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have been made in the literature, on the basis of too little experience, it doesn't seem that the proper response is an equally immoderate claim that "catastrophe theory can do nothing" on the basis of that same body of experience.

As an interested spectator, with no particular ax to grind one way or the other, I feel it is far too early to tell what the impact of catastrophe theory will be in the sciences. As it stands now, I would say that it is not yet a theory in the scientific sense; rather, it is a series of suggestions on how a theory might be built, based on some suggestive mathematical results. Its utility will depend on the art with which the mathematical formalism can be interpreted in terms of empirical experience. Attempts at such interpretation have barely begun. If some early attempts have been overly hasty, it does not necessarily mean that the formalism is meaningless or inapplicable; or that those responsible are guilty of anything beyond overenthusiasm.

I believe it is true, as imputed in Kolata's article, that the response to catastrophe theory (including the article itself) is a sociological phenomenon, whose roots it would be most instructive to explore. However, it doesn't seem fruitful to reach a decision concerning the applicability of scientific concepts on sociological grounds. In general, if an individual scientist finds such concepts uncongenial, let him not use them. There is no reason why he should take their existence as a personal affront.

The situation regarding catastrophe theory today reminds me of what happened to information theory in the mid-1950's. Then, too, extravagant claims that information theory could provide deep insights into all complex systems, from organisms to societies, were followed by a backlash in which it was asserted that the theory was impotent or fraudulent. Neither was true, and everyone lost from the resultant polarization. I would not like to see this unhappy history repeat itself.

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The controversy over catastrophe theory need not itself provide an example of the cusp catastrophe. In other words, there is a possible middle ground between the two extreme points of view.

Thom's theorem of the seven (on which the theory depends) assumes that the system is described adequately and completely by the minimization (or maximization) of a scalar potential function. It is a local theory, not a global one; that is, it applies only in the immediate neighborhood of singular points.

Any claimed application which neglects these presuppositions can be suggestive at best, never definitive. Nevertheless, it should be stressed that the overworked methodology of the correlation coefficient also depends upon local approximation. It follows that much criticism now leveled at catastrophe theory could also be applied to many sociometric and biometric studies.

I have recently been able to find a relatively simple proof of the theorem of the seven (*1*). As such accounts become more widely known, the theory will become more accessible in detail to scientists other than research mathematicians. This will enable more informed critical analysis of claimed applications.

Meanwhile, Thom's theorem provides a possible tool for application. How useful that tool is going to be is a matter that is not yet clear. The settling of this question is not likely to be aided either by irresponsibly extravagant claims on the one hand or by bombastic criticism on the other. What is required is a balanced assessment of the already numerous efforts to apply the theory.

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Carcinogens in Schools

A report appeared last September (*1*) which stated that 418 pounds of carcinogenic chemicals were then being stored or used in schools in California; that there was no evidence that students were being unduly exposed; and that safe, lawful disposal of such materials is available through the state department of health.

The 14 carcinogenic chemicals referred to are regulated by federal and state occupational safety and health acts. We find it difficult to imagine purposes which could justify the storage or use in schools of such quantities of dangerous materials, even though the compounds are distributed among some 200 institutions.

Since there are no permissible exposure levels to chemical carcinogens we

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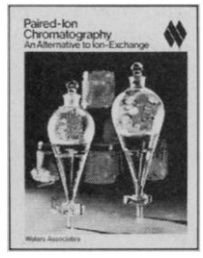

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LETTERS

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are at a loss as to what "unduly exposed" means. Evidence that students were not being exposed at all would be much more encouraging.

The safe, lawful disposal of carcinogens referred to consists of burial in a class I disposal site (*2*). We believe that disposal of carcinogenic materials by landfill is not suitable. Instead, the carcinogen must be degraded, deactivated, or incinerated.

This report (*1*) suggests that it is likely that very large quantities of chemical carcinogens (and not only those regulated by federal and state occupational safety and health acts) are present in schools (and elsewhere) throughout the country. Moreover, it is certain that these materials are often used without knowledge of their dangerous properties, without establishing safe handling procedures, with no thought given to emergency planning, and with insufficient consideration of methods of disposal.

Although we are encouraged at one state's recognition of the problem and indications of their willingness to grapple with it, we deplore the situation and strongly recommend that a mechanism for informing the users of such materials of the potential hazards associated with them be developed. Appropriate labels and data sheets provided by the manufacturer or supplier might be a worthwhile step in this direction.

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Origins of an Ecological Theory

In his review of *Biochemical Interaction between Plants and Insects* (*1*) Lawrence Gilbert (28 Jan., p. 387) infers that the highly similar theories of Feeny (*2*) and of Rhoades and Cates (*3*) relating type of chemical defense by plants to the likelihood of discovery of plants or individual plant tissues by enemies were arrived at by induction from the observed patterns in the former case and by deduction from evolutionary ecological theory in the latter. If true this would suggest that ecological theory has now reached a stage at which it can successfully compete with empiricism in describing natural patterns. Undoubtedly ecological and evolutionary ideas contributed importantly to both theories, but before we congratulate ourselves on the predictive power of "selectionist thinking" a note of caution is in order.

At the outset of a study of plant-herbivore interactions in desert ecosystems Orians *et al.* (*4*) made predictions concerning defensive chemistry in plants and the expected grazing patterns of animals that feed on these plants, largely from evolutionary theory and with a limited a priori knowledge of phytochemical patterns. Gilbert suggests that it was testing these predictions that led to the theory presented by Rhoades and Cates, but in fact most were not tested in any depth. A major prediction that was so tested, namely that herbivores that feed on annual and early-successional plants should be more generalized in their diets than those that feed on more predictable plants, such as woody perennials and late-successional species, was confirmed in the desert system, though, as Gilbert points out, this finding may have no general applicability, since most data from other environments run counter to the result. In hindsight, it appears that five or six of the predictions made by Orians *et al.* are probably right and five or six are probably wrong.

The research that was most fruitful with respect to the final theory was a comparison of within-plant distribution of defensive chemicals in the two dominant perennials creosote bush and mesquite, studies that were not initiated from the original predictive scheme. From these studies our theory was developed largely by inductive processes, with a liberal infusion of the ideas of Orians and Schultz. Similarly, Feeny arrived at his conclusions by generalizing from his studies of between-plant distribution of defensive substances, using evolutionary arguments. Thus the difference was not so much in philosophical approach as in type of data collected.

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