THE ROLE OF A BIOLOGICAL FIELD THEORY IN EDUCATION*

F. L. Kunz

Foundation for Integrated Education

I.

The general education movement was prompted in this country principally by the disparity between modern man's material achievements and his social, moral, economic and political competence. Through it, higher learning was to do its part in arresting the deterioration of society by correcting over-emphasis upon vocationalism.

From the beginning of the movement it was clear that contemporary knowledge is too vast and too complex to be taught as a whole at the descriptive-and-operational level. The criteria required to control the inevitable sampling have been arrived at in practice by arbitrated opinion and administrative fiat, necessarily, for lack of a philosophical consensus. The outcome for the most part was the now familiar pattern of selections from physical science, social studies, and humanities.

From the early days of the movement it was also evident that mere slices of learning were inadequate. To counteract specialization's effects by encouraging the student's interest in many or all major aspects of learning, is to commit ourselves to offer knowledge more and more as a meaningful whole. This task is also impossible of performance when confined to the descriptive-and-operational level.

Secular colleges do not possess an official philosophy. Indeed, except to some degree in the exact sciences, there is no body of approved, consolidated, far-reaching, concepts collected and taught. Hence for any conceptual interknitting that might be done to encourage philosophical insight, the teachers of the general course became responsible. Under such conditions a quickening of interest in the student may be effected if the courses chance to be well devised, and if the instruction is inspired.

But effective conceptual integration of subject-matter, constituting the beginning of an authoritative philosophical consensus for a given campus or for this confused country, is not likely to be achieved by this procedure in any reasonable time. In fact, it will be my purpose to try to show that a consensus will be impossible until a certain hiatus of knowledge is filled in. Since the true alternative to authoritarian indoctrination (which as a nation we repudiate) is a

---

* Read before the American Association for the Advancement of Science, Section Q (Education), December 28, 1950, at a symposium sponsored by the Foundation for Integrated Education.

democratically achieved consensus which gets its force from the worth and reasonableness of a common educational experience, our present frustration is dangerously stultifying.

The specific cause should be a matter of primery national concern. If it can be determined, we must then see if we can correct it. To this we now turn.

It is necessary at the start to be clear upon one point at least: The hope for a meaningful and enduring world consensus lies, broadly, along lines of reason and philosophy and, specifically, along lines consonant with scientific standards. This does not mean that what we now accept as established knowledge is enough, but that the basic positive methods used to achieve present accepted science are good, and the results acceptable, as far as they go. There are bound to be premature erroneous personal conclusions as to the constitution of man and the nature of the universe, and the relations of these two, based on present limited science findings. These faulty deductions are to be charged against their hasty promulgators, not against basic scientific attitudes and methods.

As befits a high-ranking cultural discipline, science has many techniques. Of these one group, namely, those of exact science, has important prior claims over all others, if insight is to be an object. For exact science gets its authority from the internal mathematical and logical structure, and is thus by its very nature philosophical in character. In addition it gives us effective and increasing mastery over nature, and thus proves out as a species of realism. Exact science is therefore coin of the realm for a world society.

The exact sciences of matter and energy are well structured, and display year by year a progressively improving internal authority. The general consensus they offer derives from the content itself. In fact, progress in structuring them has been so conspicuously accelerated this century that a general field theory may presently be taught, comprehensive of all major material phenomena. However, the subjects, matter and energy, are insentients, hence the values obtained are in the learning experience not in the content.

The situation we have just noticed, typical of physics, chemistry and astronomy, is almost exactly reversed in social studies and humanities. These have little or no meaning when divorced from values, but at present are only loosely structured.

In between matter, as such, and man, as such, lies the region of the life sciences, as such. Man is rooted in life, first, and experiences matter only secondarily. In life sentience appears, making occasion for values, since without pleasure and pain values do not even arise.

And now we confront a puzzle. The centralmost subject of biology is organization. Yet the singular fact is that despite life's importance to us, and its opulence of forms, the mathematical and logical <u>over-all</u> structuring of biology is rudimentary when compared with that of physics and chemistry. This state of affairs is known to all. Because of it, life has frequently been interpreted philosophically in terms of mechanism by the unscientific device of ignoring or postponing discussion of the special subject matter: sentience, organization, and self-directed functional form. This has led to conceptual impoverishment. The alternative has been an inadequately structured vitalism which attends to unique subject matter, but does not greatly enlarge the sovereignty of the exact sciences.

