Perspective

Students of seminar 22.A09 at the Massachusetts Institute of Technology present a a wide array of biomedical careers and how to get there.

An annual newsletter **Issue #2 - Fall 2006**

Science at M.I.T.

BY ANNA LABNO, '07

What is Biological Engineering?

Biological engineering is a new and rapidly developing discipline that attempts to fuse engineering with biology in order to harness the power of molecular life sciences. The goal of this engineering discipline is to advance fundamental understanding of operation of biological systems, and to develop effective biologically-based technologies for applications across a wide spectrum of societal needs including breakthroughs in diagnosis, treatment, and prevention of disease, in design of novel materials, devices, and processes, and in enhancing environmental health. Perhaps due to its freshness, biological engineering is not a well-defined field, but it encompasses many aspects of mimicking, modifying and controlling biological systems. In order to learn more about this fascinating field and career options within it, we have decided to learn from people who participated in its creation. During the 22.013 seminar series we had a pleasure of meeting with Dr. Denice Yeates, Dr. Fred Bowman, Prof. Bewin Engleward, Dr. Jerry Ackerman, Maria Angela Franceschini, and Prof. A. Kadak, and discussing under guidance of Prof. Sidney Yep and Prof. Bruce Rosen the various aspects of biological research, possible career options, research trends, and life at and after MIT. To gain an impression on state-of-the-art research facilities, we have toured the MIT Nuclear Reactor and the Martinos Center.

What sort of research is done in Biological Engineer at MIT?

Biological engineering customarily encompasses many sub-fields of research, many of which were pioneered at MIT. The Institute is home to the Center for Systems Biology and Bioinformatics where scientists are striving to understand the dynamics and stochasticity of biological networks as well as advance mathematical and computational modeling of networks, complex systems and proteins, and to aid discovery of molecular therapeutics (E. Alm, A. Chakraborty, C. Burge, F. Dewey, R. Kamm, D. Lauffenburger, R. Sasisekharan, P. Sorger, S. Suresh, B. Thilly, B. Tidor, L. Samson, S. Tannenbaum, D. Wittrup). A large portion of biological research at MIT focuses on biological and physiological transport phenomena where mechanical, electrical and other properties of cells are being studied (F. Dewey, A. Grodzinsky, R. Kamm, B. Langer) or new methods developed, such as biological imaging and functional measurements (P. Dedon, F. Dewey, B. Engelward, M. Lang, S. Manalis, P. Matsudaira, P. So, P.Sorger, J. Han). Many aspects of biomaterials and especially cell and tissue engineering are being studied in order to extend this understanding towards engineering applications (A. Belcher, L. Griffith, D. Irvine, B. Langer, I. Yannas, F. Dewey, B. Engelward, A. Grodzinsky, R. Kamm, D. Lauffenburger, H. Lodish, L. Samson, R. Sasisekharan, J. Sherley). Other groups focus on human diseases and study generic toxicology, infectious diseases, pathogens, molecular epidemiology and dosimetry (P. Dedon, B. Engelward, J. Essigmann, L. Samson, B. Thilly, G. Wogan, A. Chakraborty, J. Fox, L. Griffith, D. Irvine, D. Lauffenburger, D. Schauer, D. Wittrup, James Sherley). New fields such as synthetic biology (E. Alm, A. Belcher, D, Endy, B. Engelward, K. Hamad-Schifferli) and Nano-scale Engineering of Biological Systems (A. Belcher, K. Hamad-Schifferli, J. Han, D. J. Irvine, M. J. Lang, S. Manalis, S. Suresh) are developed and promoted at MIT, and are promising new directions which bioengineering might take.

So, how do I become Biological Engineer at MIT?

MIT offers many options of studying biological engineering and securing bright future as a bioengineer. The exact choice would depend on your personal interests and goals. Here are some examples of routes that you might take.

