The Level-of-Integration Concept and Ecology
Author(s): J. S. Rowe
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snag and windfall remains will add to already excessive fuel. Danger of devastating fires will increase.

Summary

During the past century the ponderosa pine forest of Cedar Valley in southern Washington has experienced profound ecological changes. There remain only scattered, patchy remnants of the original magnificent, park-like forest. The valley is now almost universally characterized by dense stands of young pine and true fir. Pole sized stands of pine that originated about 1900 have grown well. Younger age classes, however, are so densely stocked that they are growing poorly. Through competition for limited soil moisture, these young trees adversely affect the growth rate of the remnant mature overstory. This encourages continuing epidemic beetle attacks on these high value trees. Fire hazard has greatly increased. These changes, which typify similar ones throughout the Ponderosa Pine Region, are the result of over-grazing by stock and attempts at total fire exclusion.

That frequent, periodic surface fires were important in the primeval pine forest is indicated by stand structure, species composition and the tree-ring and fire-scar record. Extensive even-aged stands originated after epidemic insect attacks that were followed by fires.

Interruption of nature's cyclic process was first caused by severe over-grazing of the pinegrass forest floor. This followed introduction of great bands of sheep and of homesteaders domestic stock in the 1880's. The settlers also cut timber for sawmills and cleared for agriculture. Severe climatic conditions were not conducive to farming and most of the settlers left after 1910.

From 1893-1895 inclusive, the forest was defoliated by a great epidemic of the pine butterfly. This was immediately followed by epidemic attacks of the western pine beetle, which was encouraged by the weakened condition of the defoliated trees. The butterfly-pine beetle attacks resulted in destruction of almost one billion board feet of pine sawtimber.

Seeds from the slowly dying trees germinated in a mineral soil seed bed on the stock trampled forest floor. This resulted in millions of pine seedlings, most of which became established about 1900. It is significant that this even-aged reproduction stand was thinned by fires set by stockmen and settlers in the early 1900's. The dominant or more fortunately situated individuals survived these fires and on release from competition made greatly accelerated growth. These trees are the well stocked large pole sized stands of Cedar Valley.

Following windthrow and continuing pine beetle infestation during the 1930, 1940 and 1950 decades, the remainder of the valley seeded in to younger age classes of reproduction. These stands are dense and make up an almost universal thicket under the remnant overstory of mature trees. It is significant that but minor portions of these stands have been subjected to fire as a result of organized fire suppression following 1910.

Normal growth in these stands will not occur until they are thinned. In the meantime competition for soil moisture will become more intense and conditions for devastating insect attacks and fires will increase.

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THE LEVEL-OF-INTEGRATION CONCEPT AND ECOLOGY

J. S. Rowe
Forest Research Division, Department of Forestry, Ottawa

Introduction

Since at least the time of Comte the idea of arranging and classifying the sciences in an hierarchy according to level of inclusiveness or level of integration of subject matter has been common currency. That this notion has particular appeal in biological circles is evidenced by its widespread invocation whenever justification for a particular field of study or a scientific viewpoint is sought (for recent examples, see Egler 1942, Novikoff 1945, Sears 1949, Dice 1955, Mayr 1955, Miller 1957, Bray 1958, Muller 1958, Decker 1959, Odum 1959, Wright 1959). This article attempts to show how the idea may further illuminate both subject matter and point of view associated with *ecology*. It is also a commentary on the article by Major (1958), "Plant Ecology as a Branch of Botany," wherein he invited active discussion of relationships between plant geography and ecology.

Concept of Integrative Levels of Organization

An article by von Bertalanffy (1950) pointed up some of the implications of the independent evolution of similar general conceptions and viewpoints in the various branches of science, with reference to organization of the latter in an hierarchy. He stated (p. 164), "Reality, in the modern conception, appears as a tremendous hierarchical order of organized entities, leading in a superposition of many levels, from physical and chemical to biological and sociological systems. Unity of Science is granted, not by a utopian reduction of all sciences to physics and chemistry, but by the structural uniformities of the different levels of reality." Thus, the structural similarities and logical homologies of the many different subordinate and superordinate systems make possible the formulation and deduction of principles valid for systems in general, giving rise to a new basic scientific discipline: General System Theory.

Feibleman (1954) has attempted to systematize some of the structural uniformities and inter-relationships of the integrative levels. His "Laws of the Levels" are worth close examination; they illuminate some aspects of mechanism, vitalism and teleology, and show the value of the integrative-levels concept as a positive aid to scientific research, pointing out that the understanding of an organization at any level requires attention also to the levels above and below. However, the thought occurs that careful attention ought to be given to that which is organized at the various levels. What exactly are the integrative levels to be? Obviously there must be some logical relationships if the hierarchy is not to be misleading and a source of confusion.

