Executive Summary

The Physics Department has emerged from the recession stronger than before. Recent faculty hires, support for new research initiatives, an outstanding education program, and our entry to the new world of massive open online courses position us well for continued improvement. While we have no major concerns at this time, the lack of biophysics space and the anticipated further decrease in federal research funding may hurt us soon.

Faculty

The 2008 and 2010 Visiting Committees gave support to the Department's concerns and desires to strengthen its efforts in Biophysics and Astrophysics. No new areas of comparable need have emerged and these areas continue to require attention and support as strategic subfields where the Department wishes to improve its standing.

Since the last Visiting Committee two years ago, our biophysics group has weakened with the departure of one senior faculty member (Alexander van Oudenaarden, to co-direct the Hubrecht Institute for Developmental Biology and Stem Cell Research in the Netherlands) and the retirement of the other two senior experimentalists (George Benedek and David Litster). We have hired one theoretical biophysicist, Jeremy England. Our sole experimental biophysicist (Jeff Gore) is located far from biophysicists in other departments and the lack of suitable lab space has prevented us from hiring new experimentalists. The present situation appears unstable for lack of critical mass.

The Physics and Chemistry Departments have written a biophysics space plan and have shared it with the Dean of Science, Associate Provost for Space Planning, and the other relevant department heads and lab directors. The Chemistry Department has similar or even more severe problems in this area; the lack of satisfactory space in both departments has led to problems with recruitment and retention. We might find space for a possible senior hire in the new Institute for Medical Engineering and Science. However, this will increase, not decrease, our fragmentation and is a stopgap measure. We believe the best solution is the eventual construction of a new building, or renovation of existing ones, that would bring together ten or more biophysics groups from different departments. Ideally this would occur in the present decade. The biophysics space plan appears in the section on Strategic Planning.

Astrophysics is a lesser concern at present although its strengthening remains a long-term strategic priority. We have approached five senior astrophysicists at other institutions to see whether they would consider moving; all have declined interest. Meanwhile, we have strengthened our gravitational radiation group affiliated with LIGO by successfully retaining Nergis Mavalvala against strong offers from other institutions and by hiring a second experimentalist to the faculty, Matt Evans. The extraordinary help of many administrators (the Dean, Associate Provost, Vice President for Research, Provost, the Director of the Plasma Science and Fusion Center and especially the Director of the MIT Kavli Institute for Astrophysics and Space Research, MKI) was essential to a successful outcome. Progress is also being made on space issues in MKI in building 37. We hope that this space planning and consolidation will enable us to hire one or two senior faculty provided that we can find strong

candidates who would find it attractive to come to MIT. Importantly, we have made progress on the lack of astrophysics postdocs relative to our peers thanks to a generous gift from a member of our Visiting Committee as well as judicious use of income from Kavli Foundation endowment gifts to MKI. With the help of the Dean of Science, we have secured a new gift from the Kavli Foundation that brings the total MKI-related endowment to $20M, the amount that the Kavli Foundation is seeking for all of its institutes.

The last two Visiting Committees have encouraged us to recruit aggressively coming out of the recession. We have. In the last two years we have made 14 offers and received 10 acceptances across all areas of the Department. During this same period we have had 6 faculty retirements and will have 2 more in 2013 plus several departures. In addition, two faculty members are on leave and may not return. Several additional retirements are anticipated in the next five to ten years, after which the rate of retirements is likely to decrease significantly. Thus, the large recent hiring rate has allowed us to maintain our size, and we anticipate a healthy rate of renewal for the rest of this decade.

Not reflected in these numbers is the high cost of retention packages during the last two years, as discussed in the section on Finance and Administration. We are proactive in using early promotion and tenure when needed combined with generous research support to our junior faculty. Of the junior faculty who arrived since 2001 and who have come up for tenure, 60% have received tenure, meaning that our tenure rate has increased slightly. We lost one junior faculty member for personal reasons (Adam Burgasser) and may lose a second one (Jocelyn Monroe).

