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David L. Hull

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ARE SPECIES REALLY INDIVIDUALS?

DAVID L. HULL

Abstract

Hull, David L. (Department of Philosophy, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201) 1976. Are species really individuals? Syst. Zool. 25:174–191.—The processes which contribute to the evolution of biological species take place at a variety of levels of organization; e.g., genes give rise to other genes, organisms give rise to other organisms, and species give rise to other species. All of these processes require continuity through descent. If species are to be units of evolution, they need not be composed of similar organisms; instead they must be made up of organisms related by descent. Taxonomists do not impose this requirement on the phenomena; rather it follows from the nature of the evolutionary process itself. In addition to spatiotemporal continuity, species must also possess a certain degree of unity to function as units of evolution. Gene exchange is one means by which such unity can be promoted. The mechanisms by which asexual species maintain a similar unity are problematic; higher taxa pose an even more serious problem. However, if species are chunks of the genealogical nexus, they cannot be viewed as classes. Instead they possess all the characteristics of individuals—that is, if organisms are taken to be paradigm individuals. The major difference between organisms and species as individuals is that organisms possess a largely fixed genetic makeup which constrains their development, whereas species do not. If species are individuals, then their names are most naturally viewed as proper names, names which denote particular individuals but do not possess any intensional meaning. [Species; evolution.]

In a series of publications, Ghiselin (1966, 1969, 1974) has argued that species as chunks of the genealogical nexus are individuals, not classes of similar things, and that their names are proper names to be defined ostensively in a manner analogous to a christening (also Löther, 1972; Griffiths, 1974). Ghiselin's argument has two parts. The first is that the basic unit of classification must be some basic unit of evolution. Some biologists maintain that scientific theories are so variable and require data which is so difficult to obtain that classification should be theoretically neutral; no theoretical considerations should ever intrude during the formative stages of classification although theoretical inferences may be drawn from the classification afterwards. For these biologists, Ghiselin's position will seem wrong-headed, but it must be taken seriously by those biologists who believe that biological classifications must be in some sense "evolutionary."

The second part of Ghiselin's argument depends upon a particular view of meaning and definition. On this view, the names of individuals are proper names and, as such, have no meaning in the sense that terms like "triangle," "gold," and "game" do. They are meaningless identification tags and nothing else. They have no verbal definitions, no intensions. The twist which Ghiselin adds to the usual story is that the names of particular species are proper names because species are individuals. On the traditional view, the species category is a class of classes defined in terms of properties which particular species possess (e.g., reproductive isolation), particular species are classes defined in terms of the properties which organisms possess (e.g., pigmented feathers), and particular organisms are individuals (e.g., Gargantua) whose names are not defined at all (Buck and Hull, 1966). The relation between organisms, species, and the species category is membership. An organism is a member of its species and each species is a member of the species category. On the view being urged in this paper, both particular species and the species category itself must be moved down one category level. Organisms remain individuals, but they are no longer members of their species. Instead an organism is part of a more inclusive individual, its species, and the names of both particular organisms (like Gargantua) and particular species (like *Gorilla gorilla*) become proper names. The species category itself is no longer a class of classes but merely a class. As a class, it can continue to be defined in the usual way.[1]

Ghiselin's suggestion is a radical departure from past ways of viewing species. One would expect that shifting species from the category of classes to the category of individuals would cause extensive disruption in those branches of biology which make use of the species concept, but the changes are less extensive than one might fear. For example, the provisions of the various codes of biological nomenclature are more consistent with interpreting species as individuals than with interpreting them as classes, especially the central role played in nomenclature by the type-specimen. The fact that any specimen, no matter how atypical, can function as the type-specimen makes no sense on the class interpretation; it makes admirably good sense if species are interpreted as individuals (Hull, in preparation).

But what are species *really*: classes or individuals? Although this question seems simple enough, the sort of question which could be answered by straightforward empirical investigation, it is not. Rarely are the reasons for shifting an entity from one category to another strictly empirical, and seldom does such a shift have much in the way of direct empirical consequences. For example, Newton viewed space and time as totally independent, absolute features of the universe. For him time flowed like a river regardless of the existence or distribution of material bodies, and space was merely a place where material bodies existed. All matter could disappear without affecting space or time. On the usual interpretation of relativity theory, none of the preceding is true.[2] Time cannot flow like a river because it is not a thing at all; it is a relational property of matter. Nor can space exist in the absence of material bodies. Space and time are not two independent variables but a single relational property of material bodies. Einstein argued that space and time have characteristics very different from those supposed by Newton, but more than that, he argued that they belonged in a different ontological category altogether. Space-time can no more exist in the absence of material bodies than a person can take a swim in a gene pool.

The main purpose of this paper is to show that evolutionary theory requires a similar shift in the ontological status of species as units of evolution. Instead of being classes, they are individuals. The choice between these two alternative interpretations cannot be made on the basis of simple empirical considerations but on the basis of the increased coherence permitted by one interpretation over the other. Just as the classical way of viewing space and time consistently generated paradoxes, interpreting species as classes has been a recurrent source of confusion in biology. According to Newtonian conceptions of space and time, the speed of light should not remain constant when measured from different reference frames—but it does! Similarly, if species are classes, it is difficult to see how they can evolve—but they do!

ORGANISMS AS INDIVIDUALS

From the point of view of human perception, organisms are paradigm individuals. In fact, biologists tend to use the terms "organism" and "individual" interchangeably. Thus, biologists who wish to indicate the individualistic character of species are reduced to terming them "superorganisms." The same claim can be expressed less misleadingly by stating that both organisms and

[1] Ernst Mayr pointed out the need to emphasize the fact that the species category remains a class on the analysis being presented in this paper. Particular species can be treated as individuals and their names as proper names without treating the species category in the same way.

[2] Although the interpretation of space-time as a function of the distribution of material bodies is currently the majority view (Grünbaum, 1973), it has recently come under attack (Weingard, 1975).

species are individuals. But because organisms are psychologically such paradigm cases of individuals, it might help in understanding this notion to investigate the nature of organisms, with the intent of extending the analysis to include species.