That there are differences of opinion as to how the different levels of organization are constituted, and inconsistencies within many of the proposed heirarchies of levels, is apparent from the following examples. Egler (1942) discussed 5 levels of emergent "organisms" (organizations or systems) in which plants predominate. From the simpler to the more complex these are: individual organisms, plant communities, biotic communities, vegetation and ecosystems. Clearly "vegetation" has a different conceptual status from either "biotic communities" or "ecosystems," and there are other inconsistencies of which Egler was doubtless aware when he wrote (p. 247) that "these emergent organisms are artificially isolated from the rest of nature for purposes of study, and . . . they may be arranged in different and equally satisfactory sequences for other purposes." Novikoff (1945) listed cells, tissues, organs, organ-systems, organisms and populations in increasingly higher levels of biological integration, and Odum (1959) in a similar sequence added, above populations, communities, ecosystems and the biosphere. Mayr (1955) carried the organization levels from cells, tissues, organs and individual organisms to populations and species, while Wright (1959) suggested the gene as autonomous at the level below the cell, and demes (interbreeding populations), species, ecologic systems and world fauna and flora at successive levels above the individual organism. Note the use of taxonomic categories as levels of integration, introducing a quite different mode of abstraction in the hierarchy. According to Bray (1958) most botanists and zoologists would place the "community" as the highest level of biological emergence, although "community" has been strongly criticized by some (e.g., Muller 1958) as referring to no consistent object. Returning for a second look at Bertalanffy's (1950) statement that "Reality, in the modern conception, appears as a tremendous hierarchical order of organized entities . . ." we are justified in asking: "What reality?" and "What organized entities?" These related questions lead to a consideration of the nature of empirical knowledge.

Perception and Objects of Study

The natural sciences are concerned with empirical knowledge of nature, i.e., with what we perceive through the senses. Perception is not simply the registry by a receptive mind of what lies "out there"; rather it is an active intellectual process which provides consciousness with "objects" as vehicles of meaning for the world as sensed. Woodger (1929) has given a satisfying exposition of the relationship of perceived objects to the realm of nature and to the percipient; his theory of empirical knowledge is the basis from which the following argument has been developed.

The objects that we perceive—e.g., a house, a plant, a piece of soil—are basically volumes discriminated from their surroundings in space and time. On analysis they are observed to have structurally joined parts which strengthens our apprehension of their "objectness." On the other hand, we intuitively reduce to the status of an aggregate that in which we detect a lack of structural connection between what were first assumed to be "parts." The forest stand (vegetation community) appears from a distance to be a good solid object, but on close inspection it disintegrates into an aggregate of spatially separated trees and undergrowth plants. True there may be limited interconnections by root grafts, by epiphytism and parasitism, but community members have no *necessary* structural bonding; the unity of the community is in common occupancy of area. Still further removed from the structurally integrated object is the purely intellectual class entity such as the *species*, members of which may be widely separated in time as well as in space.

The distinction between the structurally integrated object (e.g., plant), the areal or geographic aggregate (e.g., plant community) and the non-object, non-aggregate class (e.g., species) is important in the problem of setting up a consistent level-of-integration scheme. The thesis here advanced is that each level must be an "object" as defined above, and that objects at successive levels must be structurally related. This can be illustrated by consideration of the organism, the organ and the cell, three objects whose status as integrative levels seems generally agreed upon. The organism contains the organ which contains the cell, and the cell is a structural part of the organ as the latter is a structural part of the organism.

We are now ready to state the basic propositions for a logical, useful level-of-integration scheme: The object of study of whatever level must contain, volumetrically and structurally, the objects of the lower levels, and must therefore be itself a part of the levels above. Each object will then constitute the immediate environment of the object at the level below while forming a structural-functional part of the object at the level above.

What objective level of organization stands above that of organism? According to the propositions just stated the enveloping object is the volumetrically inclusive, internally structured ecosystem (Fig. 1).

Each successive integrative level is not formed by aggregation of only one kind of lower level organization; the relationship between successive levels is not symmetrical. The object at each level is heterogeneous; it organizes a variety of spatially associated lower systems. The organ is more than cells, it is also connective tissue and other cell products; the organism is more than or-

