# Units and Concepts of Biology

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In this conference, which is concerned with the concepts and units of all science, my assignment is the sector of biology. The goal is thus set to consider the life sciences in the context of all science—to compare and contrast, with attention to both similarities and dissimilarities. An approach that is too general will lead into the problems of philosophy; one that is too particular, to the separate subdisciplines. Attention to the sector boundaries, or junctions, thus seems the most efficient, and I shall therefore emphasize the boundaries between physical and biological science and between biological and social science. Since the former boundary has had far more attention than the latter, and since differences have been noted more vividly than have similarities, my emphasis is on biosocial comparisons, a topic that has occupied a portion of my effort in recent years (*1, 2*).

## Entities

It is not chance that the cleavage between natural and social science is greater than that between the sectors of natural science; it is a cleavage between substance and action, body and soul, the objective and the subjective. Inquiring man scans the universe with his sensory end organs, orders and classifies the information thus obtained, and so imposes a structure on the world he recognizes. Here is William James' "blooming, buzzing confusion"; here, in Henry Adams' figure, is man "on a sensuous raft adrift in a supersensuous sea"; and here is the impact of Kronecker's dictum on mathematics, "God made the integers, man did all the rest." Some inhomogeneity must exist for man even to be, and emphatically for him to divide his world into classes. And, since man depends mostly on visual information (two-thirds of all the nerve fibers that enter the human central nervous system come from the eyes), and since the eye detects primarily patterns of spatial extension, man first sees his universe as a collection of material objects. An entity is distinguished from its ground and, given appropriate duration, an individual is born to the perceiver. This is the basic event.

The individuals that people man's primitive world are necessarily commensurate with his own dimensions, his sensory range, and his time span; indeed, they even seem to conform to his status as a living being, for they are strongly personified. As technology offers instruments that reveal the lesser and the greater, as man's senses are extended (and mainly, again, his vision), new entities engage his attention; but this is a later development (*3*). More immediately, various observed individuals are recognized as having some common attributes and so as being amenable to grouping or classifying. This is the taxonomic stage of knowledge, and it follows the stage of simple observation and description just because differences are more likely to command attention than are likenesses (*4*). Man thus types his observed concrete entities into sets and, as the second abstraction (the first being entity from ground), draws sharp boundaries about them.

But, as Whitehead well said, "Nature doesn't come as clean as you can think it"; and, with growing sophistication, man replaces his plateaulike typology with the graded slopes of a probability distribution in a population of nonidentical individuals. A mere collection of seemingly unrelated entities is first given meaning or pattern in terms of perceived similarities; only later is it possible to look more closely at the individuals and to reintroduce differences, but now ordered differences with significance to the larger whole. Moreover, once the initial integration (or induction) has been achieved, progressive differentiations (and deductions) can be meaningful, and subclasses can be conceived and identified, later to become graded subpopulations. This is a sign of growing familiarity with the entities of attention, indicating more interest and ordering and leading to subdivision of effort, or to fragmenting of science. Attention to a subject matter reveals finer differences and new attributes, first of whole individuals and then of their parts and structure, calls for new words to characterize these, and adds new digits to a decimal number as subclasses and sub-subclasses become significant. Here knowledge is in the morphologic stage.

So far, we have considered primarily material entities and their grouping on the basis of sensible, mainly visual, attributes. Clearly, animate and inanimate objects are more alike than are objects and the behaviors of objects; so the physical and life sciences, concerned (as a first approximation) with these two types of object, are closer to each other than they are to social science, which is concerned (still as an approximation) with the behavior of one variety of animate object. But the real shift here is from a focus on organization to a focus on action, from being to behaving, from form to function, from pattern to process, from the timeless to the temporal. "Being" is the cross section of an entity in time, and those aspects of the organization which appear relatively unchanged in a series of such instants constitute the essential structure of the entity or organism. Invariance in time helps to identify the significant units of a mature system. Conversely, along a longitudinal section in time appear the transient and reversible changes, often repetitive, that constitute "behaving" or functioning, and the enduring and irreversible changes, often progressive, that constitute "becoming" or developing. And with this shift in orientation to time there occurs a shift in the entity of concern—from an object, a pattern of matter in space, to a behavior, a pattern of events in time.

