Physical Scientists Are from Mars, Mathematicians Are from Venus; How on Earth Can We Communicate?

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BACKGROUND

The growth of technology, basic science, and mathematics has been intimately intertwined throughout the history of human civilization. The relationships involved have traditionally offered mutual support and stimulation. But as each of these three broad areas of activity has grown in diversity and complexity, unintended barriers to communication and cross-fertilization have occasionally arisen. This essay examines a few aspects of those apparent barriers between the physical sciences and mathematics communities and suggests some remedies.

My personal view of the present situation is doubtless subjective, but it is certainly optimistic. In particular it has been colored by formal training as a theoretical chemist (University of Rochester undergraduate, Yale graduate student), and by nearly four decades of basic research activity in theoretical chemistry, condensed matter physics, and materials science. It also reflects direct involvement in two recent National Research Council reports that examined the interfaces between mathematics and the physical sciences:

- *Mathematical Research in Materials Science: Opportunities and Perspectives* (Board on Mathematical Sciences, Avner Friedman, Chair, National Academy Press, Washington, D.C., 1993); and

- *Mathematical Challenges from Theoretical/Computational Chemistry* (Board on Mathematical Sciences, Frank H. Stillinger, Chair, National Academy Press, Washington, DC, 1995). In addition, I have also found the following to be personally influential:

- *Recognition and Rewards in the Mathematical Sciences* (Joint Policy Board for Mathematics, Calvin C. Moore, Chair, American Mathematical Society, Providence, R.I., 1994); and

- *SIAM Report on Mathematics in Industry* (Paul W. Davis, Chair, Society for Industrial and Applied Mathematics, Philadelphia, 1995). Indeed many of the remarks below reiterate points featured in these documents.

OBSERVATIONS

The traditional division of university faculty into separate academic departments has been an educational necessity. But it has had the effect of creating separate cultures, each with its own dialect, behavioral norms, and professional valuation and reward standards. These distinguishing characteristics in turn have been reinforced by the professional societies that serve the respective disciplines. And in some degree the editorial policies of professional journals have acted similarly.

Language differences between disciplines have become a serious problem. Each group has generated its own technical vocabulary (i.e., jargon), and in many instances a given word or phrase carries different meanings in different disciplines. This situation is troublesome enough between, say, materials science and chemistry, or between condensed matter physics and molecular biology. But many researchers report that the situation is particularly acute between these fields and mathematics, especially since the last seems to celebrate the style of expression that has aptly been called "abstract minimalism."

Deeper, methodological differences also should be recognized, beyond mere vocabulary and mode of expression. The physical and biological sciences often concentrate on inductive processes, while mathematics is primarily deductive, and this distinction can cloud opportunities for fruitful communication. By way of extreme illustration, mathematics appears to have no analogs to the purely reconstructive fields of paleontology and archeology that operate on a preponderance of physical evidence but are not amenable to direct demonstration (proof) or refutation (disproof). Put another way, the standards of "proof" can often be very different in the physical and biological sciences as compared to mathematics.

To the extent that these features have created a sense of isolation of mathematics from the rest of the scientific intellectual community, we all suffer. One unfortunate scenario that can result has recently unfolded at my undergraduate institution, the University of Rochester: the administration decided that the mathematics doctoral program could be scuttled as a cost-saving measure, citing as one reason the disconnection between the mathematics department and the rest of the university. Luckily the original draconian proposal seems to have been softened by the effect of widespread outrage from the external mathematical and scientific communities, but it is unfortunate that such a display of solidarity required the presence of a threat.

We need each other. The physical (and biological) sciences would be a dreadful morass of confusing empiricism and blind experimentation if it weren't for well-posed mathematical models to organize data and to generate predictions of novel phenomena. Mathematics would likely drift into aimless pedantry without the real-world focus and drive imposed by science and technology. In the best of circumstances mathematics rises constructively to the challenge of rigorously characterizing concepts and models, and in that process enforces precision of thought among physical scientists who often slide into lazy habits of fuzzy thinking.

We ought to be able to invent relatively painless remedies to reduce the barriers to cross-discipline communication and collaboration. Furthermore, these remedies should not, and indeed need not, erode the distinctive character of mathematics as an estimable profession. The goal instead is to improve "diplomatic relations" between mathematics and the other sciences in order to stimulate research at the interfaces with inevitable benefits for society.

RECOMMENDATIONS

1. The evaluation process for promotion and tenure in university mathematics departments should be revised, where needed, to provide a fair assessment of collaborative and/or interdisciplinary research. Furthermore, students and young faculty should be encouraged to seek research opportunities in these areas, rather than discouraged from pursuing such prospects.
2. Dual mentoring (with both mathematics and physical-science advisors) for Ph.D. programs should be permitted when the research topic lends itself to this strategy.
3. Establish intra-university faculty exchange programs between mathematics and other departments where prospects for significant interdisciplinary research are perceived. This can take the form of joint seminars, or of internal sabbaticals.
4. Require more thorough mathematical training for undergraduates in the physical and biological sciences, and in engineering, with emphasis on nontrivial applications. This might include senior

seminars on appropriate topics in mathematical physics, mathematical chemistry, mathematical biology, and so forth.

5. Establish regular contacts between the professional societies representing mathematics and those serving the physical sciences, specifically to explore the prospects for enhancing cross-disciplinary research. An expected outcome would be creation of special symposia and workshops devoted to areas of present and likely future cross-disciplinary activity.
6. Create one or more awards for mathematicians who have produced original and influential interdisciplinary research. Seeking industrial support for such an award might be reasonable and appropriate.
7. Editors of mathematics journals should be encouraged to solicit research articles at least occasionally written in a style more accessible to "outsiders." Also, well-written review articles on broad interdisciplinary subjects need to be commissioned, particularly if they concern prospects for new research.
8. Publicize recent significant mathematics advances to the physical and biological sciences communities, and invite reciprocal action from these communities.
9. Through popular articles, mathematicians need to explain what kinds of problems, concepts, and activities engage their interest and motivate them, and they should clarify how these attributes may distinguish them from other technical professionals.
10. Prepare and distribute a guidebook for mathematics students and for prospective employers in government and industry exploring the full range of valuable application areas for mathematics, including specific case histories.
11. To ameliorate language problems between the disciplines, establish a two-way online glossary of technical terms and acronyms between mathematics, on the one hand, and the physical sciences, on the other hand. It is most appropriate that this be implemented by joint action of the professional societies [see item 5 above].
12. Take appropriately assertive action to ensure that final recommendations from this workshop are publicized and implemented. This should include presentations at professional society meetings, as well as mailings to department chairs, deans, government agency personnel, and selected congressional staffers.