Given our relative size, period of duration and perceptual ability, organisms appear to us as reasonably discrete entities developing continuously in space and time. Each organism is spatiotemporally localized and as such is unique. Two organisms can be identical to each other in every respect save spatiotemporal location without thereby becoming the same organism. No matter how identical twins might be, they are still two individuals and not one. In short, organisms on the common sense level are individuated on the basis of spatiotemporal location and continuity. Nor do organisms pass casually in and out of existence. Once an organism is born, it continues to exist until it dies; and once an organism has ceased to exist, this same organism cannot come into existence again. An organism might be born similar in every respect to an earlier organism, but in the absence of the relevant spatiotemporal connections, these two organisms would not count as the same organism.

Some philosophers have argued that, in addition to its spatiotemporal character, an individual in order to stay the same individual must retain the same essence and/or continue to be made out of the same substance. "Essence," as it is usually defined, refers to some attribute or set of attributes which make the individual the *kind* of individual it is. For example, if rationality is of the essence of mankind, then a human being must retain his rationality throughout his existence to remain a human being. In addition, if retention of essence is also necessary for individuality, then he must retain his essence to remain the same individual. On this view, an individual cannot change its essence without becoming a different individual. Any individual which changes from one kind to another automatically becomes a different individual.

Must organisms retain their essence to remain the same organism? One consequence of evolutionary theory is that species as such can have no essences as defined above (Hull, 1965). Rarely if ever can a set of traits be discovered which distinguish one species from all other species throughout its existence. Species split into two or more species very gradually. At any one time, there are species in all stages of speciation. Some closely related species are quite discrete: speciation is complete. Others exhibit degrees of integration: speciation is still in progress. In others, speciation has not begun. But species also have a temporal dimension. When traced backward in time, the gaps between even the most discrete species gradually disappear. Under special circumstances, species can arise in the space of a single generation (e.g., in some cases of polyploidy), but the existence of a few cases of saltative evolution is of no help to the essentialist, since essentialism is the view that *all* genuine classes have essences.[3]

But if species have no essences, then retention of essence can hardly be a necessary condition for an organism remaining the same organism. However, there is a sense of "essence" which applies to individual organisms. At any one time, an organism exhibits a certain organization. This organization can change through time. For example, the various stages in the life cycle of a butterfly have few if any phenotypic traits in common, yet they are all stages in the life cycle of the same organism. From a common sense perspective, an organism remains the same individual in the face of all these changes because they are gradual and because it retains its unity and continuity.

[3] One way of salvaging essentialism is to claim that being a member of a class is the essence of the class; e.g., being a game is the essence of game, being a horse is the essence of horse, and being bigger than a breadbox is the essence of things bigger than a breadbox. If there was ever reason to suspect that essentialism was no longer a viable metaphysical position, this means of salvaging it is it.

But every organism also possesses a genetic makeup which not only remains largely unchanged during the course of its ontogenetic development but also directs this development. Thus, the genetic constitution of an organism might be viewed as its "individual essence." In this sense, having largely the same genetic makeup is a necessary condition for an organism remaining the same individual; it is not sufficient. Spatiotemporal unity and continuity are also necessary. In the absence of this additional criterion, all genetically identical individuals would have to be considered the same individual.

The situation is more cut-and-dried with respect to retention of substance. From the point of view of modern science, the claim that an individual must be made of the same substance throughout its existence in order to remain the same individual reduces to the assertion that an organism must be made out of numerically the same atoms from conception to death. Needless to say, organisms are characterized by exactly the opposite state of affairs. With the exception of brain cells in certain species, organisms retain their identity by means of a constant exchange of substance: new cells are manufactured, old cells are sloughed off. Thus, retention of substance can hardly be necessary for individuality in organisms.

One might complain of extending the notion of individuality to species because evolution is usually a gradual process, but the situation is not that much different at the level of organisms. Some organisms reproduce by fission or budding. For a time, the bud is clearly part of the parent organism, later clearly an independent organism, but there is an intermediate period during which no clear distinction can be made. Conversely, a single organism can result from the partial or total fusion of two previously distinct organisms. The relevant factor is organization. How closely knit can a group of organisms become before they lose their separate individualities and become one individual? Conversely, how loosely organized can an organism become before its parts become free-living organisms? As Wilson (1975) asks with respect to the pseudoplasmodium stage in slime molds, is it a society or is it an organism? Such questions are extremely difficult to answer with respect to organisms. Comparable questions may be somewhat more difficult to answer in the case of species. However, exactly the same questions arise for both. If organisms can count as individuals in the face of such difficulties, then so can species.

INDIVIDUALS AND CLASSES

The basic premise of this paper is that individuals are fundamentally different from classes (and other universals such as relations and processes) and that these differences must be reflected in language. The terms which denote individuals function differently from those that denote classes. At first glance, the distinction between individuals and classes could not seem clearer. Individuals are localized in space and time, individuated spatiotemporally, and made up of spatiotemporally organized parts. These parts in turn need not be and frequently are not similar to each other. For example, a heart, lungs, and kidneys may be part of the same organism even though they are morphologically quite dissimilar. At the verbal level, the names of individuals are proper names devoid of any meaning in the sense of intensional meaning, the sort of meaning which is supposed to be captured in a definition. An individual can be described, but its name cannot be defined. For example, "Gargantua" is the name of an individual organism. As a proper name it denotes this individual uniquely and rigidly in the absence of any knowledge save that necessary to identify it as an individual. The name "Gargantua" denotes a particular organism throughout its existence and not some feature or features of that organism. At a particular time, Gargantua was named "Gargantua," and that is that.

The preceding is a description of how *pure* proper names are supposed to function in *ideal* languages. In natural languages, of course, few if any terms function as pure proper names. Most have some sort of informal connotations. For example, one might reasonably expect Gargantua to be big, though he need not be. After all, Gargantua was not a very big gorilla, nor is everyone named "David" beloved. In addition, few proper names in natural languages denote uniquely. For example, several people often have exactly the same name. There are just too many people and not enough names to go around. That is why social security numbers are so important. The way in which proper names in ordinary languages most closely approximate the ideal is in rigid designation. They are attached directly to their referents, usually in some sort of naming ritual, without any verbal mediation.

