observe, and at present it is not known whether or not exclusively gaseous macrons exist.

These four classes of macrons compose the category (P) of simple physical macrons. This is the context of most of the research in experimental morphology up to now. The remaining two categories, (C) and (E), are therefore very embryonic at present.

Chemical (C): There are various macrons, or basic pattern phenomena, which are fundamentally chemical in origin. These occur in heterogeneous media, amid chemical reactions. Included are mechanisms of change of state, such as patterns of precipitation, Liesegang rings of crystallization, and opalescences like abalone shell. To this class also belong the classical diffusion patterns as well as the newly discovered patterns of periodic chemical reactions (see Chapter 5 by Prigogine). This is a little-studied category, which will undoubtedly be explored more thoroughly.

ISBN 0-201-03438-7/0-201-03439-5pbk.

Electrical (E): The description of basic electrical macrons is included here for the sake of completeness—in spite of being based almost entirely on speculation—and because of my belief that it will figure vitally in the understanding of the brain and in the engineering of artificial intelligence, sometime in the future.

Consider a heterogeneous medium of smoothly changing physical properties, especially electrical conductivity, and possibly containing sources of charge. This is an *electronic spacework.* An electronic network may be thought of as a spacework with discontinuities, or as a retraction of a spacework onto its skeleton of dimension one. A semiconductor device is an example of a genuinely three-dimensional spacework. However, this concept must be allowed to include matter in all phases, especially charged fluid (plasma, ionized gas, etc.). Thus, classical magnetohydrodynamics (MHD) is included in this context.

In an electronic spacework, subject to controlled external electromagnetic fields or to controlled charge exchange with the environment, macrophenomena of categories (P) or (C), as well as other unique phenomena, may be observed. Those macrons occurring uniquely in the context of spaceworks include category (E). For example, the Störmer orbits and Alfvén waves of magnetogasdynamics and northern lights are macrons of type (E). As in ionized fluids, rolls comprise transformers, Bénard cells are toroidal inductors, Taylor cells combine linear and toroidal induction, membranes are capacitors, and so forth. It may be expected that an entirely new discipline of engineering could be based upon a full understanding of macrons in specific spaceworks. The idea of a liquid crystal transistor, combining fluid, electronic, and MHD technologies, is not too far-fetched.

Macrons of type (E) will be known better in the future, when the development of specific MHD machines will make systematic observation possible.

Complex Systems of Macrons

The macrodynamics of a real event is complex in two ways. First, a single organic structure may exhibit a macron in which physical, chemical, and electrical modes are combined. This is especially the case with biological organisms. Second, two distinct structures may be weakly coupled, forming a larger, compound organic unit. Here we discuss compound modes and coupling separately.

Since basic macrons are of three types, (P), (C), and (E), there are only four types of compound macrons: (P–C), (P–E), (C–E), and (P–C–E).

ISBN 0-201-03438-7/0-201-03439-5pbk.

Physical-Chemical (P–C): A typical situation of this type is a mixture of fluid reagents. While a stable pattern of chemical origin exists, an elastic or hydrodynamic macron is excited. Since convection is faster than diffusion, the hydrodynamic macron dominates the patterns of reagent concentration and reaction rate. For example, Lew Howard and Nancy Kopell (1976) observed Bénard cells with purple hexagonal boundaries and red central cell bodies in the Zhabotinsky reaction, when the surface of the fluid was cooled by evaporation. The separation of the reagents is accomplished by a *separation mechanism*, which, for this *Howard–Kopell phenomenon*, is undoubtedly centrifugation of the reagents. The separation mechanism is also well illustrated by an analogous experiment carried out by Jenny (1967; 1972): Sand is sprinkled on a vibrating plate; it gravitates, very slowly, to the Chladni nodal lines. These motionless curves outline cells of transverse vibration, each with a center, or nucleus, of maximum motion. Now spore powder is sprinkled on the vibrating plate. This moves to the nuclei, forming small piles of powder at each nucleus. Furthermore, each pile can be seen to roll constantly in a toroidal eddy, exactly as in a Bénard cell. In the latter case, I believe the separation mechanism is differential response of the reagents to flotation in invisible Bénard cells excited in the air over the plate by the vibration.

Physical-Electrical (P–E): As in the previous discussion of basic macrons of type (E), we can only speculate on this case, which is exemplified by *plasma*. The production of a toroidal inductor in a fluid spacework by intentional excitation of a Bénard cell is an example of a compound (P–E) macron. The generation of electromagnetic waves by physical vibration of a cholesteric flexoelectric liquid crystal is another.