So long as we remain content with samples of knowledge in general education, loosely knit with a few principles, we can live with this failure in biology to offer a general structuring comparable in exactness, scope, and acceptability to that of physics. But if we look upon general education as the authoritative means to stimulate culture and insight, the conceptual hiatus under notice is intolerable. All manner of substitutes may be offered in lieu of the extension of structuring from physics through biology toward man and society. But we would do well, I think, to recognize these as being in part what they are: improvisations necessarily substituted for the philosophical lag in the life sciences.

The ideal way out of our frustration is clear. We are required to bring the life sciences up level with those of matter and energy not by reductionism, but by applying basic exact science methods throughout biology. In contemporary terms this means a biological field theory which embraces life-data inside and outside the scope of physics and chemistry. This implies in turn that biophysics and biochemistry are not enough. Organisms are sentient and display psychic activity. There is therefore a subject we cannot neglect, biopsychology. Many creatures are self-sustaining functional forms rich in symmetries and asymmetries, some apparently explained mechanically, others inexplicable. Whatever their rationale, they provide a special topic, bio-esthetics. Organisms have a unique relation to space (functional morphology) and to time(evolution, the opposite to entropy). A space-time for life would have to account for these few specimens of topics, and for many others, if social studies and the humanities are to be demonstrably linked in a valid fashion with the exact sciences of matter and energy to make an intelligible valued whole.

The chief practical questions prompted by these considerations are fairly obvious:

1. What factors, hitherto not exploited singly or as wholes by biologists, are at hand and suitable for the structuring of life-sciences?
2. If the suggestions along that line which follow seem to have promise, can they be formulated in a program of research? That is, can the problems be stated in a way that suggests specific inquiries into parts of the subject, which may in turn be significant to the whole?
3. What practical set-up and procedures are implied, additional to present familiar practices in the advancement of biological knowledge?
4. What would a sustained, systematic, and sufficient program cost?
5. Would an accelerated effort be worthwhile? We may have confidence that biological science will eventually achieve an over-all structuring. This last question is intended to suggest that special efforts might have rapid results of particular importance to society during the present times of confusion.

The first question alone calls for immediate answer. There would be no point in concentrating attention on the well-known need to improve the over-all structuring of biology unless there were reasons to believe that something fresh can be suggested. The time left may therefore be devoted entirely to a few items which promise at least the beginnings of a biological field theory. Our account here must necessarily be in skeleton form.

Contemporary physics is concerned, first, with energy; second, with the quantum series, which begins in the non-pictorable atomic world, and appears in the range of aided and unaided vision as molecules and crystals; and, third, with the relation of energy to these particulates, massed up as matter.

To give rational wholeness to physical phenomena, two major concepts are introduced, under realistic necessity: force fields and space-time. Because they are not directly perceived, fields are held by some to be but convenient fictions. For present purposes they will be conceded reality, and space-time will be allotted at least those properties which natural motions require as background. We shall assume that if space-time is useful to explain motion in physics, it should be found appropriate also to biology, wherein, however, its features are to be determined by the special ordered changes which occur in living nature.

Contemporary biology also has much to say about energy and quanta. The latter appear in living cells in such form as genes, protein and other molecules and micellae generally, and as crystals, both those occluded in cells and also engendered therein and built up as cellulose walls in plants. While the cell is alive, these particles carry electric charge patterns which change or disappear at death. In higher organisms especially, thermal and other physical and chemical phenomena are also subject to living control. Within limits, then, the directive role of life and the functionalism of form seem evident. Nevertheless it might be reasonable to believe that the directive role is only apparent, not real, that life is only an epiphenomenon, and hence that the electromagnetic field theories can presently be extended to account for living creatures.

But biology offers important novelties in space-and-time activities which lie far beyond the present boundaries of physics and chemistry. It is these which force us to look for a special field theory appropriate to biology. Reproduction exemplifies these imperatives. It allows organisms to go on as specific functional forms in space and adaptively as meaningful unbroken causal series for long ages of time. This is singular in itself. But more: Everything required to effect this seems to be passed along as a potential in the genes and germ plasm. There is nothing equivalent to this recognized outside biology, as that science is at present defined.

It is difficult to see how we can avoid the notion that there is an appropriate special space-time ground which provides the properties displayed in these and other familiar but unique features of life. It may be technically difficult to establish the existence of the necessary details of the required field structure within a single free-living cell, where we may suppose that the contents and the activities are all significant. But if the germ cell be held to be the abstract of the adult organism, then the kind of content and motion in the cell, namely, streaming of protoplasm, metabolism, mitosis and meiosis, can be considered as working out and stating itself in development and growth, metamorphosis and mutation. This is tantamount to saying that living motion, in the strict sense, is *sui generis*, and that is why the end result is a self-proportioned form in space, ongoing by repetition in time.