Let me briefly recapitulate. Man's attention is first drawn to particular objects in his experienced world. These objects are grouped into classes and subdivided into components, at first with Procrustean rigidity and later with more freedom of variance, and then interest shifts to particular processes. But, as a group is more removed from concrete prehension than are its component entities—a species seems more abstract to us than does an individual organism—and as its component entities become more or less interchangeable, so is a process more abstract and universal than are the acting objects. Permeability, to some thing—ion, gene, idea, person—and in some degree, is a property of all boundaries (indeed, a boundary may be characterized as a zone of lowered permeability), as irritability, quantified as a threshold to some environmental change, is a property of all responsive systems.

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This shift in approach is like that from phenotype to genotype or that from observation to model building.

For study of permeability or irritability, the particular system examined is not initially so important as is what is done with it, and the common denominator shifts from the object to the variable. Some attribute of the object is selected for attention and measurement as the object is manipulated. New methods arise, experiment dominates observation, and changes of the observable in time are almost universally examined. Not the nerve but the nerve impulse is the entity of concern, and this can be studied on any particular nerve that comes conveniently to hand. True, important differences appear between impulses in invertebrate and vertebrate nerves, in nerves of the frog and man, and even in separate fibers of a single nerve; but these differences are mainly quantitative ones in the same parameters. Indeed, the behavioral similarities are so significant that eventually a functional criterion may help to define a material set: a nerve cell is one that conducts an impulse, and a smooth muscle cell is sometimes best distinguished from a connective tissue cell by its ability to contract. This is the essential shift from the morphologic to the physiologic mode. It must not be forgotten, however, that manipulation remains limited to the material object: the influence of temperature on conduction rate is determined by warming a nerve, not a nerve impulse; the answer to the question, Did you ever see a dream walking? is *No.*

The pure morphologist, then, is concerned with the structure of particular objects and attempts to make his description ever more complete. Here is the gross anatomist and naturalist of the past as well as the old organic chemist describing a substance or the visiting anthropologist describing a village. (The electron microscopist or cytochemist or ethologist of the present, as well as the modern macromolecule chemist or the factor analyst seeking primary abilities or the sociometrist noting contacts or quantifying opinion, is often busy with the specific case but is usually concerned really with the class.) He observes what is; and he seeks ever more powerful tools to identify a system and fix it at an instant of time, to reveal its finer detail, to discriminate its more subtle differences, and to do this more precisely on more limited samples. His concern is primarily with the individual instance, like the clinician's with his patient, the humanistic historian's with his character or period, the artist's with his poem or painting or other unique creation of man. When a class property becomes the focus of interest, comparative studies replace those of the individual, and descriptive morphology gives way to comparative morphology or systematics or physiology or genetics or some other discipline concerned with relation or function or development. As the class or property replaces the individual—as the actuarial approach replaces the clinical approach—there is greater distance between the operator and his material, the material becomes more objectified—not Tabby, but a cat; not John and Mary Smith, but a family—and analysis is added to description.

The entities or units which are significant, which are invariable (organization) or repetitive (function) or progressive (development) in time, similarly shift from concrete material entities to abstracted properties of classes of material entities (*5*). It is an interest in such attributes as personality traits or social roles and connections as the units of structure (aside from personal behavior and role-playing as actions), rather than in the individual or groups that exhibit them, that makes some aspects of social science seem different from life science.

