[Hahn's earlier letter in *Science*] states explicitly in print a fallacy that has become an annoying commonplace —that is, that "molecular" biology alone is "mechanistic," while "traditional" biology is "vitalistic" and requires the missionary activity of molecular biologists in order to be converted to scientific respectability.

In an etymological sense it is a tautology to say that biology is vitalistic, since "vital" and "biology" are grounded upon Greek and Latin roots, respectively, for the same word, "life." Therefore if a biologist maintains that any problems are uniquely biological, and not physical or chemical, he can be said to be "vitalistic" if it is understood that by "vitalistic" you merely mean "biological" and are saying that biology concerns itself with problems appropriate to biology.

Philosophers, however, as Hahn correctly states, mean no such thing. The doctrine of vitalism in its pejorative sense implies the operation of a suprascientific force, an *élan vital* or entelechy, which would give to biological phenomena an aspect beyond investigation. This doctrine has had no standing in biology for many years. The biologist says, "Merely analyzing a class of phenomena into a more elementary level does not, in itself, explain the original phenomena. There may be logical correlations evident only at the original level of complexity to which analysis into more elements is irrelevant."

"Aha," says the biochemist (always remember that he is a chemist and not a biologist), "you are saying that vital phenomena are not investigatible by nonvital means. Therefore, you are a vitalist." What has happened is a switch from the first to the second meaning of vitalism. The biologist has intended to say only that biological phenomena have a logic and theoretical framework of their own, and the chemist has converted him into a teleologist.

The fallacy is obvious enough if removed from biology. The organic chemist pursues his research by means of perceptual three-dimensional models which are, from the standpoint of a nuclear physicist, extremely crude, not to say naive. Should the organic chemist, then, drop all current investigation and go haring after quantum mechanics, because the ultimate particles making up the atoms in his models can only be appreciated and described by mathematical formulae, and cannot be visualized by models at all? If he stubbornly maintains that the phenomena he is investigating still require the use of the crude old models, is he then guilty of postulating an entelechy? Obviously not.

The majority of molecular biologists, who claim to be in the forefront of advancing biological research, unfortunately are ignorant of that subject. This is not surprising. Most university departments offering a Ph.D. in biochemistry require only freshman biology as a prerequisite to admission and no training in any biological subject outside of biochemistry during the program. The situation in biophysics is just as bad [F. W. Ness, *A Guide to Graduate Study* (American Council on Education, Washington, D.C., ed. 2, 1960)]. The result of this one-sided training is exactly the sort of ignorance reflected in Hahn's statement that "Traditional biology has not developed great generalized theories . . . with the notable exception of the theory of evolution."

Here is a list of comprehensive theories, each forming a different kind of conceptual framework into which the whole science of biology can be fitted:

1) The cell theory—the oldest of them all, dating from the 1830's. All living material is divided into morphological-functional units having essentially the same structure in all organisms. This subdivision is the mechanical result of the limits of the efficiency of diffusion in conveying metabolites. Increase in size of organisms is thus neatly related to increase in complexity. Investigations of the cell thus become investigations of phenomena common to all living things. It is strange that Hahn should miss this, as it is this generalization, not evolution, which led biology in the direction of chemistry.

2) Biological cycles. All organisms are regarded as forming a part of the cycling of various elements (carbon, nitrogen) and as occupying positions in food chains. Essentially, biological phenomena are regarded as a particularly elegant manifestation of the law of conservation of energy. I am not sure from what period this should be dated—I would say the early 1920's, if Sir Charles Elton is recognized as the author.

3) Feedback mechanisms—encompassing both internal equilibria like homeostasis (Walter Cannon, 1929) and concepts like "the balance of nature" (much earlier) which are related to ideas like "food chains" and Malthusianism, and of course the whole of endocrinology.

4) Communities. All organisms are regarded as members of associations of organisms, which in turn have some of the characteristics of organisms themselves. The function of the organism in the community is the central idea. Dates from about 1890.

The list is certainly not exhaustive, but if we add evolution, and molecular biology, we have six different ways of looking at biology, all of them fruitful and stimulating in their own way, and all of them stimulating current research. None of them can be dismissed as being on the same level as the phlogiston theory or the geocentric universe.

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. . . Innumerable quantitative relationships remain to be established between the morphological, anatomical, and cytological levels before the basic units on the molecular level can be built into believable objects or responses. If these relationships are not established, each biologist—traditional and molecular alike—will stand accused of having developed lonely, sterile, descriptive disciplines. . . .

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The Use of "I"

There are circumstances under which we, as authors, must refer to ourselves as individuals. Yet the custom of writing objectively has been so thoroughly ingrained in us that we dislike making personal references. To avoid this problem, we have used such terms as *the author* or *we*. Clemence [*Science* **141**, 1131 (1963)] has now rightly suggested that we say "I" when we mean "I."

To permit us to follow this suggestion and yet not lay ourselves open to the charge of immodesty, I propose that we adopt the convention that an author should use the personal pronoun *I* whenever necessary (i) to avoid illogical constructions, such as dangling participles, gerunds, and infinitives, and (ii) to avoid ambiguous expressions, such as may occur when an author is referring to his own work or ideas.

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