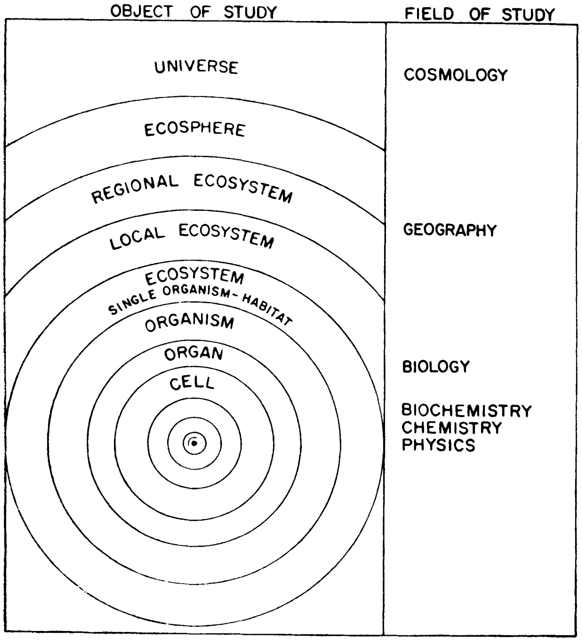

FIG. 1. Diagrammatic representation of objects of study at increasingly inclusive levels of organization; some corresponding fields of study are also shown.

gans, it is also their non-organ matrix of tissues, etc. So the object at the supra-organism level is more than a group of juxtaposed organisms or a group related reproductively; it is this group or community *plus* whatever else accompanies, interpenetrates and ties it together structurally, i.e., the land below, the air above.

A number of entities proposed as bona fide members of the levels-of-organization hierarchy come into question. The "organ-system," for example, fails when tested as the milieu of the level below, for it is not the environment of its member organs. "Organ-system" is a category which brings together by abstraction various spatially separate parts whose relationship consists in a certain cooperative outcome at the supra-organ (organism) level. Similarly "vegetation" is neither the environment of individual plants nor a structural organization of the ecosystem. "Deme," "population," "species," "flora"—all highly abstract taxonomic categories—must likewise be rejected as first order objects of study.

The Ecosystem as an Integrative Level

It has been pointed out by many that the term "ecosystem" has only categorical meaning (Sjörs 1955, Evans 1956, Friederichs 1958). This is implied too in Lindeman's (1942) inclusive definition of ecosystem as "any system composed of physical, chemical and biological processes active within a space-time unit of any magnitude." Tansley (1935) recognized that size and extent of ecosystems will be determined according to the purposes and methods of particular studies. Hills (1958) has referred to ecosystems ("forest sites") as wholes isolated from the continua in which they occur for purposes of evaluating their potential for production.

Recognition of the pragmatic element in the definition of ecosystems is a healthy reminder that there may be merit in various approaches to their selection. Some ecosystem units are practically "given" as self-evident objects, e.g., the limnologist's unit, the pond or lake. The terrestrial ecosystem is not always presented in so neat a package; usually it must be carved out of the living landscape by the use of appropriate criteria. To some people this subjectivity of boundary delineation is a stumbling block to acceptance of the ecosystem as an object of study, yet it need not be. A precise analogy is with soils, which have been made objects of scientific study despite the fact that their boundaries are fixed only by definition. Obviously study can be focussed on geographic "cores" though boundaries around them are elastic.

The criteria by means of which ecosystems can be defined and bounded are many. More important to the present discussion of the level-of-integration scheme is the fact that each ecosystem, encapsulating successively smaller ones down to the level of the individual organism-habitat cell or "monocene" of Friederichs (1958), is also part of an increasingly larger series. Thus above the level of organism extends a hierarchy of increasingly inclusive ecosystems, building from the local to the regional and on to the ultimate culmination in the all-encompassing world ecosystem or ecosphere, as Cole (1958) has called it.

The Ecosystem as a Geographic Object

Any single perceptible ecosystem is a topographic unit, a volume of land and air plus organic contents extended areally over a particular part of the earth's surface for a certain time. To some degree, therefore, it is unique in space as in time, for geography like history does not repeat itself. Study of the ecosystem is essentially topological, and the root *topos,* meaning "place," appears in many of the terms devised to describe its composition. Figure 2 shows the components of the biogeocoenosis, an ecosystem unit bounded with reference to a defined phytocoenosis (Sukachev 1954).

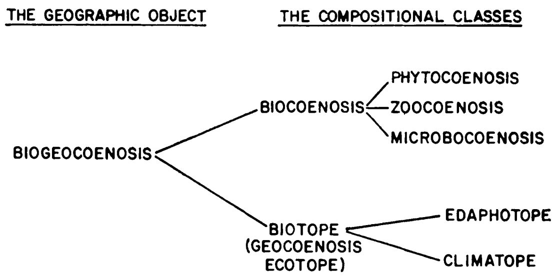

FIG. 2. Compositional components of the biogeocoenosis (an ecosystem comprehending a phytocoenosis) according to Sukachev.

