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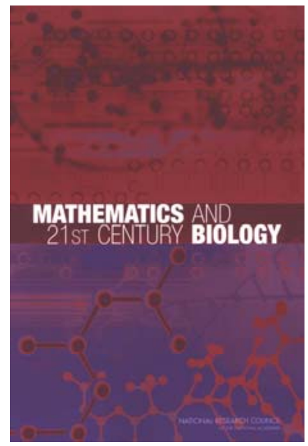
Mathematics and 21st Century Biology—*Summary*

BOARD ON MATHEMATICAL SCIENCES AND THEIR APPLICATIONS

Background



The exponentially increasing amounts of biological data, along with comparable advances in computing power, are making possible the construction of quantitative, predictive models of biological systems. To assist this development, the U.S. Department of Energy (DOE) asked the National Research Council (NRC) to recommend mathematical research activities to enable more effective use of the large amounts of genomic data and the structural and functional genomic information now being created. The resultant study is a broad, scientifically based view of the opportunities lying at the interface of the mathematical sciences and biology. This report presents a review of past successes, an examination of opportunities at the various levels of biological systems, an analysis of cross-cutting themes, and recommendations to advance the mathematics-biology connection that are applicable to all agencies funding research in this area.

Observations and Findings

Dramatic changes have taken place throughout the biological sciences over the last several years as a result of a confluence of new technologies and developments internal to biology. These include:

- Automated instruments that produce large quantities of digital data at all levels of biological organization
- Networked, high-performance, desk-top computing systems available to all biologists
- The success of the Human Genome Project in establishing accurate, whole-genome sequences as central resources in biology
- Descriptions of the basic molecular pathways that allow the development of organisms and govern their interactions with their environments

These developments are transforming biology into a more quantitative, data-intensive science with a richness and diversity that pose a substantial challenge to science policy.

While increased policy attention should be paid to this interdisciplinary frontier, it would be unwise to focus it on particular high-profile opportunities. A narrowly defined, high-profile project (e.g., an *in silico* cell) might slow the introduction of quantitative methods, retard the general training of biologists in more quantitative methods, and might not develop the range of mathematical applications that could transform many biology areas.

Primacy of Biology. Solving problems in biology, not accomplishing new mathematical feats, should be the primary objective of a long-term, broad, and diversified effort to nurture the interface of mathematics and biology. For example, while a predictive computer model may be important, it should not be the central goal in itself. Progress in both biology and the mathematical sciences is likely to be optimized by close coupling between the modeling and defined biological objectives. Contemporary biology would be best off adopting an incremental and diversified approach to the creation of more quantitative, predictive descriptions of living systems.

Unpredictability. The history of mathematical applications to biology is full of unexpected turns and reciprocal influences on the two fields. This dynamic is expected to continue. Mathematical methods will become more deeply integrated into biological research. Nevertheless, the directions that biological sciences will evolve in the coming decades and the ways mathematics will facilitate that evolution are highly uncertain.

Future Perspectives. In addition to transforming biology, greater mathematics-biology interaction might also alter those areas of mathematics that interact most strongly. The biosciences are characterized by vast time scales and extraordinarily complex non-quantitative, organizational features. Furthermore, biology, with its discrete elements, is more likely to be served by the quantitative language of computational and information sciences than the calculus of the physical sciences.

There has been great progress in applying quantitative methods to biologically motivated problems, and the process is expanding as more and more mathematicians and statisticians become involved. Just as many important developments in mathematics emerged from its application to the physical sciences, more can be expected as mathematical methods are increasingly used to understand the living world.

Recommendations

Funding agencies supporting mathematical research related to the life sciences should be receptive to proposals that pertain to any level of biological organization.

Preference should be given to proposals that indicate a clear understanding of the specific biological objectives of the research.

Priority should be given to research that addresses intrinsic characteristics of biological systems that reappear at many levels of biological organizations.

Support should be given to the refinement of general-purpose tools whose broad utility has already been established.

Increased emphasis should be placed on fostering effective collaboration between mathematical scientists and bioscientists .

For further information

Copies of the complete report, *Mathematics and 21st Century Biology*, can be obtained through the National Academies Press Web site <www.nap.edu/catalog/ >**.**

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