The present proposal, then, is that the essential methods of modern physics are to be developed in studies of life to suit the data, taken in their entirety, as befits the standards of exact science.

The method indispensable to successful description of fields and space-time is mathematics, in the usual categories of geometrical principles and attendant or additional equations. We require a field geometrically so structured as to account for the symmetries and asymmetries and the behaviour of living forms. The results must embrace palaeontology, genetics, cytology, morphology, taxonomy, and every other department of the life sciences, and it must lead to acceptable systematization of them.

The magnitude of this proposed undertaking may seem much more formidable than the task which Michael Faraday and others created for James Clerk Maxwell and his successors. But there are features which give encouragement.

In the biological field---if there is one---the test objects are given. The very opulence and diversity of life provides that thousands of aspects of its geometry are ready at hand for study. Already many hundreds of particular studies contributory to the structure of the life-field are known, such as principles of phylotaxy, cotyledon-leaf-and-plant-part groups, specificity of chromosome numbers, shapes, sizes and behaviour, growth proportions, relations of organ masses to body weights, and so on.

A suitable geometry is also available in advance, just as appropriate geometries were at hand for Relativity.

The Euclidean character of the microcosm generally, and of quanta in particular, is fairly well established; and biological forms depend on a fine world. Certainly at the point where the molecules of pure substances arrange themselves upon space-lattices as crystals, we have Euclidean space-fillers.

The geometry we seek cannot be confined to the three dimensions of space, and time taken separately, the system to which D'Arcy Thompson limited his interpretation of the geometry of life in his book Of Growth & Form (Macmillan, 1942). We need a space-time geometry, because living systems are in incessant motion. But this need also can be satisfied from mathematics at hand. The four-dimensional Euclidean regularities have been studies by Alicia Boole Stott, H. P. Manning, and many others. Recently they have been reviewed and consolidated in The Polytopes, by H.S.M. Coxeter (Methuen and Co., London, 1949).

We therefore proceed to make a specific suggestion concerning the possible role of these four dimensional analogues of the familiar regular convex polyhedra.

In three dimensions, Euclidean geometry provides us with five regular convex polyhedra, or six, if we count the sphere as a polyhedron with an infinite number of sides. Since the tetrahedron is self-reciprocal (that is, has a vertex opposite to the center of each face), they come in reciprocal couples. The dodecahedron and the icosahedron are mutually reciprocal, as are the cube and octahedron. The five regular figures constitute the three dimensional regular convex space fillers.

In a four dimensional region, required for space-time, analogues of the foregoing three couples all recur, and are joined by a fourth, namely, a polytope with 24 vertices, 96 edges, 96 triangular faces, and bounded by 24 regular convex octahedra. It is therefore self-reciprocal.

Four dimensional space thus provides us with as many couples of reciprocal polytopes as there are kingdoms in nature.

The accompanying plate lays out the series from point to polytope. (See following page)

EXPLANATION OF PLATE

Representative models of the four reciprocal couples of polytopes are displayed at the extremities of the figure above; five, if the sphere be taken separately. (For full discussion, and modelling, see The Polytopes, H.S.M. Coxeter, Methuen, London, 1949).