## Levels

An entity of interest, then, may be an object or some property of it or a class of objects or some property of the class. But the class is, of course, a kind of individual; and the more the members of the class interact—even to the extent of developing into differentiated subclasses—rather than coexist, the more does the superordinate group become a true individual rather than a collection of ordinate individuals. The shift from separated cells to a reproducing body, shown by the slime mold, remains an excellent example of such individuation; a species with interbreeding individuals determining the properties of its gene pool is a continuing superordinate individual. This is the now widely accepted relation of hierarchy and levels (*6*). The atom, an individual or unit, is built of subordinate differentiated and interacting units, the various nucleons and other ultimate (for the moment) particles, and is built into a superordinate molecule. The individual molecule, in turn, with like or unlike fellows, becomes a crystal or a colloid or some other material aggregate; the colloids form particulates; these, cells; cells, tissues and organs; these, organisms; and organisms, species and larger taxonomic categories, or, in another way, groups, communities, and larger ecosystems. I have found the word *org* convenient for those material systems or entities which are individuals at a given level but are composed of subordinate units, lower level orgs, and which serve as units in superordinate individuals, higher level orgs (*7*). The important levels are those whose orgs (entities) are relatively enduring and self-contained. Thus, a cell is more likely to continue as an individual maintained entity than is a given colloidal micelle or a cell particulate, and an organism will vary less in time than will its parts or organs.

In the course of cosmic evolution, assuming a start in chaos, orgs at a given level become more highly integrated—with a clearer boundary, with more differentiated and interdependent units, and so with a more complex structure and more powerful regulating mechanisms—and new levels are superposed. But each added level permits the combination of old level orgs, now subunits of the new org, in various ways. It is because of the explosive increase in richness of pattern with rise in level that there appears to be an emergence of unpredictable novelty. The particular org that forms is indeed understandable in terms of the units, and their relationships, of which it is built; in this sense the situation is reductionist. But the particular org and its properties are rarely predictable a priori, because of the great number of possible outcomes, with either known or unknown probabilities and with that strong dependence on unspecified values of unidentified conditions which we call chance.

Thus, higher level orgs are likely to have a greater variety than lower order ones, and they are likely to depend more on their particular past; they are more individual. But they are also less plentiful, since several subordinate units contribute to each. A handful of ultimate particles form a hundred species of atoms, or perhaps a thousand, noting isotopes, and a hundred kinds of atoms form millions of molecular species. But the total of molecules is less than the total of atoms, and the total number of members of an average species of molecule is far less than of the average species of atom. The kinds of living organisms compoundable from the subpopulations of atoms and molecules (and combined or macromolecules, as nucleoproteins from amino acid and nucleotide building blocks) must be infinite in any meaningful sense; and the groups compoundable from organisms must be even more so. Yet the number of members of each kind of organism is vastly less than of each kind of molecule; and of groups, again less. In fact, whether from insufficiency of material or of time, the actually realized species or organisms are probably fewer than those of molecules (certainly they will be with the creative meddling of synthetic chemists); and the realized groups or ecosystems or societies, far less again.

Certainly all realizable molecules or cells or organisms or groups have not been realized, and the null members are not distributed at random. Particular combinations, orgs, are more stable in a given environment than are others, and these will be "successful"—that is, will occur in larger numbers—while that environment lasts. Furthermore, individual orgs form sets, as species form genera (and elements thus fit into columns of the Mendeleev table); molecules divide as to ionization or polymerization or what not into inorganic, organic, and macro molecules; organisms classify into kingdoms and phyla and down, because of a kind of periodicity in the patterns of formation. And, the grandest dichotomies of all, the hierarchy of levels has branches. The physics of atoms is unitary. The chemistry of molecules is strained between inorganic and organic and bio but still retains a unity.

At the next level, however, is an unquestioned split into the complex inanimate orgs of geology and astronomy (and meteorology and oceanography, perhaps even of architecture and engineering) and the complex animate orgs of biology. Physics and chemistry thus are subordinate to biology, the earth sciences coordinate with it; and in many ways the earth sciences are more comparable to biology than are the former. The entities of concern in biology and the earth sciences, as compared with physics and chemistry, are more individual and there are more species of them to deal with; and as unique orgs at the supermolecular level they are closer to ourselves, are more a subject (*thou*) than an object (*it*).

In the domain of biology between the cell and the multicellular individual, the tissue is an org with cell units, and so also is an organ. The first is a population, with cells related by origin or history, and a loose org; the second is a tight well-integrated org, with cells related by function. The same threads extend beyond the individual—to species and larger population categories, based on descent, and to ecogroups of various sizes and levels, based on fundamental interrelation. Moreover, above the level of the individual occurs another major branching, with societies—especially but not exclusively of man, or even of any single species—diverging from the population axis. Here population genetics and systematics leave ethology and ecology, and here social science separates from biology. The ecosystem of a lake or forest, or of an ant hill or flock of starlings, is thus coordinate with human spatial and functional groups, the village or the tradesmen, as is the clone with the clan as a lineage group. Again there is a jump in individuality and a diminution in kinds, a greater nearness to man and a consequent shift from object relationship toward subject relationship, at the social level.