Education

Our education program has become even stronger since 2010. Our undergraduate major has continued its overall growth trend, with 94 SB degrees awarded in 2011, the largest number since 1979. This was followed by a reduction to 83 SB degrees in 2012. Surveys and informal conversations show that our students are happy; they praise our curriculum and teachers. Our undergraduate students have developed a pre-orientation program for incoming freshmen that helps recruitment, and nearly all our majors pursue multiple UROPs (undergraduate research projects) in physics or related areas. Our graduate program is also very healthy, thanks in large part to the generosity of members of the Visiting Committee in providing graduate fellowships. We are paying attention to advising and mentoring; our graduate students have requested improved feedback from faculty and in response they and we have started an annual review process.

The last Visiting Committee noted that our studio-based freshman physics classes based on Technology-Enabled Active Learning (TEAL) bears continued attention given some residual skepticism and the impact of increased freshman class size. Thanks to assistance from the Dean of Undergraduate Education and Provost, we were able to add TEAL sections last year, and we obtained the highest student evaluations ever for TEAL, comparable or superior to those obtained by our best lecturers. As a result of these and other trends, we expect the number of physics majors to grow further, putting strain on our teaching staffing and facilities. To handle this, we have hired a couple new staff members and have made some scheduling adjustments. At

their request, the Visiting Committee this year will meet with non-majors who took TEAL in addition to meeting with physics majors.

The creation of *MITx* and *edX* last year were met with great interest, excitement and uncertainty. The Physics Department is well positioned to play a leading role both within MIT and nationwide owing to its strong tradition of educational innovation. We convened a Physicsx Planning Group to oversee and advise on departmental offerings and have created a plan for putting our first subjects onto the platform. John Belcher, the lead on TEAL, and star lecturer Walter Lewin, are actively preparing 8.02 electromagnetism with the goal of offering it on *edX* in February, 2013. The strong support of the Provost, Chancellor and *edX* Director Anant Agarwal are gratefully appreciated. In addition, we are using some elements of the online platform in 8.01 mechanics this fall. Although 8.02x in 2013 will be directed to the outside world, our intention is to use major portions in the classroom in 2014. Similarly, we will develop 8.01x and other subjects with the aim of improving our educational processes on campus, while delivering a high quality physics education to the outside world.

We believe that the introduction of massive open online courses will have a major impact on education at MIT and world-wide, and we are in a position to shape these developments in physics education. To accomplish this we will need to add staff, and possibly new faculty, in support of physics education. Our experience and observations may be of interest to the Visiting Committee in light of the transformative nature of this development.

Postdocs

The 2010 Visiting Committee review featured meetings with postdocs and a discussion of our efforts to evaluate and improve the postdoctoral experience. These efforts continue. In the fall of 2010 MIT conducted a postdoc survey, and the Physics Department Head served on an ad hoc committee formed in 2011 to review the results and make recommendations to the Vice President for Research. The survey results for Physics are given in an Appendix. The central administration, School of Science and Physics Department are making progress on these issues. Last year the Department introduced a mandatory annual review and formal mentoring assignment for all postdocs appointed through Physics, including the Pappalardo Fellows. We are grateful to the Visiting Committee for their support and encouragement of our postdocs.

Finances

After the market crash in 2008 and recession in 2009, our finances have recovered thanks to generous support from our donors and the administration. After a reduction of three faculty slots to attrition in 2010, and some reductions in support for new hires, we have managed to sustain strong success in recruiting and retention of faculty. However, the costs have grown large; over the last two years alone, we have made commitments of nearly $10M in Physics funds. This is unsustainable.

Declines in federal funding are perennial concerns. We have prepared for them by cutting graduate research assistantship offers to incoming students while maintaining approximately constant numbers of graduate fellowships, resulting in an incoming graduate class size of 34

compared with our average of 40. For the first time, this year all incoming graduate students are supported by fellowships, most of them provided by MIT. We prefer not to further cut the class size in order not to disadvantage the large number of new junior faculty members. The cost of a graduate fellowship or research assistantship now exceeds $72K; fortunately, our fellowship endowment principal has grown faster than the fellowship costs. We are grateful to Visiting Committee members for their help with graduate fellowships.

Diversity

The Physics Department continues to promote an inclusive climate and to strive to increase the numbers of women and underrepresented minorities. During the last two years we have achieved several notable successes.

In 2011, 38% of our 94 physics bachelors degree recipients were women, compared with 45% of all MIT graduating seniors and approximately 21% of all physics graduates nationwide. The numbers fluctuated downward in 2012, but remain above the previous baseline of about 30% women. More work remains to be done at the graduate level, where we are close to the national average of 18% women in physics.