Chemical-Electrical (C–E): Spaceworks designed specifically to separate ionized components into a particular spatial pattern could be used to grow semiconductor crystals, specialized lenses, or any frozen, precipitated, or crystallized solid in a given pattern. These media are *electrochemical spaceworks.*

Physical-Chemical-Electrical (P–C–E): Physical macrons in fluid reagent mixtures, including liquid crystal and solid components, some of which are charged or otherwise electroactive, comprise the patterns of living organisms. Embryology provides countless examples. This general case may therefore also be called *bioplasma.*

Whereas in the laboratory, macrons of a pure, basic type can be created, in the real world of phenomena only the general case is found. Suppose now that two single systems of bioplasmic (P–C–E) type are at hand, and their separate stable modes are known. Let these two now be weakly coupled, by physical contact, chemical mixing in

ISBN 0-201-03438-7/0-201-03439-5pbk.

small exchanges, interaction through the electromagnetic field, or a combination of these means. The coupled system will now have its own stable modes. How are the combined macrons related to the original separate macrons? This relation, which we call the *algebra of macrons*, is the most intriguing problem of morphology. The classical ideas of resonance, sympathetic vibration, and so on, serve as clues. The experiment of Jenny (1967; 1972), showing the vibrating plate and the overlying air in related macrons (revealed by the eddying piles of powder at the nuclei of the plate macron), gives a more useful example of macron addition.

In fact, there are no pure macrons. In order to study the stable modes of one system, we must couple it to another. Thus, all experiments in morphology are actually examples of coupled macrons, and because the number of organic units in a coupled system of the phenomenal universe is always large, we shall one day be led to a probabilistic, or statistical-mechanical, theory of complex macrons for hierarchical systems. However, this is far off at the moment. We have, at present, only a very rudimentary preview of the mathematical theory of basic macrons.

Geometry of Macrons.

A full understanding of the mathematical description of macrons would require a knowledge of the theory of dynamical systems up to the current research frontier and beyond. For those who wish to pursue this exciting hobby, the introductory book of Hirsch and Smale (1974) provides a good starting point. For our presentation, we shall require but a single concept of that theory, that of *attractor*, which is easily grasped on an intuitive level.

Suppose that a particular medium is to be studied, for example, a bowl of salty jelly. We have to assume (1) that a suitable mathematical space has been described, called the *phase space*, such that each point in the phase space corresponds to a completely satisfactory description of a configuration, or geometrical posture, of the jelly; and conversely, that each posture of the jelly corresponds to a unique labeling point in the phase space. Therefore, jiggling the jelly defines a curve: a point in the phase space, moving along a path. Next, we have to assume (2) that the particular experimental situation of the jelly—for example, if it is stirred in a precise way—is described by a *dynamical system* in the phase space. This is a mathematical structure with the following properties:

ISBN 0-201-03438-7/0-201-03439-5pbk.

(a) The phase space is divided into a number of different zones, called *basins of attraction* (see also Chapter 4 by Holling, Section 3);
(b) In each basin there is a distinguished set, its *attractor*, which is a sort of atomic, or basic, representation of a dynamical system;
(c) If the jelly, in the chosen experimental situation, is set going in any original state, its corresponding curve of successive states in the phase space will proceed in a unique fashion toward a final equilibrium motion near the attractor of the basin in which the curve started.

If we ignore here the nonequilibrium states—which is justified for structures for which the approach to equilibrium is very swift—then all we need to know about dynamical systems is their attractors, which is excellent, because all dynamical systems may then be represented by the same types of "atomic" attractors, in different "molecular" clusters. Further, these common attractors are classified by a system which begins with a simple sequence, starting with the simplest. Here are the first three attractors in this sequence:

1. a single point, corresponding to static equilibrium—the jelly ceases to jiggle, or dies;
2. a circle, with a parameter, corresponding to a cyclic repetition of states, an oscillation in the jelly with a single period, or frequency;
3. a two-dimensional torus, with a curve spiraling indefinitely around it, as in toroidal inductors—corresponding to an *almost periodic motion*, a compound oscillation with two independent frequencies, irrationally related.

This sequence continues with tori of increasing dimension and more complicated compound oscillations, until very chaotic motions are included. The full description of this list of attractors is, in my view, one of the great achievements of mathematics in the twentieth century.