## Becoming; History

History, or becoming, I said in a preceding section, is a regular change, normally progressive, in a system along the time axis; function, or behaving, is a repetitive perturbation along this secular trend; and structure, or being, is the instantaneous status. The units and subunits of an org are nodes of stability, relatively constant in time. These are the structural residues of past action, the molecules or organs or institutions that have become fixed, yet which also carry the cumulative changes of becoming. It is critical, however, that, whatever role process initially played, traces of the past can be carried forward only by concrete material entities, not by abstracted units (*8*). The neurone can evolve or develop by changes in its components, and so the nerve impulse can also change, in speed, intensity, and what not; but the impulse, per se, does not develop; it is a single action and has no history. So also, the individual person—or generations or groups of persons—carries the history of a society, even though the role or status is the unit of interest. And, of course, the gene—or generations and arrays of genes—carries the heredity of the organism and the population. It is well to note, to prevent confusion, that secondary material products of the primary entities may also be carriers of the information and ordering, the amount and kind of matter, which the past imposes on the present—wooden vascular tubes, seed cases and egg albumen, chitin or bony skeletons, elastic fibers and plasma antibodies, nests and burrows, buildings and machines, books and recordings, are examples—but these separate material carriers only reemphasize the point.

In the becoming of a given entity, there may be a shift in emphasis from one carrier of the past to another, and the shift is normally up the hierarchy levels. A gene, if it is a nucleoprotein molecule, is the product of vast chemical adventures, from the formation of atoms and simple molecules in the distant past of its ancestral lineage, to relatively minor shifts in kind or arrangement of atom or radical, the mutations of its macromolecular maturity. The cell is directed in its development, first by the information stored in its genes, later by the structures and substances that have been formed partly under their influence—reduplicating particulates, somatic mutations, adaptive enzymes, and the like. The organism, in turn, develops by virtue of the various cell types that are differentiated early in its individual existence and their later patterning and other modification as tissues and organs. And the group, finally, changes as its component individuals learn differential roles and skills. It is hardly surprising, then, that higher level orgs are more individualized than lower level ones, that they are more determined by their particular experience, and that they carry a richer and more characterizing past. A society becomes what it is through learning by its individuals, morphogenetic development by their cells, reduplication with mutation by their genes, and so, by regress, into the domain of chemistry.

Attention was focused, in the preceding paragraph, on the units as carriers of the past. Equally essential in shaping each present from its immediate past is the environment acting on the unit. Indeed, at each stage of development of an org, the heredity is fixed in the units entering that stage; and the environment, interacting with these units, leads to new fixations—irreversible changes—in these units or in superordinate ones. Thus, of course, arises the progressive specification and differentiation of orgs, an amorphous totipotentiality yielding to a concrete realization. And the magnificent inventions of gene reduplication and recombination, of heredity and sex, insure stability with variation; as the environment, operating through mutation and selection, insures guided change. At other levels, the mechanisms of becoming are less understood; but there is little doubt that they are similar in broad principle, dissimilar in all else.

Since at each stage and level future development could be along any one of a number of branching paths, depending on the vicissitudes at the moments of decision, the difficult problem is not that of diversity but that of uniformity. More than 40 cell generations lie between human egg and baby, and at each division a slight difference in cell properties or arrangement could magnify through subsequent ones; yet billions of babies have been born within the fantastically narrow range of "normality," only a negligible scattering of monsters outside of it. Of course, too great an abnormality cannot continue its development and is cut off by death; but, aside from such selection, there are self-regulating or homeostatic mechanisms in operation at all times and levels. If enzyme molecules are too active, a fall in substrate concentration and an increase in end-products will slow the reaction. If cells multiply overrapidly, they become too far removed from a source of nourishment and are retarded. If a liver is lagging in its many functions or a nerve trunk is failing to innervate its peripheral field, the structures will grow or regenerate—controlled by still unknown mechanisms—

until performance is adequate. Populations of predators and prey regulate each other in quantitatively predictable ways. And if a man deviates far from the norm of his culture, social pressures and sanctions—by better understood mechanisms than the morphogenetic ones—bring him into line or exclude him. Homeostatic processes nudge orgs toward a uniform state. The interaction of units to form a superordinate org is regulated, as is their action to maintain it.