Classes, on the other hand, are very different sorts of entities. (For the sake of simplicity I am limiting my exposition just to classes, although a comparable distinction exists between individuals and things like relations, processes, quantities, and properties.) Classes have members not parts. These members are members of the same class because they are similar to each other in one or more respects. For example, all atoms with an atomic number 79 and all samples made up predominantly of such atoms count as gold, and vice versa. The names of classes can be and usually are defined intensionally. Classes have the members which they do *in virtue* of their definitions. According to the traditional notion of definition, class terms are defined by sets of traits which are severally necessary and jointly sufficient for membership in the class. Anything which is gold must be made up of atoms with atomic number 79, and everything with atomic number 79 is gold. Many terms in highly structured contexts can be defined in this way, but others cannot. For example, "game" is a meaningful class term which functions reasonably well in ordinary discourse, but it cannot be defined in terms of necessary and sufficient conditions without extreme artificiality. Thus, some philosophers have suggested that many words can be defined only by means of statistically covarying traits. Such "cluster concepts" are defined polythetically in terms of the possession of enough of the most important traits characteristic of the class (Wittgenstein, 1953).

Both proper names and class terms denote. Proper names are supposed to do so uniquely and rigidly, whereas class terms are supposed to denote precisely, though neither uniquely nor rigidly. Each proper name is supposed to denote a single individual, and each individual is supposed to be denoted by a single proper name. An individual can also be described. This description might succeed in designating this individual uniquely, though it need not. If it does, then it is termed a definite description. Such definite descriptions do not play a role for proper names analogous to that of definitions for class terms. For example, Gargantua was often described as the biggest gorilla in captivity. Even if this definite description had been accurate, "the biggest gorilla in captivity" would not function as a definition of "Gargantua." Discovering that someone had made a mistake, that gold really did not have atomic number 79, would have extensive ramifications for the rest of physics. Discovering that Gargantua really was not the biggest gorilla in captivity or that the Empire State Building is not the tallest building in the world would have little effect beyond the point of immediate consideration.

Assigning names is in general rather an arbitrary exercise. Any term can be applied to anything one wishes. In the case of individuals and their names, the relation is completely arbitrary and remains so. Individuals are the sorts of things which can be picked out and baptised without any recourse to the meanings of other terms. Conversely, proper names are exactly the sorts of terms best suited to designate individuals. Because the connection between a proper name and its individual is so arbitrary and isolated, the act of bestowing a proper name becomes proportionately important. Exactly which name was given to which prince and which prince was born first? In the case of class terms, which name goes with which class is arbitrary but the definitions are not. Words which are defined intensionally in terms of the properties characteristic of their members form vast, interlocking networks of definitional connections. A change in the meaning of one term requires modifications in the definitions of others. For example, in the next section, we will discuss at some length such terms as "organism," "kinship group," "colony," "population," and "species." The more we find out about one level of organization, the more we find out about the others, and changes in our conception of one level frequently have ramifications for our conceptions of the other levels. One of the chief benefits of having proper names in a language is that they provide a way of breaking out of these interlocking circles of definitions. One can know who Daddy is without knowing what daddies are, and the former can help in teaching the latter. Proper names also introduce a certain degree of stability into the flux of meaning change. As languages evolve, words change their meanings. If all terms in a language had meaning, the system would be too fluid to permit successful communication. Proper names can aid in resolving the problems posed by meaning change.

One way of coming to appreciate the difference between proper names which denote without the interposition of meaning and intensionally-defined class terms is to see what happens when two such terms denote the same entity or entities. For example, Samuel Clemens *is* Mark Twain because both of these proper names denote the same individual. However, two intensionally-defined class terms can denote exactly the same individuals and yet remain distinct. For example, if the names of taxa are viewed as class terms, then it just so happens that Mutica and Cetacea have the same known members. On the usual set-theoretic interpretation, however, classes are individuated on the basis of membership: two classes are identical if and only if they have the same members. Thus, on this interpretation, Mutica is identical to Cetacea, a consequence which no taxonomist could accept because Mutica is a cohort and Cetacea is an order (Gregg, 1954). However, if classes are interpreted intensionally, the two classes can be kept distinct (Buck and Hull, 1966). Two classes are identical if and only if the terms referring to them mean the same thing. Ideally equivalence of meaning is required for two intensionally defined classes to be one and the same class, but given the realities of natural languages, close approximations will usually suffice.[4]

Given the preceding contrast between proper names and intensionally defined class terms, what then is the appropriate relation between an organism and its species? Is it part-whole like the relation between particular protons and the atoms of which they are part, or is it member-class like the relation between particular atoms

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[4] The characterization of the proper name—class term distinction presented in this paper is fairly common, but philosophers have presented other characterizations as well. For example, Wittgenstein (1953) suggests treating the names of individuals and classes in the same way—as cluster concepts. Thus, "Moses" would denote the individual who possessed enough of the traits most characteristic of Moses, and "game" would refer to all those activities which possess enough of the most important characteristics of games. Although Kripke (1972) agrees that the names of individuals and certain classes of general terms should be treated in the same way, he takes just the opposite tack. They both should be treated as "rigid designators." Just as "Moses" was attached to Moses as a baby independently of any trait which Moses might possess, "gold" was attached to a particular substance independently of any meaning or meanings of the term "gold." In this paper I am arguing that Kripke's analysis applies to the names of species, a class of terms which have traditionally been viewed as being general, but I have also argued that species are actually individuals and not classes. Thus, it should come as no surprise that their names are rigid designators. Whether or not Kripke's analysis is also applicable to genuinely general terms is still a moot question. On the surface, at least, the role of meaning and meaning change seems to be too important to replace with the process of transmitting rigid designators in a link on link reference preserving chain.

of gold and gold?[5] In short, what is the ontological status of species? Are they classes or individuals? As I argued earlier, such questions cannot be answered profitably without references to particular scientific theories. An atom of gold belongs in the category "individual" because atomic theory requires atoms to be viewed in this way. If atomic theory is ever abandoned or modified extensively, atoms may come to be conceptualized quite differently, but for now particular atoms of gold must be viewed as individuals.

The names of particular species like *Cygnus olor* and *Drosophila melanogaster* began their careers as class terms. Initially it was thought that the names of all species could be defined by sets of essential traits. Man, so the story goes, is a rational animal. But no matter how hard they tried, taxonomists could rarely find sets of traits which divided living organisms into neat little packets. Some divisions were fairly sharp; others exhibited even gradation. Evolutionary theory finally explained this frustrating state of affairs. As a result, taxonomists have come to adopt the notion of polythetic definition for the names of biological species (as well as higher taxa). In fact, several philosophers, including this one, have argued that the names of species are the best examples available of cluster concepts (Beckner, 1959; Hull, 1965). Other examples of cluster concepts are taken from relatively informal contexts, enabling opponents of cluster analysis to argue that the only reason such terms cannot be defined in the traditional way is lack of knowledge or vagueness of context; if "game" functioned in a scientific theory as well-formulated as Newtonian theory, they argue, it too could be defined in terms of a single set of necessary and sufficient conditions. Similar excuses do not apply in the case of biological species. If "*Cygnus olor*" cannot be defined in the traditional way, it cannot be because of ignorance or informality of context. Our inability to distinguish most species by sets of necessary and sufficient conditions follows from evolutionary theory just as surely as quantum indeterminacy follows from quantum theory.