We have also increased significantly the numbers of underrepresented minority students. In 2007, 12% of our SB degrees and 0% of our PhDs were awarded to underrepresented minorities. By 2012 these percentages had grown to 13% and 11%, respectively. The Physics Department, along with Biology and a few others, has met the goal set by a faculty resolution in 2004 to triple the numbers of PhD degrees awarded to underrepresented minorities within a decade. A statistic of national relevance is the number of students receiving a minority scholarship from the American Physical Society. During the past academic year, MIT held 29% of these scholarships nationwide (a total of 12 scholars; the second place institutions were Harvard, Columbia and the University of Puerto Rico, with 2 each). This year we are again at the top, with 28%.

Underrepresented minorities and women represent the largest potential growth areas for US citizens entering physics and other technical fields. To take advantage of this talent pool we must increase the numbers applying to graduate school and coming to MIT. The Physics Department has recently begun awarding multi-year graduate fellowships to women, as our peers have been doing for several years. We also provide multi-year fellowships to underrepresented minority students. To increase the numbers further, we have begun a Bridge program for underrepresented minority students who have completed a bachelors degree in physics, have spent a summer at MIT doing research in the MIT Summer Research Program, and who wish to strengthen their preparation further before starting the PhD at MIT or peer institutions. Our first two bridge students have arrived this fall. They are brought into faculty research groups along with incoming graduate students. They take classes, conduct research and receive mentoring from some of our best faculty mentors. This effort aligns with the national physics bridge program led by the American Physical Society.

The Challenges Facing MIT Biophysics

MIT Departments of Physics and Chemistry
October 3, 2012

Introduction

The last decade has seen a dramatic transition as the study of biology has become increasingly quantitative, partly as a result of the introduction of new techniques from the physical sciences and engineering. These scientific advances present great opportunities, but also significant challenges since existing Departmental and campus structures are not always aligned with the needs of the changing research landscape. In particular, new modes of training and collaboration between disciplines will be required to pursue the most important open scientific questions, and new space will be required. Here we summarize the challenges facing the interdepartmental biophysics and quantitative biology community at MIT and the opportunities for strengthening it. As Dean Kastner wrote in support of a recent biophysics training grant proposal:

> Application of the physical sciences and engineering to questions in the biological sciences is playing an ever-increasing role in advancing a mechanistic understanding of biology, with important and broad implications for biotechnology and human health. Whereas physical and biological scientists have traditionally worked in isolation from one another, with little cross-fertilization between fields, the past decade has seen the emergence of a new breed of quantitative physical biologists that command knowledge of both fields. This new breed of scientist requires interdisciplinary collaboration and training in topics at the interface of the life and physical sciences. MIT is strongly committed to promoting such education and training of graduate students in order to foster the next generation of quantitative physical biologists to positively impact science and society.

The biophysics community is currently dispersed across the MIT campus

There are currently biophysics research groups in nearly a dozen different Departments on campus. In many cases these groups are isolated from other groups interested in similar problems or approaches. The Physics Department believes that it is essential to bring a critical mass of these research groups together in one location. In addition, given the growing excitement at the interface of the physical and life sciences, MIT must make a concerted effort to hire more biophysics faculty. The importance of this goal is recognized within the individual Departments, where biophysics searches have recently taken place in Physics, Chemistry, and Mechanical Engineering. Unfortunately, the lack of a central location for biophysics research has hampered the development of the community and makes it difficult to attract top faculty candidates to MIT and to retain them once they are

here. The creation of the Biological Engineering Department has filled an important intellectual gap at MIT, but a healthy interdisciplinary community of biophysics researchers will necessarily involve a mixture of faculty within and outside of Biological Engineering.