This completes our excursion into dynamical systems theory, and its concept of attractor. By now the intention of this excursion is probably clear: *the mathematical description of a macron is an attractor.* In itself, this does not help us much to understand macrodynamics or morphogenesis.[1] It is actually the theory of *transitions of attractors*, or *catastrophes*, as developed by René Thom (1973), which is the basis for the geometry of macrons, as it has developed so far. Here is the concépt of catastrophe, as used in dynamical systems theory.

Returning to our original experimental situation, we have supposed that the medium of the experiment—salty jelly (or an economy, an

[1] It should be noted that "atomic" attractors, at this stage of theory building, represent global stability and therefore cannot, by themselves, adequately describe nonlinear behavior, in particular, the amplification of fluctuations which may drive the system to the point of a catastrophe, or qualitative change from one attractor to another. (Comment by E. J., editor)

ISBN 0-201-03438-7/0-201-03439-5pbk.

electronic black box, or whatever)—is described by a phase space; and that the specific experimental situation—comprising the fixed values of the various intrinsic and extrinsic control parameters—is described by a particular dynamical system, with its molecular cluster of basins and attractors. It follows, then, that changing the values of the controls will change the dynamical system, the basins, and the attractors, which correspond to observable states, or macrons. Thus, as the controls are smoothly changed, the attractor under observation must be expected to change. But the attractors belong to a discrete list, and can only change in jerks. These are the catastrophes and they may be considered as boundaries of particles, providing a mathematical (nonlinear spectral theory) version of particle–wave duality. In fact, an esoteric quantum field theory based on this analogy has been suggested by Thom, and may one day be developed.

Dynamical systems theory provides us, in addition to the classification of attractors—point, circle, torus, and so forth—, with a classification (not yet complete) of catastrophes, or allowable (i.e., generic) transitions of attractors. This classification also begins with a discrete list of increasingly complex phenomena. We end this mathematical aside with a description of the two simplest types of catastrophes: the *leap* and the *wobble*.

Suppose the system is observed in a certain macron (attractor) and the control parameters are gradually changed. The macron is gradually distorted, but undergoes no definite change of type. Suddenly, at a critical value of the controls, it changes instantaneously into a completely different macron. This is a *leap*. In the simplest case, it is a point (steady-state) attractor which leaps. The steady state suddenly changes to a radically different steady state. For example, the onset of Taylor cells in rotating fluids is a leap catastrophe.

The wobble is a subtle catastrophe, almost unnoticeable. In the simplest case, called *Hopf excitation*, a point attractor changes into a circular attractor, as the control parameters are changed through a critical value. At first, the circle is very small, corresponding to a *wobble*, or oscillation of very small amplitude. As the controls continue to change, the circle (and wobble) grows until the oscillation becomes noticeable. For example, the fluttering of the boundaries of Taylor cells in rotating fluids is an example of a wobble catastrophe.

It is possible to organize all the attractors and catastrophes, referring to a given experiment with controls, in a single geometric model. This is called the *logos*. The structure of these models, the *geometry of macrons*, is the triumph of Thom's theory of catastrophes. Unfortunately, it is unapproachable without technicalities. In an experimental situation, however, it is possible to construct a map of the logos more or less empirically by exploration. The confusing feature is a kind of

ISBN 0-201-03438-7/0-201-03439-5pbk.

hysteresis: the observed state, for a given control setting, may depend on the direction of approach to that control setting. For each control value (such as rate of stirring of the salty jelly), many attractors may exist. The geometry of macrons can be a great help to the experimenter at this point. This will become clearer in the context of the example discussed in the next section.

For those who would like to know more of macron geometry, the basic references are included in the bibliography. My "Introduction to Morphology" (R. Abraham, 1972) includes some helpful illustrations. *Warning:* The classical literature of catastrophe theory (Thom, 1973, and Zeeman, 1971) assumes that the phase space is finite dimensional. This is not the case in macron theory. The extension to the infinite-dimensional case, technically very difficult and not completely satisfactory, is discussed by Ruelle and Takens (1971) and by Marsden and McCracken (1976).

Techniques of Macroscopy.

The study of macrodynamics must be founded on the observation of basic macrons of types (P), (C), and (E), and their coupling behavior. Here we describe the construction and operation of the *macroscope*, a universal tool for the observation of transparent macrons of physical (P) types based upon prototype instruments built by von Békésy (1960), Jenny (1967), Schwenk, Settles (1971), and others.