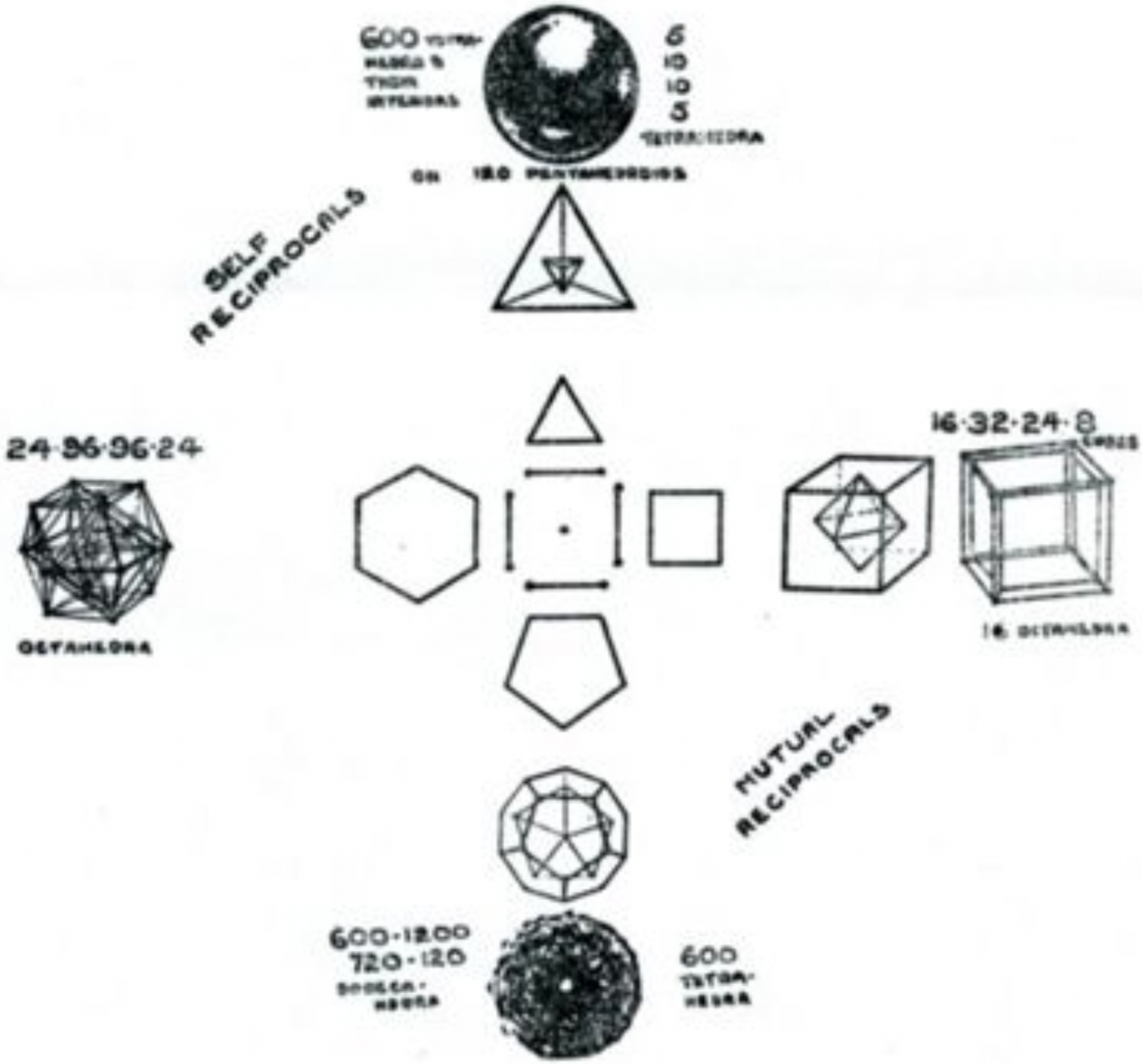
To the right is the series point, line, square and cube-octahedron, ending with a correct perspective model of the four-dimensional analogue of the cube. Above this figure are the numbers of its vertices, edges, square faces, and cubic cell boundaries, and below are the corresponding data for its reciprocal, the four-dimensional analogue of the octahedron, which is bounded by 16 octahedral cells.

Running vertically downward from the center is a series ending in a model appropriate to the dodecahedron (and icosahedron) with the numbers of vertices, edges, faces and bounding cells also indicated.

To the left runs the series appropriate to the 24-hedroid. Since there is no regular three-dimensional representative here, a space is left blank. The hexagon is its correct representative in the plane.

Vertically upward is the series appropriate to the tetrahedron and pentahedroid.

The suggestion is that the reciprocal nets connected with the terminal figures constitute the basic field geometry, respectively, of crystals, plants, cold-blooded animals, and warm-blooded creatures, specialized in the four geological eras. The assumption is that the life-field is geometrically totipotential, and that the geometrical nets associated with the analogue of the cube and octahedron came into play first, in the earth's crust, and remained in expression, to be joined by the geometry appropriate to plants, both occurring in that kingdom. The structure of the field is thus displayed in natural forms progressively; and in each higher kingdom, cumulatively.


600
6
10
10
5
SELF RECIPROCALS
24·96·96·24
16·32·24·8
MUTUAL RECIPROCALS
600-1200
720-120
600

When the series of reciprocal couples is referred to natural forms, immediate confirmations of their probable usefulness come to light.

Here we have opportunity only to notice a conspicuous feature of the argument.