Perhaps the primary obstacle facing the MIT biophysics community is the lack of an interdepartmental space to bring researchers together. The biophysics groups are therefore unusually dispersed across campus. For example, a representative list of 20 biophysics faculty (most participated in a recent biophysics training grant application to the NIH) are located in 17 different buildings:

- Alexander-Katz, Alfredo (Materials Science and Engineering, located in building 12)
- Bathe, Mark (Biological Engineering, located in building 16)
- Blainey, Paul (Biological Engineering, located in the Broad Institute)
- Chakraborty, Arup (Chemical Engineering, located in building E19)
- Cheeseman, Iain (Biology, located in the Whitehead institute)
- England, Jeremy (Physics, located in building 6C)
- Gore, Jeff (Physics, located in building 13)
- Kardar, Mehran (Physics, located in building 6C)
- Keating, Amy (Biology, located in building 68)
- Griffin, Robert (Chemistry, located in NW14)
- Manalis, Scott (Biological Engineering, location in building 76)
- Martin, Adam (Biology, located in building 68)
- Mirny, Leonid (IMES, located in building E18)
- Ribbeck, Katharina (Biological Engineering, located in building 56)
- Seung, Sebastian (BCS, located in building 46)
- Stocker, Roman (Civil & Env Engineering, located in building 48)
- Ting, Alice (Chemistry, located in building 18)
- Tokmakoff, Andrei (Chemistry, located in building 6, leaving MIT for Chicago)
- Voigt, Chris (Biological Engineering, located in building NE47)
- Zhang, Feng (BCS and Biological Engineering, located in building 46)

This lack of centralization poses a challenge to the development of a coherent and synergistic intellectual community and makes it difficult to recruit top biophysics graduate students and faculty to MIT. Remarkably, the majority of core biophysics faculty at MIT therefore work in isolation from other biophysicists in disparate buildings.

Despite the lack of a shared space, there has been significant activity within the biophysics community over the last several years. In particular, there is a bi-weekly seminar series with outside speakers, monthly faculty chalk talks, bi-weekly student lunch seminars, and an annual over-night retreat. The retreats in both 2011 and 2012 attracted 75 attendees from 25 different groups, including 15 faculty. These are truly interdepartmental gatherings, with faculty and students from over ten different Departments on campus.

In addition, we now have a graduate certificate program in biophysics (http://biophysics.mit.edu/MIT_Biophysics/Certificate_Program.html) with six graduate

students enrolled and one already graduated. This non-degree program allows graduate students enrolled in one of the existing Departments to broaden their expertise and engage with the biophysics community outside of their home Department. We hope that over the next few years this certificate program will transition into an interdepartmental graduate program in biophysics.

All of these activities have made a major impact to bring together the community, but there is no substitute for being physically located next to researchers interested in similar problems and using similar techniques. Being located together allows for shared core facilities, frequent informal and formal interactions, and sharing of expertise. In many cases, the most valuable interactions occur informally next to the coffee machine, but this can only happen if the biophysics research groups are next to each other. Having the biophysics community in a single location would also make MIT much more competitive when applying for collaborative funding such as for Centers or graduate training.

MIT's peer institutions have first-rate new interdepartmental biophysics space

In contrast to the situation at MIT, our peer institutions have recently constructed buildings to bring together physical and life scientists in one location:

- Stanford: Bio-X Clark Center, completed in 2003 (245,000 square feet, 40 faculty)
- Berkeley: Stanley Hall, completed in 2007 (285,000 square feet, 40 faculty)
- Princeton: Carl Icahn building of the Lewis-Sigler Institute (additional link), completed in 2003 (98,000 square feet, 12 – 15 faculty and four Fellows)
- Harvard: Northwest lab (530,000 square feet, but only ~half for systems biology)
- Chicago: Gordon Center and the Institute for Biophysical Dynamics, completed in 2007 (400,000 square feet, but not all dedicated to the IBD; 15 IBD faculty located together in this building)

MIT recently completed the construction of the Koch Institute, which brings cancer researchers together with scientists and engineers with a wide range of different backgrounds. We believe that a similar integrative center would play a major role in advancing MIT's impact on biophysical problems in other domains.

In addition to interdepartmental biophysics space, our peer institutions also have well-established biophysics PhD programs:

- Stanford biophysics
- Harvard biophysics
- Berkeley biophysics
- Princeton Quantitative and Computational Biology

A goal of the biophysics community is to have a physical home for biophysics research that can also act as the home of an interdepartmental graduate program in biophysics. Such a biophysics graduate program would help to attract top students who do not feel well-served by the traditional Departments.