If species are conceptualized as classes, then at best the names of species can be defined only polythetically, but there is another way of accounting for the phenomena in question. Species names cannot be defined in the traditional manner because they cannot be defined at all. They are proper names introduced by a baptismal act denoting particular chunks of the genealogical nexus (Ghiselin, 1974). The lists of traits which taxonomists include in their diagnoses and descriptions do not perform the function of definitions but are, at most, definite descriptions. They help biologists decide whether or not the specimen before them belongs to a particular species (Hull, in preparation).

SPECIES AS INDIVIDUALS

From Darwin to the present, evolutionary theory has always included a strong principle of heredity. Not only must different organisms be characterized by different phenotypes and these phenotypes have different rates of survival and reproduction, but also there must be a correlation between parents and offspring in the contributions of each to future generations. It is not enough for genes to mutate; they must also be able to replicate themselves in a fashion which passes on their organization largely intact. Organisms must do more than just cope successfully in their environments; they must also reproduce themselves. The essential role of spatiotemporal continuity can easily be overlooked in the evolutionary process, espe-

[5] An atom of gold can be both a member of the class of gold atoms and a part of a sample of gold; this sample in turn is a member of the class of all such samples. Samples of gold have properties which individual gold atoms lack and vice versa, but the reductionist claim is that the gross properties of a chemical substance (e.g., the malleability of gold samples) are derivable from the structure and arrangement of gold atoms.

cially when it is described in terms of "populations" and gene "pools." Neither term in its most general usage requires continuity. A population is merely a collection of individuals characterized by the distribution of one or more of their traits. Usually the membership of such collections is chosen on the basis of some criterion (e.g., editors of North American newspapers, stars increasing in brightness, tax-free organizations), but they need not be. They could be chosen at random. As biologists such as Mayr (1963) have repeatedly emphasized, the populations which function in evolution are populations in a much more restricted sense: descent is required.

Similar observations can be made about the gene-pool metaphor. There are many kinds of pools: typing pools, car pools, betting pools. Some of them require continuity of membership; others do not. For example, all the typists working in a typing pool of a particular company could quit and be replaced by new typists without the typing pool becoming a different typing pool. For the proper functioning of a typing pool, the identities of the typists are irrelevant. Such is not the case with gene pools. Both immigration and emigration take place in natural populations, resulting in changes in the gene pools of these populations, but in neither case could all the relevant individuals suddenly be replaced without destroying the evolutionary process. Evolution is a selection process, and selection processes require continuity. A more precise description of evolutionary processes is complicated by the fact that the events operative in evolution occur at a variety of levels and these levels are integrated by the part-whole relation.

Nothing is more obvious about the living world than the existence of intermeshed levels of organization from macromolecules, organelles, and cells to organs, organisms, and kinship groups. Each of these levels is related to the one above it by the part-whole relation, not class-membership or class-inclusion.[6] The main concern of this paper is whether a radical break occurs above the level of individual organisms and/or kinship groups. Are organelles part of cells, cells part of organs, organs part of organisms, and possibly organisms part of kinship groups, but organisms are *members* of populations and/or species? I think not. The relation which an organ has to an organism is the same as the relation which an organism has to its species.

Evolution, as it is usually characterized, results from mutation and selection. According to one time-honored formula, genes mutate, organisms compete with each other and are selected, and species evolve. To put the matter dogmatically, *the* gene is *the* unit of mutation, *the* organism is *the* unit of selection, and *the* species is *the* unit of evolution. But most biologists see the evolutionary process as being much more

[6] Logicians have set out in great detail the differences between class-inclusion, class-membership and the part-whole relation. The part-whole relation is transitive and relates entities of the same logical type. For example, a particular proton, atom, and molecule are all of the same logical type —they are all spatiotemporally localized individuals—and the relationship between them is transitive. If a proton is part of an atom and this atom is part of a molecule, then it follows that this proton is also part of the molecule. Classes can also be related transitively, but the relation is class-inclusion, not part-whole. For example, planets, celestial bodies, and material bodies are all classes related transitively. If all planets are celestial bodies and all celestial bodies are material, then it follows that all planets are material. The situation is very different when the entities being related are of different logical types. The member-class relation is *in*transitive and relates entities of different logical types. For example, a particular atom of gold is a spatiotemporally localized individual, gold is a class, and the physical elements form a class of such classes. Thus, if an atom is a member of the class of gold atoms and gold is an element, then it follows that this atom can*not* be an element. A particular atom can no more be an element than I can join the United Nations. Only nations can join the United Nations, and a particular person cannot be a nation (Buck and Hull, 1966). However, things do not come with their logical type written on their faces. As I have argued earlier, ontological status is theory-dependent.

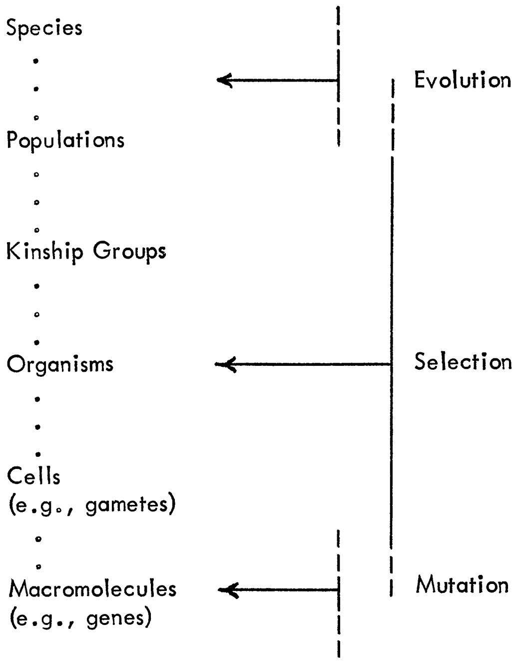

FIG. 1.—Mutation and selection range over various levels or organization, resulting in the evolution of entities at higher levels of organization.

complicated than this. Genetic changes can be as slight as the alteration of a single nucleotide or as major as the loss or gain of entire chromosomes. As Lewontin (1970) has argued, selection occurs at an even wider range of levels of organization, from macromolecules to kinship groups, probably at the level of populations, possibly even at the level of species (see Fig. 1). There is no doubt that entities such as genes, gametes, organisms, and certain kinship groups possess the degree and kind of organization necessary to function as units of selection, but this organization begins to disappear at higher levels of organization. However, as Schopf (1973) argues, colonies can function as units of selection if they are sufficiently well-organized. Wilson (1974) concurs, arguing that even a society "can equally well be viewed as a superorganism or even an organism."