As earlier emphasized in discussion of the level-of-integration scheme, a clear distinction needs to be maintained between the compositional categories and structural parts of objects. A simple ecosystem such as a "pine forest sand dune" can be analyzed into various structural parts: 1) into individual "cells," each consisting of one tree with its immediately surrounding air-soil volume, or 2) if there is an evident horizontally extended structure, into spatial units or volumetric landscape elements such as are centered on groups of trees, or 3) into structural-functional layers such as may be delineated by certain strata of the soil (Nikiforoff 1959) or strata of the atmosphere. Sukachev (1954) has designated the horizontal layers of the ecosystem "biogeocoenotic synusiae."

It is surprising that our vocabulary is inadequate for concise description of the ecosystem synusiae. The volume underfoot in which plants are rooted is commonly designated "soil" and studied as a whole and by horizons in pedology, but there is no comparable term nor field of study for the above-ground volume in which the shoots and crowns of trees and plants are likewise "rooted." We are aware of the contents of the air layer, but its own substantiality and stratification of composition, density, temperature, turbidity, etc., have largely escaped our attention, except where reciprocal influences on the forms of plants have been observed.. Topoclimatology, as defined by Thornthwaite (1953), is perhaps concerned more than any other branch of science with this layer or synusia, but none has treated it *in toto* as an object of study equivalent in importance to the soil stratum.

Relationship of Phytocoenosis to Ecosystem

Within the framework of the preceding sections, the status of the phytocoenosis or plant community can now be assessed. The phytocoenosis is an aggregate, a grouping based on area. But the object that occupies area at the level above the individual organism is the ecosystem, and logically the phytocoenosis is seen as a botanical component of ecosystem. It is a compositional category, not a unified structural part, and its status has neither the objectivity of its component individual plants nor of the ecosystem from which it is abstracted. The same can be said for other components similarly separated from the ecosystem on the basis of compositional class rather than structure. However, the soil body has a substantiality not shared by the phytocoenosis or zoocoenosis, for it is a volumetric whole, a clearly defined structural-functional layer. Soils might themselves be considered ecosystems, but recognition of their close dependence on the stratum above suggests their more logical treatment as ecosystem parts rather than as independent "natural bodies" (Crocker 1952).

Recognition of the basic difference between aggregate and structured object illuminates many problems which arise in the attempt to make communities and populations first-order objects of study. For example, some of the difficult and controversial subjects of "vegetation science" —e.g., competition, succession, productivity—are much simplified when examined at the level of the organism and at the level of the ecosystem.

Points of View in Scientific Study

Major (1958) continued the discussion by Egler (1942) of the "points of view" from which the subject matter of the various natural sciences can be studied. Both writers referred to Tschulok's (1910) presentation of 7 incommensurate material points of view applicable to the study of biological objects, these being taxonomy, morphology, physiology, ecology, chorology, chronology and genetics. Egler added "composition" to the list but dropped "genetics," considering the latter viewpoint to be covered by physiology, at least where individual organisms are the objects of study. Major reinstated genetics as "genesis," while accepting "composition" as a necessary auxiliary viewpoint. Despite the considerable attention they have attracted, the points of view do not seem to have been clearly defined in relation to "object of study" and to one another, nor integrated in a general theory of knowledge. In the following section the concept of integrative levels of organization will be shown to be relevant in providing a framework which gives specific and consistent meaning to a number of these viewpoints.

In Woodger's theory of knowledge previously referred to, the realities are strands of history or "events"; for example, the ontogeny of a frog is an "event," and the persistent stable phases—egg, larva, adult—we know as "objects." An object is what a slab of space-time is known as, and to our perception it is basically a volume, a form with related qualities. Thus the first viewpoint is morphology, the apprehension of physiognomy or form. Beyond perception of form, understanding is added in two ways. One mode of comprehension is analytical, looking within to the morphology of parts in their structural relationships (anatomy) and perhaps making an inventory of them (composition). The other mode of comprehension looks outward, seeing the object whole and searching for its relationships with the external world.

Now performance is the concomitant of form at all levels. What an object does continuously or repeatedly (its performance) is its function, and the antithesis between form and function rests simply on the artificial separation of space and time (Woodger, *op. cit.* p. 327). Concerned with study of function is the viewpoint physiology, the reference being primarily to the analysis of parts. Thus the question "How does the object function?" asks what are the performances of its parts in the service of the whole, while "What is its function?" asks what it does as a part of something more inclusive.

The outward looking viewpoint, concerned with study of the externally conditioned processes of an object, is ecology. Two different methodological approaches are usefully distinguished. First, the object may be maintained at the center of interest as a unity opposed to an unorganized, "factored" environment. Second, the object may be placed as a structural-functional part of more inclusive levels of organization, i.e., as an active constituent of a larger whole which directs its activity. In the latter sense, environment is conceived as itself an organized entity, and the realistic coenotic relationships with the object are implied.

