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(1) As reported in Chem. & Eng. News (Sept. 10, 1962). The literature references should not be interpreted as either an endorsement or disapproval of the biochemicals by the cited investigator.
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mathematics, as the “science of structure,” provides the syntactical rules permitting the formation of “grammatical” scientific sentences (and the rejection of ungrammatical ones). From this point of view it is a matter of historical accident whether a particular mathematical concept arises in response to needs of scientists or develops from within pure mathematics and is later applied in science. The “crucial sentence” of Hamming in which the lack of need for empirical verification of mathematical concepts leads to the conclusion that much of modern mathematics is more closely related to medieval scholastic arguments than to science seems quite irrelevant to the main point at issue. All mathematics has that characteristic; science makes extensive use of those branches of mathematics whose postulates are in fact verified (often in such an extremely indirect manner, however, that using a strong word like “verify” may not be appropriate). In the growth of theoretical science one is continually presented with new situations in which new kinds of postulational systems must be employed.

The mathematicians, by providing the scientists with the fruit of their labors, permit a wide choice of new formal tools with which new attempts to organize experience can be made. The symbiotic relationship between science and mathematics, in which science uncovers problems that can inspire new developments in mathematics, and mathematics develops formal systems which accelerate the progress of science, is so well appreciated and so fantastically fruitful that it is hard to imagine anyone trying to “legislate” away any of the essential freedoms so helpful in the past.

The real issue in the dispute, I believe, is the nature of numerical analysis. Is it pure mathematics, or is it a field of applied mathematics close in spirit to the sciences? Numerical analysis generates desired arithmetical or other mathematical data in a well-defined mathematical system (for example, a set of partial differential equations with given boundary conditions) by mathematical methods. It is thus “all mathematics,” in contrast to theoretical physics, where the nub of the problem is the discovery of a formal system which adequately describes experience. Introduction of constraints (such as minimum cost or errors) does not change the fact that the problem is fundamentally mathematical.

Whenever a sphere of applications develops which makes demands on a particular mathematical discipline which go beyond the state of development of the field at the time, the “customers” frequently proceed to remedy the deficiency from the point of view of their application rather than from the point of view of pure mathematics. If these “customers” are scientists or engineers, for whom the empirical has much importance, they will tend to neglect rigor, elegance, generality, and even consistency, in their attempts to get their main jobs done. From Hamming’s article it would appear that this has occurred in numerical analysis, and that the “customers” may have tended to dominate the field in recent years because the pure mathematicians were otherwise occupied. It may be that because of history and tradition this will continue for some time (or even permanently). If I may venture to prophesy, however, I predict that the challenge of developing the mathematics of numerical analysis on a rigorous basis in keeping with the standards of pure mathematics will eventually be taken up. The subtle logical and combinatorial problems associated with computers, switching networks, systems design, and numerical analysis have so many interesting and important facets both from the viewpoint of applications and from that of pure mathematics that I cannot see the pure mathematician forever ignoring these fields. I also do not see how the “customers” will make much headway on many important problems unless some of them become, in effect, highly competent pure mathematicians. This kind of thing has often occurred in the past, and will probably happen many times in the future. Ultimately the development of numerical analysis as a “science” can be expected to encompass construction of a solid basis, in the sense of pure mathematics, similar to what has occurred in statistics. Modern probability and statistics, with their rigorous measure-theoretical basis, are a far cry from the simple data collection and reduction of the past. Along with the development of the “pure” basis has come a tremendous increase in the power and scope of statistical methodology and of its usefulness in applications. We expect to see a similar evolution in numerical analysis.

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