MASSACHUSETTS INSTITUTE OF TECHNOLOGY

In 1930, the MIT Corporation recognized that the engineer of the future would need a deeper understanding of science and that the new education needed could not be provided without a top-tier science faculty. The MIT Corporation recruited Karl Taylor Compton to be President with the mission of making MIT a leader in science. Until that time, MIT had done a good job of training people to build and run the machines of the industrial revolution, but they were not prepared to exploit the new knowledge of quantum mechanics, atomic and subatomic physics that were about to reshape technology. The decision to turn the leadership of MIT over to a scientist could not have been better timed. By the beginning of World War II, Compton had placed MIT in the top rank of science universities, which allowed it to participate in the development of radar and to a play a leading role in post-war science and engineering research.

The US Government's appreciation of the importance of science for national defense led to an exponential growth in the fraction of the federal budget spent on research, which reached a peak during the Apollo program of the 1960's. As defense-research spending declined after the Cold War, Federal spending on the life sciences grew rapidly, so that the fraction of the Federal discretionary budget spent on research was roughly constant from the 1970s onward. MIT faculty members followed, by reorienting their research to address the exciting opportunities provided by the revolution in molecular biology. Thus, for over 60 years, MIT has been among the leading science, not just engineering, universities in the world because of generous funding by the Federal Government. Nonetheless, MIT is unusual among the great US research universities in the dominance of engineering compared to other fields. This engineering culture affects faculty members and students in the sciences, in particular, by making it easy and attractive to translate scientific discovery into technology and bring technology to the marketplace.

The generous funding for fundamental science is no longer forthcoming. Austere budgets have kept the growth of funding in the physical sciences far below inflation since the end of the Cold War. The same has been true for the life sciences for the past decade (except for the two years of stimulus funding during the Great Recession). In times of reduced Federal funding, applied research and use-inspired basic research does much better than fundamental science. The volume of research spending in the School of Engineering at MIT has continued to increase at the same time as that in the School of Science has declined. This is, in part, because Engineering has significant industrial funding for relatively short-term research and, in part, because MIT's new sources of funding, from foreign governments and foundations, are focused on applied problems. Even in science, many faculty members are reorienting their research toward use-inspired topics—disease rather than fundamental mechanisms in biology and neuroscience, or energy rather than fundamental questions in physics and chemistry.

Why is it important for MIT to be first rate in fundamental science, in addition to use-inspired science and engineering? First, being top-tier in science attracts students who otherwise would not come to MIT. Richard Feynman would have gone elsewhere as an undergraduate if Compton had not made MIT outstanding in science, and each year we admit undergraduates who are winners of contests like the Physics and Math Olympics. Our graduate students, who have gone on to win Nobel prizes, would not have come to MIT if it were second-rate science. These brilliant science students contribute much to the culture that gives our engineers a special educational experience, just as they benefit from interactions with great engineering students.

Second, intelligent people everywhere are excited by the fundamental discoveries made by our faculty members, students and researchers in the School of Science. For example, the identification of planets orbiting around distant stars that might support life has caught the attention of our students and alumni and strengthened their allegiance to MIT, and the recent public excitement about the confirmation of the inflation model of the earliest universe reminds us how valuable it is to have faculty members like Alan Guth.

Last, fundamental scientific discoveries lead to new technologies and move them to the marketplace more rapidly at MIT than at all but a few universities. One only needs to count the startup companies in Kendall Square that have been founded by MIT Science faculty members, students and postdocs to see how well this is working. No doubt, this is in large part because our Science faculty members have absorbed the culture of our Engineering colleagues, but it would not be happening without outstanding fundamental science research being done at MIT.

President Rafael Reif has made support of basic science a high priority both in his inauguration address and in his planning for a resource-development campaign. Several funds have been established that support fundamental science, although some support applied and use-inspired research as well:

1. We are seeking chairs, for senior and junior faculty members, which would provide discretionary funds to their holders, as well as making it easier for MIT to sustain the size of our Science faculty. Chairs given to the School of Science are awarded to faculty members by the Dean with approval of the Provost; chairs given to a department are awarded by the department head with approval of the Dean and the Provost.
2. We are seeking fellowships for graduate students. These are critically important since our science faculty members' research grants are less able to support students. It is especially important to support students in the first few years of their graduate careers, when they are taking courses and exploring research areas, a time when it is difficult for faculty members to justify supporting them on research grants. Fellowships given to the School of Science are awarded by the Dean in consultation with the department heads; those given to a department are awarded by the department head.
3. We are seeking research initiation funds. These will primarily be used for equipping the laboratories of new and mid-career faculty. At MIT the vast majority of faculty members are hired at the junior level, so most of these funds will support young researchers, but we also seek to re-invest in laboratories of senior faculty (e.g. via proposal matching funds) so that their research can maintain cutting edge stature. Funds given to the School of Science are awarded by the Dean in consultation with the department head and the Provost.
4. We are seeking funds to renovate laboratory space for earth, atmospheric and planetary sciences and particle and nuclear physics.