The foregoing explains some of the differences of opinion surrounding definition of "ecology." Without reference to a level of integration scheme, ecology (at least behavioral or ethological ecology) is simply the study of the contingency of objects on abstract external factors, for example, the effects on a plant of impinging light, heat, moisture, nutrients. This is the basis on which Mason and Langenheim (1957) analyzed the meaning of *environment*. However, in the context of an hierarchy of organizations, ecology becomes study of the contingencies of objects at any level on the more inclusive levels of organization; for example, the ecology of a plant is its reaction to the ecosystem in which it participates, just as the ecology of an ecosystem is its relationship to the larger system which in turn surrounds it.

If the two modes of comprehension—the inward and the outward looking—are applied to the objects in an hierarchy of integrative levels, an overlapping of viewpoints must result. As we have seen, the physiology of an object looks to the functions of its parts, or to its function as a part, while the ecology of an object at any level seeks relationships to the more comprehensive world around it. So the ecology of a plant growing at a certain place coincides with some part of the physiology of the ecosystem which comprehends that place. The ecologist, working up through the hierarchy of organizations, at each level meets the physiologist working down.

As points of view that can be focussed on various objects or levels of organization, neither physiology nor ecology need imply a field of study. However there has been a tendency for physiologists to arrogate the individual organism as their field, calling the autecological aspects of their studies "environmental physiology." For example, the first experimental work on photoperiodism seems to have been pure ecology, though carried out by physiologists (Garner and Allard 1920). The ecologists, perhaps in self defense, have been making advances toward adoption of the ecosystem: "Ecology deals with all super-individual structures or organizations" (Dotterweich, *vide* Stocker 1956); "The ecosystem is the basic unit of ecology" (Evans 1956); "Ecology is the science of the super-individual complexes of nature" (Freiderichs 1958); "Ecology is the study of the structure and function of nature" (Odum 1959); "Ecology is the study of ecosystems" (Krajina 1960). Of course "ecology" has always denoted an inclusive subject matter in the English-speaking world, and inasmuch as study of the ecology of the organism demands attention to the physiology of the ecosystem, ecologists are perhaps justified in embracing this important study of process. Taking a leaf from the physiologists, the field might be called "functional ecology"! Billings (1957 p. 387) has of course used the precise phrase: "ecosystem physiology."

In addition to the relationships in form and function of wholes and parts, a number of viewpoints add meaning to an object in terms of position in space, development through time, and ties of class. Where an object is in space, relative to known points on the earth's surface, is its chorology. Establishment of the chorology of more than one object allows the formulation of spatial relations; for example, the detection of pattern in the distributions of individuals and populations. Note that such pattern of individual organisms is an element of structure though not total structure, at the ecosystem level above. Chorology elucidates ecology by showing where similar objects do and do not occur. Migration is chorologic change in time, and it is well to remember that individual plants rarely migrate, though the race or species does. The subject "geography" is discussed later, and it is enough here to note that a useful distinction can be drawn between chorology as the systematic viewpoint directed to the place in space of particular phenomena, and geography proper as study of "place" itself. Failure to distinguish between the viewpoint and the field of study is at the root of McMillan's (1956) argument that geographical study is a necessary preliminary to autecological investigations. I would say, rather, that chorology is one of a number of viewpoints that complements ecology, and that all viewpoints can profitably be applied to study of earth-place, the object of geographical investigation.

The viewpoint chronology traces the sequence of forms (and functions) culminating in a particular object. In philosophical terms, chronology describes an event, a strand of history, in terms of successive phases having sufficient endurance to be known as objects. From the standpoint of the terminal object, the chronology is called its ontogeny or genesis. The course it runs depends on both internal (physiological) and external (ecological) processes: it is both autogenic and allogenic. Given a regularity of internal and external conditions, chronology of similar objects (their ontogeny, development or "succession" of forms) can be expected to follow similar courses, i.e. chronology becomes predictable. Without this regularity in autogenic and allogenic factors, new objects appear in the sequence, and variation—often unpredictable—is recognized. This is evolution at the object level.

The relationship of objects according to likeness is classification, systematics. It is the striving for intellectual completeness that places classification as the synthesizing viewpoint, primarily based on morphology but drawing on all other viewpoints in order to establish, between phenomena, the maximum of relatedness in form and function, space and time. A distinction has to be made between the classification that is automatically and unconsciously done at the level of perception where what is sensed is identified as a particular object (tree, rabbit, etc.), and the conscious logical relating by kind that can be carried to elaborate lengths on the basis of selected criteria to yield morphologic, compositional, physiologic, ecologic, "geographic" and genetic classifications. Some implications are worth examining in detail.