**Behaving; Regulation**

This viewpoint has been little applied to the secular changes of long-range becoming, but it is the daily bread of moment-to-moment behaving. The vast bulk of the functioning of any enduring system is as displacement-correcting responses. Here is the negative feedback of engineering or the adaptive or self-regulating or homeostatic response of physiology. All orgs maintain themselves in a dynamic or flux equilibrium by mobilizing internal reserves to oppose environmentally imposed change; or, more rigorously, each unit responds to loads imposed on it by its environment (which may be the superordinate org of which it is part) with responses of its subordinate units that tend to eliminate the stress on the whole, even at the expense of a greater temporary displacement of the part. It is in the particular mechanisms and sequences that different orgs, and especially different level orgs, differ from one another; and each case must be examined individually, as for its structure. Yet here also important commonalities exist.

The organization of an org, its function-structure complex, is investigated by imposing displacements on it. Ordinarily an input is presented, and the output is observed, the stimulus-response situation. But the thruput in the system can also be manipulated—as in plucking a piano string, stimulating a neurone pool or cutting a nerve tract, or blocking an artery or a highway—and the spread of, or adjustment to, the disturbance tells much about the system. The quantitative relation between magnitude of displacement and strength of restoring influence—linear, concave, convex, sigmoid, or more complex—as also the existence of different or like mechanisms for restoring displacements from opposite directions, and whether the return is oscillating or damped, might serve to group widely different orgs into classes. There is a limit of homeostatic tolerance, an amount of displacement of a system beyond which it will not return. Change is then irreversible, and process leaves behind it structure—behaving shifts to becoming and alters being, sometimes leading to pathology and dissolution.

General questions can also be asked at this level about the degree of displacement tolerated in relation to kind, repetition, frequency, direction, and other aspects of the load; about the safety factor; about the speed of change of physiological zero, or adaptation; and about many other matters. Moreover, since structure is a product of history, or irreversible process, the character of the material change can serve as an index to properties of the action. A highly regular structure, as a honeycomb, indicates a highly determined process, even though this is a behavior of a group of organisms. Striated muscle fibers are highly ordered longitudinally and more variable in section; presumably the micelles are arranged very powerfully, once formed, but the number in a fiber is determined more by chance.

**Being; Organization**

An organism has organization, an ordering of material in space and of events in time. Any random arrangement is an order; the essence of ordering is that some particular order, out of all possible ones, will be produced. The particular one can be defined in relation to the observer, as near and far; or to some polarity he chooses, as large and small; or to a functionally related object, as key to lock; or to a generatively related object, as parent to offspring; or to an unrelated object, as a photograph or model to the original. Of these, the ability to reproduce itself, along with any fixed aberration, is the most demanding and is especially characteristic of biology; and life has been defined as "the repetitive production of ordered heterogeneity." The guiding information is carried, and the given arrangement is imposed or reproduced by various means, from electric fields around linked pyrimidines in nucleic acids (four of which can "code" the building of the 20 amino acids of proteins), through the protein antigens of cellular immunity, the metabolic and allied gradients of morphogenesis, the engrams of racial or individual experience, to the coded tapes of calculators and the culture traits, especially language, of civilizations.

Communication of information across org boundaries, between entities at the same or different levels, is not only the means of fixing the past; it is also the means of responding to the present. Nerve impulses and hormones, like talk and books, are transient or more enduring signals (or symbols). Perhaps hearing is more important than vision to social man, as is often claimed, because speech is the vehicle for the immediate communication of information in ongoing interacting behavior. Indeed, a major difference between physical, biological, and social orgs may be in the relative importance for them of the energy, substance, information, and meaning that cross their boundaries. The higher the level, the more do individuality and specificity enter and the more is the system coded to, or discriminating of, differential environmental stimuli or information.