In addition, President Reif has approved the creation of a new fund with the goal of supporting the research of mid-career faculty members in the fundamental sciences. We are finding that this cohort is being hardest hit by the restricted growth of research funding. Junior faculty members have multiple ways of starting their research programs: Foundations target faculty members only a few years past the Ph.D., and government agencies set aside funds for young investigator awards. Unfortunately, even very successful faculty members, once they earn tenure, find it difficult to secure funding to maintain the research effort they established with young-investigator funds. Fundamental Science Investigator funding would provide support analogous to the HHMI Investigator program in the life sciences, but would be provided only to faculty members addressing very fundamental questions, such as the nature of dark matter, the underlying science of climate, or the origins of life.

Fundamental Science Investigator awards would provide fellowships for three graduate students and one postdoctoral associate, the minimum size effort for an experimental effort in science. The Fundamental Science Investigator Award would provide a funding base that would allow the faculty member to lead a small research program without relying on outside funding. This base would also make him or her much more competitive in pursuing other funding sources, because high-risk research could be carried out with funding from the Investigator Award, and the results could justify funding from risk-averse Federal agencies or foundations. The Fundamental Science Investigator Award holders would be selected by a committee composed of the six department heads in the School of Science—Mathematics, Physics, Chemistry, Earth Atmospheric and Planetary Science, Biology, and Brain and Cognitive Sciences—and would be chaired by the Dean of the School of Science. Each awardee would have an initial appointment with a comprehensive review after five years, carried out by the same committee, and although it could be renewed, such renewal would not be semi-automatic as it is with chairs.

What kinds of research would qualify for funding under the Fundamental Science Investigator program? Each discipline has a set of fundamental questions, and these give the flavor of the topics that are most difficult to support because they are not inspired by some application. A list of examples is attached. In some cases one can imagine applications, but they are decades away. Of course, grand challenges come and go, and we would not restrict our support to any pre-ordained list.

Our focus in fundraising for fundamental science is on single-investigator research. Some of the research-initiation funds mentioned above will be used to seed multi-investigator projects. However, in general, such projects as satellites to search for extra-solar planets require very large amounts of funding, and we cannot imagine doing much more than seeding them.

Except for the renovation funds mentioned above, it would be best to have endowment gifts, so that we could undertake the long-term planning needed to best utilize them. However, we are happy to accept funds for fellowships and research initiation that are expendable.

Examples of Fundamental Questions in Science

Brain and Cognitive Science

How can the results of multiple levels of analysis—genes, neurons, circuits, algorithms—be combined into a comprehensive understanding of the mind?

How does the brain discover order in complex sensory input and use it to understand the world? What changes in brain circuits cause memories to be formed or lost, and how do sleep, emotion, and age affect what we remember?

How does the brain produce a complex sequence of movements with a dexterity far exceeding robots?

Mathematics

What is the distribution of prime numbers? This problem relates to unsolved questions such as the Riemann hypothesis, the twin prime conjecture, Goldbach's conjecture, and other problems in number theory.

What are the statistical features that appear in random structures? Random objects may demonstrate behaviors such as connected clusters, but the conditions under which these form are poorly understood. Can we characterize all possible shapes of various types in various dimensions? Recent progress in this field includes the solution to the Poincare conjecture, but much work is left to be done.

Can we understand what makes certain problems computationally difficult to solve while others are computationally easy? This field is known as computational complexity theory and includes the P versus NP problem.

Physics

How do we explain the pattern of elementary particle masses?

What is the dark matter that makes up about 85% of all mass in the universe?

How do qualitatively new phenomena emerge at low energy in quantum matter?

Are there simple physical rules governing the collective behavior emerging from complex biological systems?

Chemistry

Can we design and synthesize molecules with specific properties from first principles? Can we understand energy migration in molecules and soft and hard matter?

Can we understand matter far from equilibrium and describe it with non-equilibrium statistical mechanics?

Can we understand decoherence in molecules and materials?

Biology

How did eukaryotic cells evolve from prokaryotes?

How did each of the approximately ten fundamental types of signal transduction pathways evolve? What are the processes and pathways that govern differentiation of stem cells into specific cell types? How do the biochemical processes for biochemical energy conversion (including photosynthesis and oxidative phosphorylation) work at the quantum-mechanical level?

Earth, Atmospheric and Planetary Sciences

How do solar systems form, how common are habitable planets in our galaxy and do they harbor life?

How did planet Earth form, what is it made of, and how do processes deep in its interior control phenomena observed at its surface such as the magnetic field, natural hazards, evolution of landscapes, climate, and life on geological time scales)?
Where, when, and how did life originate, and what stimulated the evolution of complex life on Earth? What are the roles of clouds, the cryosphere, and the oceans in the history and future of Earth's climate?

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