MIT's biophysics space needs and potential solutions require further study

The Physics Department faces difficulties in building a biophysics group because of its lack of any space close to the other life scientists and biophysicists on campus, who are concentrated to the East of the Main Group. The Department's experimental biophysicists reside in the Center for Materials Science and Engineering (Building 13), which lacks core biological facilities. Moreover, the conversion of materials science labs to wet labs for biophysics reduces the space available to experimental condensed matter physics. The Physics Department Head has presented these concerns to the Dean of Science. Several space options have been discussed but none of them appear satisfactory at this time. The Chemistry Department faces similar space challenges. Both departments have recently lost tenured biophysicists to institutions with superior space (U. Chicago, Utrecht).

Center for Biophysics

If we were able to create a biophysics cluster for ~10 research groups from across campus then an administrative structure would be necessary to coordinate space, administer grants, and do fund raising. We believe that the best way to do this would be the creation of an interdepartmental Center, since no single Department will have control over the biophysics space. Such a Center would also fill an important gap in the administration of grants. For example, the biophysicists in the Physics Department (Jeff Gore and Jeremy England) apply for NIH funding through the Materials Processing Center. This arrangement is less than ideal for both the faculty and for the Center, since the research overlap is exceedingly weak.

Physics Department: Re-establishing and growth

Over the last ten years, the biophysics / soft condensed matter group in the Physics Department has actually shrunk in size. Ten years ago the group consisted of:

1. George Benedek
2. Alexander van Oudenaarden
3. Michael Feld
4. Mehran Kardar
5. David Litster

With recent moves, upcoming retirements, and the unfortunate passing of Michael Feld, the group will soon consist of:

1. Jeff Gore
2. Jeremy England
3. Mehran Kardar

Indeed, the current faculty list is so small that it is difficult to find a third member of committees for qualifying exams (since the research advisor is not allowed to be one of the three faculty). Leonid Mirny and Sebastian Seung, both with secondary appointments in physics, have been valuable members of the biophysics community. Recently, Arup Chakraborty has also joined with a secondary appointment in physics.

By 2020 it is essential for the biophysics / soft-matter group in the Department to not only rebuild to its former size but to expand beyond this level. A reasonable plan over the next eight years would be to hire one senior experimentalist, two junior experimentalists, and one junior theorist. In addition to these core faculty hires, we believe that it would also be valuable to make joint appointments with other Departments such as Chemistry.

Developing a biophysics cluster would also have substantial benefits to the hard condensed matter group in building 13. The condensed matter group at MIT is unusually small given the size of the Department and the breadth of the research within condensed matter. Moving the experimental biophysicists to another location on campus would provide space for the planned growth of experimental condensed matter physics within the department.

Chemistry Department

Since 2007, the Chemistry Department identified and offered junior faculty positions to 7 experimental biophysical chemists, but was able to recruit only one of them, Professor Christian Degen, to begin his career at MIT in 2009. Several of these individuals had a secondary offer from the Physics Department. Two years later, Professor Degen, a Swiss national, received an offer from ETH and returned to his homeland. The low percentage of acceptance (14%) by the biophysical candidates compared to the percent acceptance (71% of 7 offers) by candidates in other subfields of chemistry suggests two main challenges in attracting these individuals.

One challenge is the lack of centralized space, even within the department. Given its interdisciplinary nature, biophysical research is presently conducted within multiple sub-disciplines of chemistry, including the physical, biological, and synthetic chemistry subgroups. Two of the chemistry faculty who are very active in the biophysical community (Ting and Tokmakoff) are in different sub-fields within the department and hence, are located in different buildings. Tokmakoff has recently announced his departure for the University of Chicago.