The more also does the study of higher level orgs involve the use of experimental methods and mental tools dealing with patterns of relatedness. The forking paths of a nerve impulse through a brain, or an infection in a population, or a rumor in a community reveal connectivity patterns; and for the analysis of these relations of "organized complexity" are coming to hand the new techniques of set, game, and probability theory, of topology and stochastics, and of other nascent branches of mathematics or logic.

History produces structure, and structure determines function—becoming gives being, and this is capable of behaving; order is produced and maintained—but the relations are so intimate and seemingly reciprocal that the distinctions sometimes seem artificial. Further consideration shows that this is not the case. For the function of an org at its level depends on the structure of its subordinate units, and the structure of these subordinate-level orgs depends, in turn, on the history of their sub-subordinate units. Contraction of a muscle fiber is possible by virtue of the fibrillar and membrane structures, and these are produced by processes involving macromolecules, enzymes, and other submicroscopic units. It would lead too far afield to develop the notion, but it deserves thought, that history, structure, and function stand in relation to one another as do cause, org, and purpose. In both triads, time runs, say, from left to right through past, present, and future; and levels rise from left to right through subordinate, ordinate, and superordinate. Incidentally, function (the noun), with an overtone of duty, relates an ordinate unit to a superordinate org; at its own level, functioning has an overtone of pleasure.

**Conclusion**

In the remaining space, I can merely suggest the concrete application of these considerations. Again a brief recapitulation. The units of man's attention are first concrete objects, directly sensible. These are classified, then seen as populations with variance; dissected or combined, to sub- and superordinate units forming hierarchical levels; compared and analyzed so that functional units replace or add to structural ones; and considered in relation to time, both as to irreversible development and to maintenance or restoration of equilibrium; and in relation to order and the information carriers that reproduce it. The world of organized experience thus plots on a map, with orgs at different hierarchical levels—molecule, cell (or crystal), organism, group, population (or society)—along the ordinate; and with their properties—becoming, being, behaving—along the abscissa. The entities, the disciplines concerned with them, the manipulative and rational methods for studying them, and the resulting concepts about them, can be classified into appropriate squares of such a table.

The hierarchy has two major branchings: (i) above the molecule level, into more organized entities with or without the collective properties that describe the living; and (ii) above the organism level, into entities based on human or non-human components. Biology is thus superordinate to physics and chemistry and, at its lower levels, coordinate to the earth sciences; it is subordinate to and, at its higher levels, coordinate to the social sciences. The boundaries are reasonably sharp; yet the biochemist or biophysicist or electron microscopist, concerned with molecular traffic and macromolecular edifices, is much closer in attitudes and operations to the physical scientist, while the systematist or population geneticist or ecologist, concerned with organism traffic and population edifices, is much closer to the social scientist, than these different-level biologists are to one another. And perhaps the biologists operating between cell and organism levels are most akin to, say, meteorologists and might find rich mental nutrition by learning how they handle such problems as storms by the study of individual hurricanes, from Alice to Zelda.

The attributes that help define living orgs are (i) highly ordered and clearly bounded heterogeneity, spread over many levels and with many differentiated units at each; (ii) dependable mechanisms for reproducing units and patterns, by reduplication of the information carriers, and for altering them, by recombination of carriers and by the innovating (mutagenic, imprinting) and selective action of environment on the carriers; (iii) powerful homeostatic mechanisms for maintaining and regaining equilibrium, including especially the use of transported material, transmitted activation by energy or signs or signals, and stationary dominance-subordination gradients. The gene, materialized as a macromolecule, and the idea, materialized as an engram, chiefly among the transmitters of enduring order, are the bearers of structural and behavioral heredity; they carry the past of the entity and account for its individuality. The hormone and the nerve impulse and the sound or gesture, chiefly among the transmitters of transient order, are the bearers of information and instruction to and from orgs or their subsystems and evoke adaptive or innovative behavior that maintains the entity or modifies it in conformity with environmental pressures.