As we mentioned earlier, the tendency of biologists to use terms such as "organism" and "superorganism" to characterize the sort of organization necessary for something to function as a unit of selection is instructive. Organisms possess the degree and kind of organization necessary to compete with other organisms and be selected. Hence, anything with a comparable organization is also an "organism"; see for example, Ravin's "The Gene as Catalyst; The Gene as Organism" (1976). A similar observation can be made about the term "individual." The main thesis of Williams' *Adaptation and Natural Selection* (1970) is that all apparent cases of group selection can be explained entirely in terms of selection at the level of individuals, but then Williams turns around and calls any group which is actually functioning as a unit of selection an "individual." For example, mammary glands contribute to individual fitness, the individual in this case being the kinship group. But regardless of the terminology which the biologist chooses to express himself, the message seems clear enough. Entities at various levels of organization can function as units of selection if they possess the sort of organization most clearly exhibited by organisms; and such units of selection are individuals, not classes.

Like mutation and selection, evolution occurs at more than one level or organization. At the very least, populations and species evolve. Spatiotemporal continuity is necessary for evolution to take place, but another characteristic is necessary as well—the potentiality for open-ended development. A gene or an organism cannot evolve because not enough change can take place before they cease to exist, either terminally or by replication. There is no limit to the genetic change that can take place in a species or population before it becomes extinct or speciates. As might be expected, there are borderline cases; in biology there always are. For example, species of bees can be divided into annual and perennial forms depending on the individuals which make it through the winter. In annual species only the fertilized queen survives to form a "new" colony; in perennial species, the "same" hive can continue indefinitely. From a common sense perspective, the colonies produced in successive years by the same queen are new individuals, but genetically they are continuous. Perhaps the colony waxes and wanes in size, but its continued existence is limited by the duration of its queen. However, in perennial forms, it is possible for a new queen to replace her mother and take over the hive. This queen in turn could be displaced by one of her daughters, and so on indefinitely. In such circumstances, hives could possess not only the sort of organization necessary to function as units of selection but also the potentiality for open-ended development necessary to function as units of evolution.

The situation in the case of higher taxa is even more problematic. No one claims that genera, families, etc. can function as units of selection, but might not they form units of evolution? Certainly higher taxa evolve but do they respond as units in the evolutionary process the way that species and populations do? In order to function as units of evolution, not only would higher taxa have to possess requisite spatiotemporal continuity but also they would have to function as units in macroevolutionary laws not reducible to processes operating solely at the level of species and/or populations. Whether or not higher taxa have the characteristics necessary to be counted as individuals depends upon which principles of classification are used in their construction. If higher taxa must be monophyletic at the species level, then they possess the requisite spatiotemporal continuity, but if Simpson's (1961) minimal monophyly is all that is required, then they do not. But integration by descent is only a necessary condition for individuality; it is not sufficient. If it were, all genes, all organisms and all species would form but a single individual. A certain cohesiveness is also required, a cohesiveness which is problematic even at the level of species and populations.

The distinction between populations and species is not always clear. Sometimes a population is co-extensive with its species; sometimes a species is made up of two or more populations. Just as kinship groups do not form in all species, it may be the case that not all species form populations, at least, not if "population" is defined in terms of gene exchange. As Mayr (1963) sees the situation:

> Between the individual [the organism] and the species is a level of integration of particular importance to the evolutionist, the level indicated by the word *population*.... Under the impact of modern systematics and population genetics, a usage is spreading in biology that restricts the term "population" to the local *population*, the community of potentially interbreeding individuals at a given locality.

On Mayr's view, only sexual species can form populations. Asexual species may evolve, but they do not form true populations.

A similar position exists at the level of species. According to Mayr's (1969) reformulation of his classic definition, "Species are groups of interbreeding natural populations that are reproductively isolated from other such groups." Ghiselin (1974) agrees but emphasizes the reproductive competition between the parts of species. Species are "the most extensive units in the natural economy such that reproductive competition occurs among their parts." Although asexual organisms may compete with each other, they cannot compete for mates. Perhaps asexual organisms do not form populations and species of the sort which exist among sexual organisms, but like higher taxa, they do evolve. As Mayr (1969) himself observes, "*Species are the real units of evolution*, they are the entities which specialize, which become adapted, or which shift their adaptation." Because such biologists are well aware that asexual forms specialize, become adapted and shift their adaptations, the thrust of their remarks must be directed elsewhere. It seems to be this: asexual species lack any intrinsic mechanism for promoting evolutionary unity. If asexual organisms form cohesive units of evolution, they must do so entirely on the basis of the unifying effects of external causes, and considerable doubt exists with respect to the nature and efficacy of such external causes.

Thus, asexual species and monophyletic higher taxa are much in the same position. Both possess at least one of the characteristics necessary to function as units of evolution—continuity in time—but doubt exists if they possess sufficient unity and, if they do, how this unity is maintained. Simpson (1961) defines the species category so that it is at least possible for asexual organisms to form species. "An evolutionary species is a lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies." But Simpson does not go into much detail about how unitary these evolutionary roles and tendencies have to be before a lineage can count as a species. Perhaps groups of sexual and asexual organisms do not form the same kind of evolutionary units, perhaps they evolve in strikingly different ways, perhaps their evolution is governed by two distinct sets of laws, but they nevertheless evolve. Similarly, if macroevolutionary change is more than a summation of microevolutionary events, then complexes more inclusive than species might also form units of evolution and count as individuals.