The instrument combines five units (see Figure 6.1): (1) a color schlieren-optical system, of Settles–Toeplitz type, with a four-inch field of view, terminating in a rear projection screen; (2) a transparent vibrating dish, driven by a high-fidelity loudspeaker outside the field of view; (3) a sine-wave generator, controllable in the rectangle: 0–1000 Hertz by 0–15 watts; (4) a control rectangle monitor, including cathode-ray tube and two digital meters; and (5) a xenon arc lamp, capable of microsecond flashes up to 1000 Hertz at 100 watts average power, triggered by (i.e., synchronous with) the sine-wave generator, with adjustible phase lag.

In operation, the fluid or elastic medium (which must be perfectly transparent) is placed in the transparent dish. The instrument is switched on, and the experimenter steers the control parameter around the rectangle with two knobs, while watching the colored image on the screen. Leap and wobble catastrophes are readily observed, and can be plotted on the face of the CRT control monitor with a wax crayon. The geometry of the logos is easily discovered by exploration. The exploration of different media indicates the effect of the intrinsic control

ISBN 0-201-03438-7/0-201-03439-5pbk.

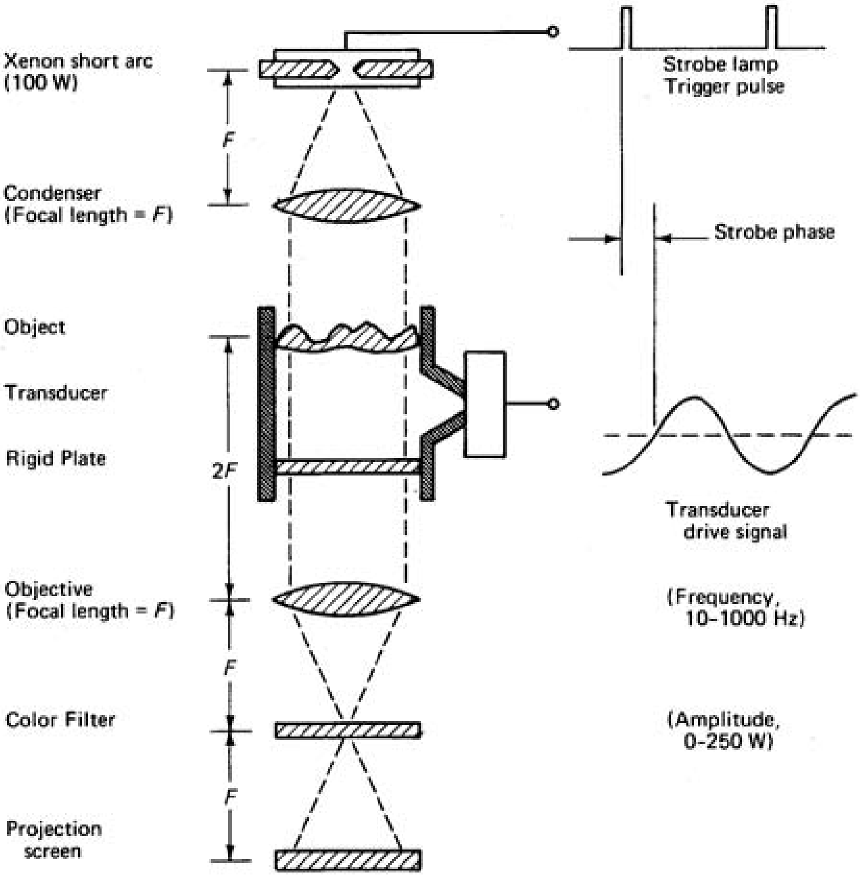

FIGURE 6.1. Schematic view of the four-inch macroscope of the University of California, Santa Cruz. (Diameter, 4 in.; F, 48 in.)

parameters—for example, physical dimensions and viscosity—upon the logos.

But what is the relationship between the colored image on the screen, the physical macron within the medium, and the mathematical attractor which describes it? Theoretically, the physical parameter represented on the screen is the *horizontal gradient vector field of the index of refraction of the medium, expressed in polar coordinates of color and intensity.* In practice, interpretation in macroscopy, as in radiology, is learned by experience. Two separate causes of coloring must be distinguished: deformation of the surface of the medium (lenticulation) and pressure waves within it (pressurization). Normally, two separate images are superimposed on the screen, the λ-image (due to

ISBN 0-201-03438-7/0-201-03439-5pbk.

lenticulation) and the π-image (due to pressurization). Fluid flow within the medium is not revealed, but can be observed directly by the usual technique: dusting the medium with aluminum powder. Also, rapid Bénard cells (boiling) cause concentric rings in the λ-image, and discs in the π-image.