Classes of objects can be arranged in time sequences to show presumed relationships; this constitutes phylogeny, chronology of the race or type. As Gilmour (1940) pointed out, the group or class of organisms is formed on the basis of correlation of attributes; it is prior to the phylogeny that can be derived from it. Thus classifications are phylogenetic by arrangement, after the classes have been organized on other grounds, and phylogeny must be considered derivative from systematics rather than the reverse. In one of its meanings, "history" is used to refer to the progenitors of an object far back in time, i.e., to racial evolution or phylogeny. It is clear that history in this meaning is speculative, non-inductive, describing a unique evolutionary succession on the basis of a taxonomy whose worth for this purpose is untestable. History as evolution of the race is by no means trivial, but dealing as it does with non-objects in explanatory rather than predictive ways (Scriven 1959) it is well to contrast it with development of the individual (ontogeny, morphogenesis) which *is* amenable to empirical study. It is also noteworthy that classification at analytic levels is basic to the viewpoint composition.

The foregoing treatment of the scientific points of view covers much the same ground as Major's (1958) article though with some differences of interpretation. A brief comparison will serve the purposes of summary.

Major begins with composition and structure, the latter viewpoint treated here as morphology and, by reduction, as anatomy. Thus structure is the inter-relation of parts (anatomy) as dominated by the character of the whole (morphology). In repeating Tschulok's definition of structure as "arrangement of these units of composition," Major placed the latter as a primary viewpoint. It seems more reasonable to me to reverse the priority, making composition subsidiary to structure because it is classificatory and "non-organic," yielding a quantitative inventory of parts at whatever level of analysis is desired; in short, it derives meaning from the structure it describes. Major's definition of the viewpoints physiology and ecology, looking to the processes within and the relationships without, are acceptable, as are the expressions of chorology as distribution in space and of classification as both summary and organization of knowledge. However, some confusion is introduced with the viewpoints genesis and history, the former treated as study of evolution and short-term change, the latter as long-term (palaeobotanic) change. It seems more reasonable to differentiate the chronology of objects (morphogenesis, and genetics in part) from their nonempirical evolutionary pasts (history or phylogeny), the latter viewpoint relying on classification.

All the viewpoints are inter-related through the objects on which they are focussed; they bring mutual support to scientific studies, particularly within a level-of-organization scheme (Fig. 3). Major's difficulties in setting forth a logical exposition of the scientific viewpoints largely stem from the impossibility of treating the community as analogous to the individual organism all down the line.

Nature of Geography

Space and time have entered the previous discussion in two ways: 1) as the necessary framework of perception and 2) as points of view—chorology and chronology—whereby particular phenomena are systematically placed

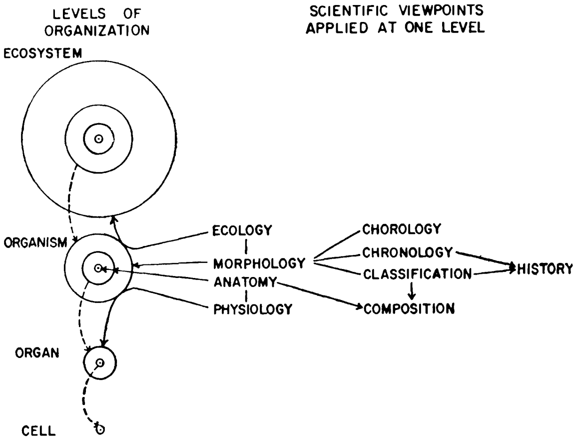

Fig. 3. Related objects (levels of organization), and scientific viewpoints as applied at one level. Note that the viewpoints, anatomy, composition and physiology are applied in descending the levels while morphology and ecology are applied in ascending.

in spatial and temporal relationships and sequences. In yet another aspect, that of geography and history, space and time provide the unifying background for phenomena that may not be systematically related.

Hartshorne (1939) in his stimulating monograph "The Nature of Geography" drew attention to the argument that 3 different approaches are available and necessary for the full comprehension of reality. The idea was proposed by the philosopher Kant (*vide* Hartshorne 1939) in an essay on geography, wherein he pointed out that we may "classify" our empirical knowledge according to conceptions (logical classification) or according to time and space (physical classification). Through the former we obtain a system of nature, a register of the whole; through the latter a geographical and historical description of nature. Description according to space (treating all phenomena of a region) is geography, that according to time (all phenomena of a period) is history. This last is "history" treated as subject rather than as viewpoint. Apparently influenced by Kant, Humboldt placed geography as the study of that which exists together in area, as opposed to the systematic sciences focussed on particular phenomena, and much later the German geographer Hettner independently formulated the same idea (Hartshorne 1958). The "object" of geographical study is therefore to be understood as earthspace and its contents, i.e., the complex juxtaposition of phenomena that gives character to region, locality, place. By this definition, "plant geography" is the topical study of plants associated in place, as characteristic of that place.