A simple characterization of the units which function in evolution is further complicated by the fact that the units at various levels of organization are related by the part-whole relation, and the functions which they perform are both multiple and variable. For example, genes can function as units of both mutation and selection. Kinship groups can function as units of selection, but in certain circumstances might also be able to evolve. Some entities possess sufficient unity to compete with each other but not the open-ended organization necessary to evolve (e.g., organisms). Other entities are capable of open-ended genetic change but may lack the requisite unity (e.g., asexual forms and higher taxa). The entities which function in the evolutionary process, so to speak, slide up and down a functional zipper, performing different functions under different conditions. In addition, because these entities are interrelated by the part-whole relation, changes at one level ramify throughout the entire system. For example, the alteration of a single nucleotide in a gene can dramatically alter the way that the gene functions. The death of a queen bee is not just one death out of many but a major event in the history of the hive.

None of the preceding is true of intensionally defined classes. A member of a class can change or cease to exist without affecting the class in the least. For example, one atom of gold could be transmuted into lead without affecting gold or lead. Similarly, if all gold atoms were to cease existing, the class of gold atoms would temporarily have no members. Later when atoms arose with the appropriate atomic number, gold would come into existence again. However, once a species becomes extinct, it cannot arise again. If a species of flying reptile were to evolve which was identical in every respect to a species of extinct pterodactyl save origin, it would have to be classed as a new species. Similarly, if a man were born identical in every respect to Adolf Hitler save origin, he would still have to be counted a new human being and not Hitler. The same species can no more re-evolve than the same organism can be born again.

SPECIES AS INDIVIDUALS: OBJECTIONS

Numerous objections can be raised to interpreting species as individuals rather than as classes. Some of them arise from a failure to make the necessary conceptual shift. For example, Darwin argued that species evolve gradually in time; Agassiz replied that whatever evolves, it cannot be species because species are eternal and immutable. But not all objections can be dismissed as simple misunderstandings. Rarely in areas of intellectual dispute is one position superior in every respect to its competitors. Rather one must weigh the strengths and weaknesses of competing hypotheses and choose accordingly. In the preceding discussion I have emphasized the strengths of the position being urged in this paper and the benefits which accrue if it is adopted. It is now time to turn to a discussion of various weaknesses and drawbacks to this position.

Earlier I described individuals as reasonably discrete, spatiotemporally continuous and unitary entities individuated on the basis of spatiotemporal location rather than similarity of some kind. But one might object that species lack these characteristics. For example, in most cases new species arise gradually. Some biologists (e.g., Simpson, 1961) are willing to divide a gradually evolving lineage into species even though no splitting takes place; others (e.g., Hennig, 1966) recognize new species only when a single species splits into two or more species. But in either case, the changes are usually quite gradual taking thousands of generations. But there are processes in nature which serve to narrow the boundaries between ancestral and descendant species. For example, Mayr (1963) argues that speciation in sexual species always (or almost always) takes place when small populations become geographically isolated from the main body of their species. Because of their small size, such populations will represent an atypical and impoverished sample of the parental gene pool. In addition, any changes introduced into such small populations will have greater effect. Small populations almost always become extinct, but when they do not, they can give rise to new species in a relatively short time. The end result is that the number of organisms intermediate between the ancestral and descendant species is reduced considerably.

Polyploidy is another mechanism which can sharpen the temporal boundaries between species. In autopolyploidy, mitosis occurs without the cell dividing, resulting in a cell with double the number of chromosomes. Occasionally autopolyploids are reproductively isolated from the organisms which gave rise to them. In allopolyploidy, organisms from two distinct species mate successfully to produce sterile offspring, sterile because the chromosomes of the parental organisms are so different that they cannot pair at meiosis. However, if mitosis occurs in these hybrid individuals without the cell splitting, meiosis can then take place. Each chromosome pairs with its replicate. In many cases allopolyploids are distinct species from the two ancestral species that gave rise to them. Thus, not all evolution is gradual; sometimes it is saltative.

If processes similar to those just described are common in nature, then the boundaries between ancestral and descendant species can be narrowed considerably, though not to a one-dimensional Euclidean line. But, of course, the replication of genes and the reproduction of organisms does not happen instantaneously either. If absolutely discrete boundaries are required for individuals, then there are no individuals in nature. It is only our relative size and duration which make the boundaries between organisms look so much sharper than those between species.

The degree and kind of unity required for individuals is even more problematic. For example, organisms are usually quite compact. The cells, tissues, and organs which comprise an organism typically do not wander off to rejoin the organism later. The parts of a species are not so compact, nor their spatial boundaries so discrete. Populations and species do have ranges. In some groups, they are quite stable; in others they wax and wane. Some ranges have sharp boundaries; others are more amorphous. Populations of sexual organisms fulfill the requirements of spatial proximity most fully because of the requirements of reproduction. There is no fertilization at a distance. Either the organisms or their propagules must come into contact. But ancestor-descendant contact is required in all species. Regardless of the mode of reproduction, offspring come into existence in reasonably close proximity to their parents.

The requirement of *spatiotemporal* continuity and unity might also prove to be too narrow for all individuals. As Ghiselin (1974) points out, the United States of America did not become any less an individual when Hawaii and Alaska became states. Nations and species are usually quite compact geographically, but they need not be. In the case of nations, political and socio-economic ties are also important. Nor is reproduction the only relation which unites organisms into more inclusive units, especially in species of social organisms. But similar observations can be made with respect to organisms as individuals. Anyone who thinks that the parts of an organism are always in contact should read up on slime molds (Bonner, 1967). Just as a single population can break down into several smaller populations, possibly to unite later, the "same" slime mold can exist in a colonial hydroid form, as separate free-living cells, and as a single slug-like creature.