The image, with the control parameters left fixed, is usually moving. In fact, it is full of fast action (e.g., like boiling) and also presents a slow progression through different forms.[2] The slow motion repeats itself periodically. This is a toroidal attractor. Counting the dimensions of the torus strains the human space-time pattern recognition facility, and justifies the warning of Anthony (1969) that macroscopy causes brain damage. But when the driving signal is very small, the image may be still. This does not mean that the macron is a point attractor (stable equilibrium), because the illumination is stroboscopic, and stops all periodic motion at the driving frequency. At this point, the phase between the driving signal and the arc lamp must be adjusted through a full cycle to determine whether the macron is a point or circle attractor.

Macroscopy is impossible to describe verbally or photographically. Color cinematography and videotape cassette are the appropriate media for registration of experimental data in this field, and in experimental morphodynamics in general. Moreover, by using your imagination freely, you may think of countless experiments to do with a macroscope, the results to be stored in color videotape cassettes. Also, many different macroscopic devices are feasible, including one under development at present, in which video equipment itself is used as an analogue device to generate macrons and catastrophes.

2. APPLICATIONS TO MORPHOGENESIS

A long series of applications of catastrophe theory to morphogenesis already exists, thanks to the inspired works of Thom (1973) and Zeeman (1971; see also Isnard and Zeeman, 1975). The majority of these applications belongs to static theory and shows that the geometry of point macrons alone is adequate to model a fantastic variety of morphological phenomena in the real world. Therefore, in this section, I shall give a selection of sample applications which are essentially nonstatic, or vibratory, in nature. These are from the traditional four levels of the phenomenal universe.

[2] The cover of this volume shows the nucleation of a new macron, photographed by the author with the macroscope of the University of California, Santa Cruz.

ISBN 0-201-03438-7/0-201-03439-5pbk.

Cosmology.

There is not much to say on this level beyond the basic observation of Jenny (1967; 1972): sand patterns on vibrating plates are analogous to galactic patterns of stellar material. If this analogy is pursued further, there arises a classical conundrum: What cosmic driving force corresponds to the plate, and how is it coupled to the galactic dust? This is the basic problem of the priority of the *word* in the philosophy of the Cabala, or the *tapas* of the *Rigveda*, which I have transliterated as Cosmic Will in the preface. In any case, it is beyond mathematics, I think.

Geology.

Here I can cite a few sample applications from each of the three basic planetary spheres. Regarding the morphogenesis of the *geosphere*, a basic morphogenetic situation is presented by the condensing sequence of gaseous, liquid, and solid phases, which could be studied in the macroscope. I suppose the conservation of the vorticity inherited from the initial motion of the cosmic material determines a certain macron in the sphere of mixed phases, combining elastic lenticulation of the crust—determining the location of continents, floating mountain ranges, ocean basins, and perhaps a network of global rifts along the nodal surfaces—with Bénard cells of convection in the hotter liquid core. These cells may be the driving force of continental drifts and earthquakes.

In the *hydrosphere*, I suspect that global ocean currents are toroids of the Taylor cell type. Local temperature gradients must produce Bénard cells, some of which may be very stable. Perhaps these are responsible for sculpturing the conical projections of the ocean floor. On a smaller scale, Bénard cells are obviously responsible for the honeycomb patterns on the bottom of icebergs observed by the Jacques Cousteau group.

Macrons in the *atmosphere* are manifest in the wind patterns of the weather map. Bénard cells cause honeycombs in sand dunes and sun cups on glaciers. It is not unlikely that the prevailing westerly winds contain Taylor cells girdling the equator. Hydrodynamical macrons around spinning spheres probably deserve closer study. The macroscope is an ideal tool for such practical investigations.

Biology and Neurophysiology.

Much has been written on biological morphogenesis (see Waddington, 1968–1972) and undoubtedly there is much more to come. The book of d'Arcy Thompson (1945) has become a modern classic. Comparison of

ISBN 0-201-03438-7/0-201-03439-5pbk.

the nature drawings of Haeckel (1974), or of the photographs of Strache, with the macrophotos of Jenny (1967; 1972) is very suggestive. Turing's (1952) revolutionary article on phylotaxis was perhaps the starting point of modern mathematical morphogenesis. The mechanisms of chemotaxis and ecotaxis are active areas of research. Macrodynamic explanations of nongenetic heredity, orgasm, telepathy, and many other phenomena are easily proposed. I shall confine myself here to two applications which are the subject of current empirical study: the ear and the brain.