Experts familiar with crystallography and structural chemistry have established the role of the cube and octahedron in the geometry of their subject matter.* In general it may be said that these figures provide the basic frame of reference for inorganic crystals, broadly, the mineral kingdom. Besides the foregoing positively established state of affairs, there is a significant negative statement which can be made about the geometry of this kingdom: the regular convex dodecahedron does not occur in inorganic crystals. The nearest approximation is, I believe, one form of pyrites, but the dihedral angles are unequal. In short, the overwhelming evidence is for a basic cube-octahedral geometry for the crystals.

A few years ago the suggestion that inorganic crystals are in any significant sense a part of the life series might have sounded quite fantastic. But William Stanley's work on the tobacco mosaic virus may be the beginning of a new outlook, giving earlier data of relation of crystals to life fresh meaning: For crystals are occluded in many types of living cells, for purposes which, I believe, remain obscure. Woody plants engender within their cells crystals which migrate to the walls to build cellulose. No less significant is the fact that there are now known a few hundred substances of organic origin which display the optical properties of crystals when, in their pure state, they are held between certain temperature ranges. The notion of living cells as aperiodic crystals thus becomes part of a whole system.

We have, thus, reason to put aside the idea that the bifurcation of nature into living and non-living occurs when crystal cells give way to protoplasmic cells. Instead we conceive of inorganic molecules and crystals as indispensable to life, and as joining with organic molecules in the fluid system of the cell to make possible the expression of a well- and consistently-structured field.

The suggestion is that evolution is the sequential exploitation and display of the geometry of the life-field, from the simpler cube-octahedral systems of the inorganic, to the richer system of the dodeca-icosahedral system, both being unitedly displayed in plants; and so to animal forms and tissues, where the field displays an additional complex from the twenty-four hedroid couple.

The contents of the cell are doubtless selectively maintained in accordance with the geometric properties of the field appropriate to the species, exercised through the specific numbers, shapes, sizes and behaviours of the chromosomes and genes.

Where, then, is the bifurcation in nature between living and non-living? I would be inclined to say that none is directly apparent, and probably none exists. There are merely ordered systems of many magnitudes, among the largest being the whale, the greatest dinosaurs,

* see The Nature of the Chemical Bond, Linus Pauling, Cornell University Press, 1940

sequoias, and beds of crystalline rocks, the series going down and vanishing out of sight as single cells and quanta. If there is a bifurcation, it is between the ordered and the apparently non-ordered, but in fact even this may be fictitious.

We are facing the facts which suggest that inorganic molecules and crystals are the necessary basis of life, having come first presumably in the evolution of the planet. We are but suggesting that the mineral systems display an internally consistent geometry based upon the cube and octahedron, and that this is in turn part of a larger, closely-knit, geometric system, and that we are therefore impelled to inquire whether the rest of the kingdoms of nature exploit the rest of this geometric series.

In principle, there is nothing novel in the suggestion. If investigation justifies the concept, it will then be time to make some revisions in our philosophy of life, and these we must expect. For if a problem has remained for centuries before us, unsolved, we must conclude that the thinking which frames it has had some defects. Changes in that thinking may require of us some considerable adjustments.

Some of the features of that required new thinking are suggested to us by analogy from recent events in physics. It may turn out that the field and not the cell is totipotential. In that case crystals of inorganic origin may come to be regarded as very limited expressions of the life field. In such event, all that is left of the complex space-time order are such items as rational parameters, symmetries, and the like. Everything else is necessarily suppressed, because a static three-dimensional system cannot display more. The evolution of protoplasm, then, was a device which allows of more of the field potential to exhibit itself. It affords motion in a liquid medium. Thus the organic molecule can be in constant conjunction with the lower orders of the field geometry displayed by inorganic substances present.

This kind of thinking implies a re-definition of biology, as the science of the self. Crystals are then merely self-forming and self-existent. Plants are self-sustaining and self-perpetuating. Animals display self-motility and self-direction. Thus life becomes both scientifically and philosophically the condition precedent to the appearance of self-conscious, moral, aesthetic man.

The notion implies that the field, besides having as its structure a consistent geometry of great interest, may also have a carrier feature which appears in living forms as sentience. As remarked above, it is obvious that sentience is the root base of values, for without pleasure and pain, why should there be any occasion to choose a course? We would be inclined to look upon the just internal proportions which we call rational parameters as all that is left of an aesthetic and meaningful wealth in the field. In short, the universe is indeed consistent, charged with value, and human life has meaning. The purpose of the studies here proposed is, in fact, that we may bring out of the realm of belief and into the realm of knowledge, good reason, teachable truth, about this intelligible universe.