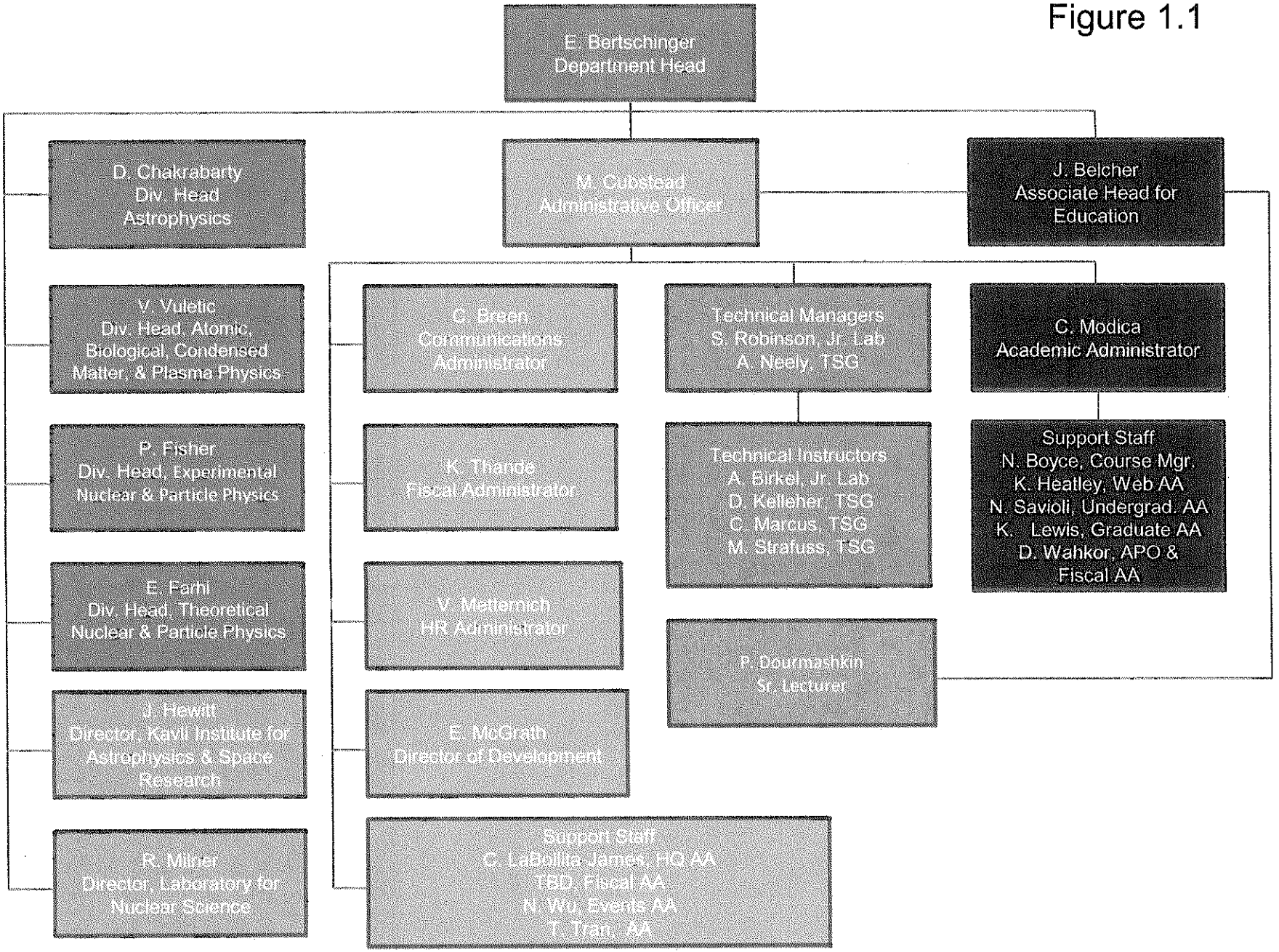
An additional challenge is the lack of <u>suitable</u> centralized space. That is, biophysical chemistry requires the marriage of wet laboratories with highly instrumental dry laboratories. Wet laboratories requiring hoods are necessary for the biological piece of biophysical investigations while dry laboratories, such as high quality laser space or vibration free laboratories are required for physical characterization of the investigations. In the Chemistry Department, no sufficient space exists with an intermingling of both wet and dry laboratories. In the case of Professor Robert Griffin, the unavailability of suitable main campus space to house his 900 MHz NMR instrument and lower field instruments mandates that his laboratory is in NW14. He unfortunately does not even have an office on the main campus because of lack of space.

Concluding thoughts

There is a great deal of excitement surrounding biophysics at MIT, both among the Departments and among incoming students. Unfortunately, the lack of a shared

interdepartmental space for biophysics and quantitative biology has made it difficult to strengthen the community and to recruit top faculty and students to MIT. Notably, all of our peer institutions (e.g. Harvard, Stanford, Berkeley, Princeton, Chicago) have in the last ten years found the will and resources required to construct a modern biophysics building to bring quantitative biology researchers together from across campus. We hope that MIT will find a way to bring together a critical mass of biophysicists to leverage our existing strengths in the physical and life sciences and engineering so that we can realize the scientific opportunities provided by the convergence of these disciplines.

Figure 1.1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