When geography and the systematic sciences are contrasted it is on the supposition that the object of geographic study is unique while that of the systematic sciences is not. Actually all phenomena are to some extent unique, but the more inclusive the level of organization, the more apparent the elements of uniqueness become. Thus the individuality of the organism stands out in comparison to that of the cell, while the individuality of the ecosystem (a geographic entity) is still more clearly evident. Quoting James (1954), "In the field of geography, as long as attention is focused exclusively on the difference between places, the unique quality of each place is emphasized, and for some purposes this is exactly what should be done. However, likenesses between places may also be important, and for some purposes more important than the differences. The identification of the similarities between places is a geographic method of arriving at a generalization . . . of the characteristics of area." This means that geographic entities are amenable to systematic study; it is only necessary to concentrate on their repetitive characteristics. Although classifiability of subject matter is a prominent characteristic of the systematic sciences, and uniqueness to which only description is fully adequate the mark of geography, the separation of the two is merely a matter of degree. The differences are certainly not of the fundamental kind that sets history apart from both in the different dimension of time.

Ecosystem and Points of View

The ecosystem as here used is a geographic object, and the relevance of the points of view to geographic study can be illustrated with it. At the same time, some questions concerning the suitability of the ecosystem as an object of biological research may be answered.

From the viewpoint morphology, a terrestrial ecosystem is a volume of earth space with organic contents, separated from its neighbors by reasonable divisions in the empirical continua of biota, soil, physiography. It resembles a model formed by a slab of clear plastic (atmosphere) bound to a porous slab of metal (lithosphere) by wooden dowels (the plants and other organisms). Horizontal or vertical slices through it reveal the anatomical structure, hitherto dissected in bits and pieces by the microclimatologist, the botanist, the pedologist and the geomorphologist working separately. An inventory of the parts, sorted into classes, is given by the viewpoint composition. The physiological viewpoint is directed to internal functions: the production and cycling of materials in and between the anatomical parts, the accumulation of matter and energy in the whole. The ecology of the ecosystem is its relationships to the larger enveloping geographic system of which it is a part and with which it continuously exchanges materials and energy. From the chorologic viewpoint, ecosystems are mapped in their positions at the earth's surface. Chronology records the character of sequent ecosystems at one particular place, and the genesis of a particular one by "succession" refers to the observable changes that come about through time in a fixed space. Such changes are both internally and externally conditioned (autogenic and allogenic), and given some regularity in both physiological and ecological processes, the chronology may run at least a predictable short-term course. Ecosystems can be classified according to similarities in form, structure and composition, with support from the other viewpoints. It needs to be stressed that the ecosystem is not just an amplified phytocoenosis; typology must therefore be based on more than botanical composition (Rowe 1960). Finally, history seeks to trace in generalities and for particular places the climatic and geomorphologic changes of the past, as well as the evolution and migration of organisms, leading up to the syntheses of contemporary ecosystems.

In dealing with such patterned, intergrading objects as soils and ecosystems there is a necessary close reciprocity between the definition of units and classification. The class concepts formed in one area will be used in another to divide a continuum into reasonable segments. Thus classification is more than systematization of what is already given; it is a means of "catching the rabbit."

Vegetation and the Points of View

It has been shown how objects in an hierarchical level-of-integration scheme are amenable to scientific study by a number of incommensurate viewpoints. These same viewpoints can be focussed on presumed objects of study and used to detect those that are specious. As the status of the plant community as a first-order object of investigation has been questioned, it will now be tested by the scientific viewpoints.

The community is an aggregate of objects whose primary bond is common occupancy of area. This areal basis confers a degree of apparent substantiality on the community, for once the area is bounded a spatial unit appears. Furthermore the non-structural viewpoints chorology (position in space), chronology (succession), classification and composition are perfectly applicable to the areal community, as they are to many other non-objects. It might be noted that even the flora, whose abstract status will be granted without argument by most, can be mapped in space, chronicled in time, dissected into compositional categories and classified on paper. It is significant that vegetation is more commonly mapped, and classified according to composition, than studied.

Difficulties are encountered when the community unit is subjected to the viewpoint morphology, for immediately one perceives that both outward form and inner structure lack articulation. The idea of structure in vegetation takes certain liberties with what is perceived; the eye skips from plant to plant across the intervening spaces, searching out the repetitive growth forms which are then used to delineate a diffuse physiognomy.