Another characteristic of individuals is that they are spatiotemporally unique; they are individuated on the basis of spatiotemporal location and continuity, not some degree of similarity. Once an organism has ceased to exist, numerically that same organism cannot come into existence again. An organism genetically identical to it might be born, but these two organisms can no more count as the same organism than can identical twins. The situation is somewhat more complicated in the case of species. Phyletic evolution produces no problems. If a single species gradually evolves into a second species, the ancestral species is clearly extinct. No other species, no matter how similar it may be to the descendant species, can have the same origin. On the principles proposed by Hennig (1966), the same situation exists in cases of speciation. According to Hennig, once a species splits in two, the ancestral species is considered extinct regardless of how similar it might be to one of its daughter species. But many taxonomists conceptualize speciation differently. Just as the same organism can bud off successive progeny, the same ancestral species can give rise to successive daughter species. How are these daughter species individuated? For example, a single population might become geographically isolated from the parental species and become reproductively isolated. Thousands of generations later, a second population might do the same. Unlikely though it might be, these two daughter species might be capable of interbreeding and merge to form a single species. Similarly, in the case of allopolyploidy, the parental species remain and could give rise to successive hybrid species capable of interbreeding and merging to form a single species.[7]

To be consistent, one must say in both cases that two different individuals were produced but that they merged to form a single individual, the way that the free-living cells of slime molds merge to form a single slug. However, instead of such difficulties counting against the individual interpretation for species, they argue for it. If species were classes, their origins would be irrelevant. Any organism which possesses the defining characteristics of a species would automatically be included in that species regardless of its origins. The fact that biologists do consider origins so important implies that they do not visualize species as spatiotemporally unrestricted classes. The slots in the periodic table remain forever open. Any atom which arises with the appropriate atomic number counts as an instance of that element regardless of how, where, or when it arose. The slots in the phylogenetic tree have spatiotemporal limitations.

The preceding objections have primarily concerned difficulties in applying the notion of an individual to species. My defense has been in each case that comparable dif-

[7] The core of these objections was conveyed to me by Leigh Van Valen (personal correspondence).

ficulties can be found for organisms, and organisms are supposed to be paradigm individuals. If organisms can count as individuals in the face of such difficulties, then so can species. However, some objections are more fundamental, questioning the notion of an individual itself rather than just its application. One might argue that there really is no difference between classes and individuals, or that one and the same entity might be both an individual and a class, depending on the context. My response to these objections depends upon certain fundamental views concerning the nature of science as such and its goals.

The individual-class distinction used in this paper hinges on distinguishing spatiotemporal properties from all other properties. One might argue that just as gold is defined in terms of atomic number, Gargantua and the Empire State Building are defined in terms of their spatiotemporal location. Many class terms are defined by means of one-place predicates, attributes which a single individual in isolation can have. For example, even if there were only one person in the world, he could have blonde hair, blue eyes, and an upright stance. But many of the most important predicates in science are two-place predicates indicating relations. It takes two mass points to gravitate and two gametes to mate. Many important class terms in science are defined by means of relations, sometimes relations between two classes, sometimes relations which the members of a single class have to each other, and sometimes a relation which each of the members of the class has to some specified focus.

For example, "planet" can be defined as any relatively large nonluminous body revolving around a star. Although the relation is spatiotemporal, the class itself is spatiotemporally unrestricted because planets can revolve around any star whatsoever. The problematic cases are those "classes" defined in terms of a spatiotemporal relation to a specific spatiotemporally localized individual. For example, "forest" could be defined in terms of a sufficiently large number of trees, each of which is no further apart than a certain distance from at least one other tree in the complex. (In fact, the definition would have to be a good deal more complicated than this.) On this definition, the term "forest" would be a spatiotemporally unrestricted class, but each particular forest, such as the Black Forest, would not be. Similarly "river tributary system" might be defined in terms of those rivers which flow into one main river. On this definition, "river tributary system" would be a spatiotemporally unrestricted class, but each particular tributary system such as the Mississippi River and its tributaries would not be. Such complexes can be treated as classes only at the expense of collapsing the distinction between classes and individuals.

One might be tempted to acquiesce, but the distinction between spatiotemporal individuals and classes defined by other means cannot be dismissed so lightly. As mentioned earlier, human-sized individuals are epistemologically quite useful. One can indicate the connection between a name and an individual much more easily than between a term and some attribute or feature of that individual. If any words in a language are going to lack intensional meaning, the names of individuals are the most likely candidates. However, the most important reason for retaining the individual-class distinction is the differing roles each plays in science.

On the usual analysis, a scientific law is supposed to characterize timeless regularities in nature. It must be spatiotemporally unrestricted. To the extent that a law of nature is true, it must be true anywhere and at any time. If Newton's laws are true, they must be true for all planets revolving around all stars, not just the few planets revolving around the sun. In addition, if a law is true, it must be true now, a million years ago, and millions of years hence. Our knowledge of the laws of nature may change, but fundamental to our current understanding of science is the belief that the regularities which scientific laws are designed to capture are eternal and immutable. This view of science, for example, was at the heart of Lyell's uniformitarianism. Earthquakes might vary in their intensity, ice ages might come and go, catastrophies might occur, but all of these events must be governed by natural laws and these laws themselves cannot vary from place to place or from time to time. The appropriate conditions are not always present, but when they are, the law must apply. Similarly, the fundamental premise of Einstein's general theory of relativity is that the laws of nature must be expressed in a form that is invariant with respect to any choice of space-time coordinates.

The preceding characterization of the laws of nature may be mistaken. Perhaps miracles do happen, or perhaps there are no eternal and immutable regularities in nature. If so, then science as we conceive it is impossible. Fossils mean nothing; after all they could have been placed there by God or by natural processes no longer operative. Carbon dating is of no avail because radioactive decay might take place haphazardly. Possibly different laws apply in different galaxies. If so, then we would have to start scientific investigations afresh as we wander from place to place.[8] All of this may be true, but until there is evidence that such claims are true and someone explains how we could come to discover the truth of such claims, the most rational decision would seem to be the retention of the conventional analysis of scientific laws.

[8] The living creatures with which biologists are familiar all arose here on earth, probably from a single primal source. Hence, one might think that biologists, unlike physicists, would have to approach living creatures which arose elsewhere in the universe from scratch, but such is not the case. Evolutionary theory, for example, applies to any entities anywhere and anywhen which fulfill its basic requirements. If these creatures reproduce themselves in ways which permit some heritable variation, and reproduce themselves differentially depending in part on their ability to cope with their environments, then evolution will take place.

Much of the resistance to the preceding characterization of scientific laws stems from the overemphasis which philosophers have placed on laws. For example, some philosophers have claimed that the *only* way to explain anything scientifically is to infer it from a law of nature. Of course, recourse to particular circumstances is also necessary on occasion, but the explanatory power resides in the laws. Because many scientists, especially those working in such historical disciplines as cosmology, geology, paleontology, and human history, can rarely derive the sequences of events which they investigate from any laws of nature, philosophers tend to dismiss the efforts of these scientists as not being genuinely explanatory, and these scientists in turn tend to dismiss the analyses provided by such philosophers as not being adequate. Historical narratives describing the evolution of mammals, the splitting of Pangea into the various continents, and the rise and fall of the Third Reich certainly *seem* explanatory. In this case, I think that our intuitions are accurate and the usual philosophical analysis of explanation is too narrow.