The student of the living stands between the students of the material and of the human on an ordinal scale. He deals with entities or orgs or systems that are less when compared to the latter, but more when compared to the former; more various and more individualized: more highly ordered and capable of more varied behaviors; more dependent on a particularized past and a discriminated present and so on fixed or transient information; more devoted to self-maintenance and self-duplication over the short run—by stability, supplied by feedback and inheritance—and more devoted to change and adaptation over the long run—by modifiability, supplied by learning and gene shift and guided by environmental selection; more sensitive to more environmental variables and more able to dissociate the response from the stimulus in magnitude, kind, and time interval; more personified and closer to the observer and harder to dimensionalize and quantify; more "free" to achieve their "purposes" and reach their "values," including survival and "progress," and to be "aware" of the attendant experience of inner "private" and outer public "reality"—if these words add anything to what has been said.

Such an exercise in analysis and integration is more than an exciting mental adventure; it can have important and useful consequences. The attention of an investigator may be directed to other disciplines from which ideas or skills or information can be plucked ready to apply to his own. Social scientists have been slow in exploiting biology in this way, but they could profit much from its approach and content. Acculturation as a stress, culture as a self-regulated internal environment, institutions as organs, ideas as heritable social mutations and subject to the same factors or pressures as operate for organic evolution, ideologies as polar or balanced views of man as a whole entity and man as a unit in a larger unity—such viewpoints can demonstrably aid understanding of the social epiorganism or the body politic.

The interrelations of subdisciplines in an investigator's own field may be exhibited, so that the great unities are not lost in the small particulars. This may spark the seminal insight that leads to a new structuring of the universe of interest and, failing this, must reveal areas of research emptiness or duplication. And this also should favor presentation of biology as a dynamic whole, with a few penetrating concepts replacing a legion of detailed facts and words, to our students and to our public. Life science is a great entity, and part of a greater one; biology, all science, will attract more and better members and more generous and enthusiastic support when, in all senses, the forest is added to the trees.

#### References and Notes


1. My thoughts on this topic have been much enriched by participation in a symposium on "Concepts of biology" that was sponsored by the Biology Council of the National Research Council about a year ago (the symposium is soon to appear as a monograph) and by the ongoing theory workshop discussions with my colleagues at the Mental Health Research Institute, University of Michigan.
2. R. W. Gerard, "The scope of science," *Sci. Monthly* 64, 496 (1947); "A biologist's view of society," *Common Cause* 3, 630 (1950) [reprinted in *Yearbook Soc. Advancement Gen. Systems Theory* 1, 161 (1956)]; R. W. Gerard and A. E. Emerson, "Extrapolation from the biological to the social," *Science* 101, 582 (1945); R. W. Gerard, C. Kluckhohn, A. Rapoport, "Biological and cultural evolution," *Behavioral Sci.* 1, 6 (1956).
3. R. W. Gerard, "Instruments and man," *Instruments* 18, No. 10 (1945).
4. ———, "The organization of science," *Ann. Rev. Physiol.* 14, 1 (1952); "From spirits to mechanism: two centuries of biology," in *Facing the Future's Risks*, L. Bryson, Ed. (Harper, New York, 1953), pp. 111–144.
5. Much confusion has arisen from the use of a given word as a noun, a structural connotation, and as a verb, a functional one. Thus, *function* in physiology, *adaptation* in systematics, and *role* in sociology, as examples, when used as nouns, refer to an existing state; as verbs, to an action. The state, in each case, carries an implication of purpose and value, of the org at one level to the superordinate system; and the action, similarly, implies a behavior of the unit that has utility in the larger setting. Adaptation of the individual, in adaptive amplification, is different from the adaptation it has acquired to an environmental situation; the adaptive radiating of a population is different from the adaptive radiations of a phylum.
6. R. W. Gerard, "Levels of organization," *Main Currents in Modern Thought*, 12, No. 5 (1956).
7. ———, "Organism, society, and science," *Sci. Monthly* 50, 340, 403, 530 (1940).
8. ———, "Experiments in microevolution," *Science* 129, 727 (1954).