Without structural form, the basis for performance is lacking; hence the difficulties of applying the viewpoint physiology in vegetation. Individual plants have their functions; not so the community. Major's statement (op. cit. p. 357) "there is a physiology of vegetation expressible by water and CO_2 relations of plant communities *considered in their ecosystems* . . ." (my italics) touches the important point; the reality is a physiology of the ecosystem, in which plants function. Again, the ecological viewpoint cannot apply in any clear way to the stand of vegetation. Becking (1957 p. 467) defines synecology as "study of the inter-relations between a plant community and its environment." But can a community be said to have an environment as separate from the environment of its members unless it is considered to be a volumetric object, ie., an ecosystem?

Discussion

There are signs that students of community biology are not entirely satisfied with the present basis of their subject. For example, Bray (1958) pointed to a neglect of structure analysis in the study of communities, while Miller (1957) noted that "community ecology has been particularly slow to progress from the study of structure to that of function." Contemporary books on quantitative ecology (Greig-Smith 1957, MacFadyen 1957) stress the importance of community structure, while in fact dealing primarily with mathematical analysis of composition, growth and population pattern. Shift in attention from community to the ecosystem which comprehends it could give deeper meaning to structure and function by providing the operational framework.

The argument does not imply that the community concept is valueless; the aim is to set the community in its logical place within the purview of science, thus avoiding the difficulties inherent in its treatment as an object of study of the same status as individual organism and ecosystem. Its limitations being recognized, the community remains a useful though limited subject of study. Also, like the concept *species*, it can serve the purpose of summarizing and classifying knowledge gained at more objective levels. For example, the "vegetation stand" or "community of plants" is a useful envelope in which to file information concerned specifically with plants juxtaposed in particular areas, such information having been gained by the objective study of the individual plants and of the ecosystems in which the plants are functional parts. Again, there can be no doubt that, as a topical aspect of geography, the description and mapping of vegetation has proven uses. In short, plant sociology serves its own purposes admirably, but for many other purposes, e.g., as the basis for study of problems of productivity and land management, it is inadequate.

It is of interest that the individualistic nature of the phytocoenose or vegetation community can be deduced from its relationship to the geographic ecosystem. While Gleason's (1927) argument for the "individualistic concept" of the association was not derived in this way, it did stem from sound geographic and historical considerations, and he was fully aware of the uniqueness that position in earthly space and in time imply. The controversial point of the "individualistic concept" has been the implication by many of its champions and opponents that its acceptance rules out the possibilities of classification. This, however, is a misconception of the nature of classification. There is no antithesis between individualism and classification so long as purpose finds *some* similarities in the units defined. Ecosystems, soils, phytocoenoses, even organisms, all are individualistic but none the less all are classifiable.

Summary

The concept of the integrative levels of organization is an illuminating one in the field of biological research. It can be a source of confusion, however, if entities of different orders of abstraction are built into the hierarchy. From a theory of empirical knowledge which is derived from Woodger (1929), a basis for relating the objects of study at successive levels according to the principle of spatial inclusiveness and structural relatedness is presented. The object of each level is seen as the environment of the objects at the levels below and as a specific structural-functional part of the object at the level above.

The ecosystem, a geographic life-filled space, is the object of study at the level above the organism. It is divisible into structural parts, vertically or horizontally, or into class parts (components) such as plants, animals, climatic and soil environment. Thus the status of the stand of vegetation (phytocoenose) is clarified; it is the abstract botanical component of a volume of earthly space (the ecosystem) which stands as the primary object of research.

Six primary viewpoints and three derivative ones are shown to encompass adequately the study of an object. As a form in space it is studied by *morphology*, and analytically by *anatomy*. A quantified catalogue of its classified parts is given by the viewpoint *composition*. Relating the object as a percept to inner and outer phenomena are the viewpoints *physiology* and *ecology*, respectively. Relating the object systematically to other phenomena in space, in time and by kind are the viewpoints *chorology*, *chronology* and *classification*. *History* traces past evolution deductively, by means of reasonable classification and circumstantial evidence. Within an objective, integrative level-of-organization scheme, the viewpoints physiology and ecology are shown to overlap where objects at adjoining levels are studied. Thus, for example, the physiology of an ecosystem coincides in part with the ecologies of the constituent organisms.

The ecosystem can be examined from all the viewpoints even though it is a geographic (i.e., unique) entity. However, the application of the points of view to vegeta-

tion as subject matter shows the limitations of the latter as an object of study. It is concluded that parallel concepts such as *population* and *community* also lack the substantial form and structure that confer first order objectivity, hence these too qualify for scientific study only as phenomena of lesser status than individual organism and ecosystem. Classifiability is, however, unaffected by the conceptual status of these entities.

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