One way to rectify the situation is to challenge the traditional conception of a scientific law and claim that such singular statements as "Mammals arose from reptiles" and "Nixon resigned the Presidency" are laws of nature. What is in a word? Certainly one could call all sorts of statements "laws of nature," but then a distinction would have to be made between those laws of nature which supposedly reflect eternal, immutable processes and those laws of nature which do not. Another possibility (and the one which I favor) is to argue that historical narratives can be just as explanatory as derivations from scientific laws even though they concern unique sequences of events (Hull, 1975).

Certain biologists might object to interpreting species as individuals because it seems somehow a demotion. Class terms (as well as a variety of other terms) function prominently in scientific theories and laws. The names of particular individuals do not. Sometimes, of course, reference is made to a particular individual in a law (e.g., mention of the sun in Kepler's laws), but if such reference is not eliminable, then the statement is descriptive and not a law of nature. If Kepler's laws had not been generalizable to star systems other than our own, it would no more count as a law of nature than Bode's law. Similarly, if Mendel's "Laws of Pisum," as he called them, had been applicable only to garden peas, no one would have ever had the occasion to rediscover Mendel.

The rationale for distinguishing between individuals and classes is the differing roles which each plays in science. If individuals are spatiotemporally localized and laws of nature must be spatiotemporally unrestricted, then it follows that no law of nature can make uneliminable reference to an individual. Any statement which mentions a particular individual will necessarily be spatiotemporally restricted. Thus, it follows that if species are individuals, no law of nature can refer to particular species. Such statements as "All swans are white," even if true, would not be scientific laws. However this is *not* to say that such statements are inconsequential. If the discernment of theoretically significant classes is so important in science, then the identification of theoretically significant individuals should also be important. Both are equally necessary. If subsuming a particular instance under a law of nature is explanatory, I see no reason for dismissing the integration of a part into a theoretically significant individual as totally nonexplanatory.

In spite of how it might first appear, reinterpreting species as spatiotemporally individuals poses no threat to the status of evolutionary theory as a spatiotemporally unrestricted scientific theory because no version of evolutionary theory actually refers to particular species anyway. From Darwin and Wallace to Levins and Lewontin, the laws which have been propsed for the evolutionary process have been couched in completely general terms. They do not concern particular genes, gametes, organisms, colonies, populations, or species but theoretically significant *kinds*; e.g., dominant genes, organisms which reproduce sexually, and founder populations. Although inferences about particular species are sometimes possible, Darwin's theory concerns the evolution of species (a class), not the evolution of swan (an individual). The claim that mammals evolved from one or more species of reptile, true though it may be, is not a law of nature or part of evolutionary theory. It is a singular, descriptive statement. The phylogenetic development of mammals is not a general feature of the universe but a particular consequence of the evolutionary process.

Finally, one might object that the ontological status of entities is not fixed. In certain contexts a planet might be an individual, in others a class, in yet another a process. The same can be said for organisms and species. For example, Cohen (1974) argues:

> No doubt a biological species can usefully be conceived not only as a class that has many individual organisms for members, but also as a populational whole that has these organisms for its parts and is an "integrated unit of biological function" as Ghiselin calls it. The former conception has an obvious appropriateness for some taxonomic purposes, the latter for some explanatory ones.

It is certainly true that from the perspective of Ptolemaic astronomy, the earth is not a planet and that from the perspective of Copernican astronomy it is. It is also true that biologists from Aristotle to Darwin and beyond have viewed species as classes. The issue is, given a particular scientific theory, how must an entity be conceptualized? In this paper I have attempted to show why, from the point of view of evolutionary theory with its strong principle of heredity, species must be interpreted as individuals. From the point of view of some other theory or from a future version of evolutionary theory, anything is possible. However, I believe sufficiently in the unity of science to maintain that eventually all scientific theories must be compatible. If one theory requires that species be spatiotemporally restricted and another that they be spatiotemporally unrestricted, at least one of these theories must be false.

But the two different contexts which Cohen mentions explicitly are taxonomic and explanatory. If one failed to read the rest of Cohen's writings, one would think that he was advocating the separation of classification and theory, as if one could produce a scientific classification in the absence of any theoretical considerations. As I mentioned in the opening paragraph of this paper, one school of taxonomists at times seems to have advocated just such a view of the relation between classification and theoretical science, but contemporary philosophers, including Cohen, reject such a view. Classifications and theories are too interconnected to permit such a dichotomy. If some unit of classification (e.g., the taxonomic species) is to correspond to some unit of the evolutionary process (e.g., the evolutionary species), and if species function as individuals in the evolutionary process, then taxonomic species must also be individuals. There may well be "taxonomic purposes" for which the class interpretation has an "obvious appropriateness," but I fail to see how these purposes can take precedence to those of theoretical science.

One alternative remains. Instead of claiming that species are both individuals and classes or that they can be interpreted as one or the other for different purposes, one might argue that species are neither. Perhaps the distinction between individuals and classes is too crude. Perhaps species might be viewed more profitably as belonging to some hybrid category such as a "complex particular" or "individualized class." Or possibly they are "event-entities."[9] I find these suggestions both plausible and intriguing. Further work in this direction might lead to the abandonment of the claim that species are individuals. However, I think I have adduced ample reasons in this paper for concluding that, at the very least, species are not classes. Spatiotemporal continuity is necessary for species to function as units in the evolutionary process. Whether or not spatiotemporal continuity is also necessary for something to be an individual, it is sufficient for not being a class.

[9] The suggestion that species might be "complex particulars" can be found in Suppe (1974), while Leigh Van Valen suggested the "individualized class" interpretation (unpublished manuscript). Frederick Schram argues that species might be viewed profitably as "event-entities" constrained in space-time (unpublished manuscript). In addition, I have presupposed a particular philosophical outlook throughout this paper, an outlook which is a lineal descendant of logical empiricism. A phenomenologist, for example, would disagree with many of the basic, unspoken assumptions of my arguments. But such is the nature of arguments. Not everything can be defended at once. From a phenomenological point of view, species might have a metaphysical character quite different from that which I have described in this paper, but then I have yet to see a detailed phenomenological interpretation of species as units of evolution.

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