The process of audition is more or less understood, except for the mechanical to neural transducer, the cochlea. This is a closed vessel of fluid (perilymph) with a mechanical input piston on one end, and a very complex pressure-sensitive organ stretched within the fluid and comprising a flection sensor (organ of Corti) embedded in a jelly (endolymph) bound by two membranes (Reissner and basilar). Obviously, this is a natural macroscope. Realizing this, von Békésy (1960), the great pioneer of perception research, made a transparent model of the cochlea and looked at the macron produced in the perilymph. He observed an eddy current which, now bearing his name, has dominated speculation on mechanisms of the cochlea ever since. Recently, Inselberg (Inselberg et al., 1975) has suggested that the eddy of von Békésy is artifactual. On the basis of our macroscope results, it would seem that the elastic macron—which was invisible to von Békésy—is more likely than the simmering macron he saw to be the mechanism of hearing. This question is the subject of current research.

We shall now consider the brain from the macron point of view. As a physical object, it is apparently a bioplasmic spacework with hierarchical structure. Its very physical structure suggests an elastic macron with clearly defined nodal surfaces. Its various segments support compound physical (elastic), chemical, and electrical macrons—which are coupled through the dendritic surface. So far, there has been no discussion of a functional role for the elastic vibrations of the brain body. But from the macrodynamic point of view, the elastic behavior is coupled to the electrochemical state through known plasma mechanisms, and probably also through liquid crystal (flexoelectric) mechanisms as well, so the possibility of a functional role cannot be ignored. In any case, what can be said at this stage is just a conjecture: *a thought is a macron of the brain bioplasma.* This suggests a physical mechanism for a holistic approach to brain function, and is certainly at odds with the connectionist theory of the neural network. This conjecture leads easily to more precise conjectures for specific brain functions. For example, the transfer from short-term to long-term memory might be explained as follows: A short-term memory is a brain-body macron, metabolized (or

ISBN 0-201-03438-7/0-201-03439-5pbk.

driven) by the neural network. This macron maintains a spatial pattern of various biochemical and ionic particles, as in the Howard–Kopell phenomenon. As this pattern is maintained through repeated neural activation of the macron (thought), some molecules within this pattern become attached to membranes and thus immobilized. This physical realization of the engram (macron) pattern is the long-term memory. Recall is effected by a macron resonance phenomenon; and so forth.

The juxtaposition of these two examples of macrodynamic processes, hearing and thinking, suggests that the whole information-processing chain can be interpreted as a flow of macrons extending, through coupling, across different media. This idea has been carried to extremes by Thom (1973), in his psycholinguistic theory.

The morphodynamic conjecture for brain function is not about to be established by any current research program. Yet there is some work on electrical macrons in the dendritic surface—that is, spatial patterns of EEG potentials. Various results (F. Abraham, 1973; Adey, 1974; Brazier, 1969; Freeman, 1975) suggest that brain macrons have functional roles. As a last laugh, we propose that the classical salty jelly experiment of Kennedy (1961), supposedly ridiculous, has serious implications.

Noology.

Probably the macrodynamic brain theory has eliminated all but the most credulous readers. If there are any survivors, we may as well dispose of them now by discussing the macrodynamics of consciousness. Actually, this is not impossible, as there exists a (quantum) mechanical theory of consciousness, thanks to Walker (1970), which admits of a macrodynamic formulation. However, let us ignore the question of mechanism. Suppose a human being can be identified with a conscious unit, a particle in the noosphere. Suppose, furthermore, that these macrodynamic units are coupled by communication, a macron resonance phenomenon, as described in the brain speculation. Then, the noosphere may be described as a complex system of macrons. Actually, this idea can be formalized mathematically, so that an archetype in the collective unconscious becomes a stable elastic vibratory state of the noosphere (the Big Salty Jelly in the Sky). This provides macrodynamic mechanisms for astrology, telepathy, clairvoyance, synchronicity, and so forth, as I have proposed in "Psychotronic Vibrations" (R. Abraham, 1973). The existence of a new force, the psychotronic field, is a separate question.

ISBN 0-201-03438-7/0-201-03439-5pbk.

3. CONCLUSION

In this introduction to macrodynamics and its applications, there is admittedly an inordinate amount of speculation. I regret this sincerely, but as many have discovered, speculation is much faster than experimental work. I must therefore single out especially the hardware projects, described in the section on techniques of macroscopy, as terra firma in this ocean of dreams. And I confess that my goal in these hardware projects, in addition to my own curiosity, is a political one: to stimulate a wave-conscious, morphological orientation in scientific research.

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