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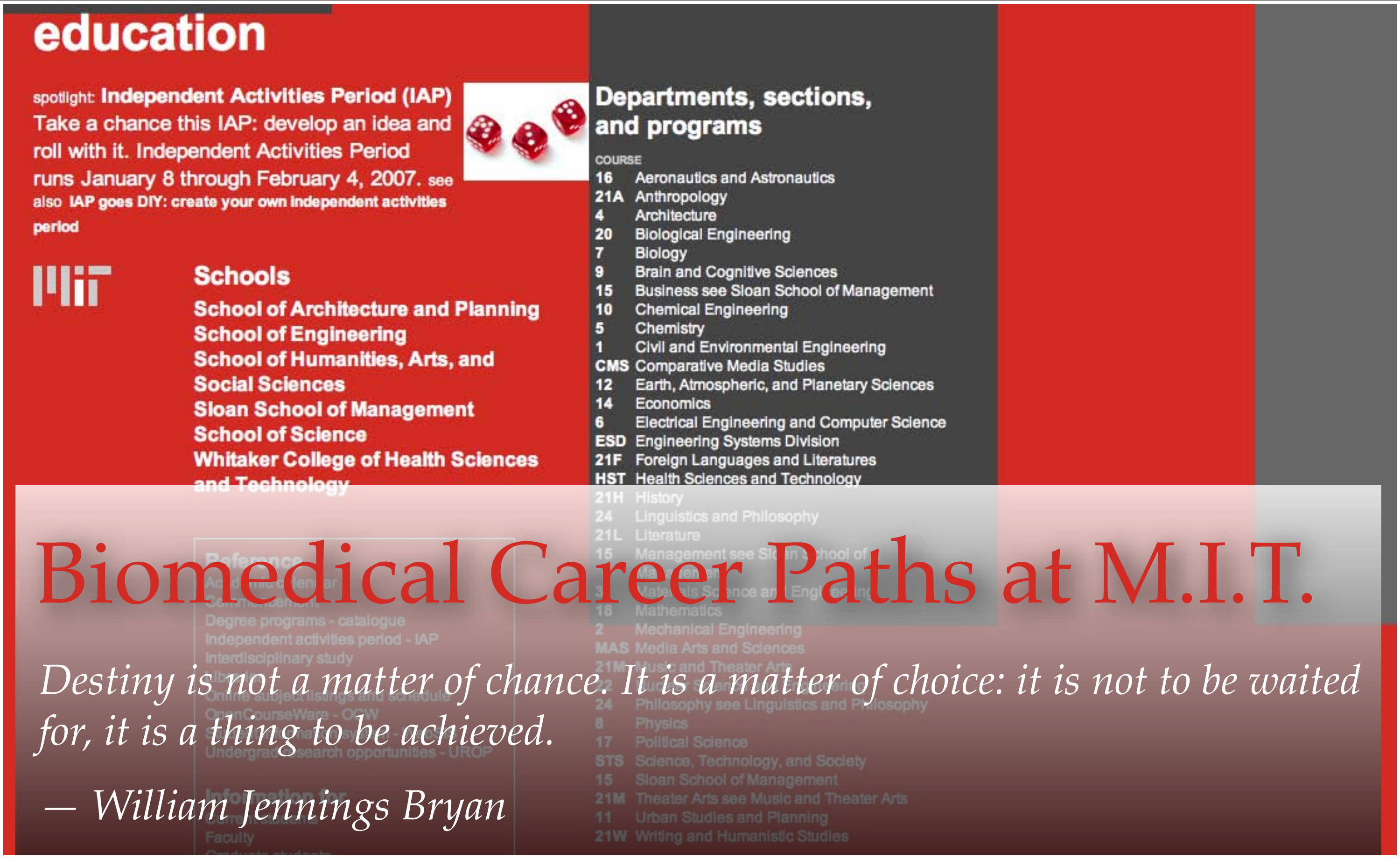


Biomedical Career Paths at M.I.T.

Destiny is not a matter of chance. It is a matter of choice: it is not to be waited for, it is a thing to be achieved.

— William Jennings Bryan

Path 1:
Major in Biological Engineering (Course 20).

Although Course 20 was formally established in 1998 as a new MIT departmental academic unit, with the mission of defining and establishing a new discipline fusing molecular life sciences with engineering, it was the Class of 2008 that would provide the first graduates with a Science Bachelor (SB) degree in Biological Engineering. The department still has limited enrollment, and thus ones wishing to follow that path need to discuss it with their academic advisors and Linda Griffth, the Head of Biological Engineering Department, to secure themselves a place. Biological engineering at MIT is dealing mostly with understanding the basic principles of operation of biological systems and applying them to modify those systems or even create new ones. Unlike many other universities, it is not focused on applying engineering to medicine. To reflect the emphasis on integrating molecular and cellular biosciences with a quantitative, systems-oriented engineering analysis and synthesis approach, Biological Engineering has created a program unique on national scale. Students take basic science classes, out of which the required ones are 5.07, 5.12, 18.03 or 3.016 and 7.06 alongside more specialized classes such as 22.110, 6.00, 20.310, 20.320, 20.330 which survey the most important areas of molecular bioengineering. Additionally, core training includes fundamental laboratory classes 22.109, 20.309 and capstone designing project 20.380. Example roadmaps are available at the departmental website. Besides the aforementioned core classes, you are free to take any of the many classes offered by the department or, depending on your interest, in other departments such as chemistry, chemical engineering, mechanical engineering, physics, biology and mathematics. For example, if you were passionate about Cell and Tissue Engineering, you would want to ensure that you start learning about Materials for Biomedical Applications (20.340J), Biomaterials-Tissue Interactions (20.441) and specifically about tissue engineering and its applications (20.360). On the other hand, if you envision your future as a system biologists you would want to make sure that you possess enough mathematical and computational sophistication necessary to tackle complex problems of systems biology, and take more classes in mathematics department, for example 18.303, 18.086, 18.06, 18.330 and perhaps 7.36 or BE.420.

Path 2:
Major in Chemical-Biological Engineering (10B).

For those of you who prefer a more classical approach to biological engineering with a well established MIT department, the Chemical-Biological Engineering would be a great option (ask Xin, she knows). This course has been developed for students who want to focus on biological applications of chemical engineering. Course XB provides strong foundation in chemical engineering but also requires additional biology courses in place of 5.310 and 10.32. In addition, the laboratory and design elements feature biological topics and processes. Although the core curriculum of course X is very structured, there are many options within restricted and unrestricted electives to explore your interests. Course X is also very careful about scheduling its classes so that there are no major scheduling conflicts with either Biology or Biological Engineering.

Path 3:
Major in Mechanical Engineering (Bioengineering and Biomedical Engineering 2A-1).

Department of Mechanical Engineering offers an interesting option for those who are interested in strong engineering background and want to have flexibility in exploring biological options. The program allows students to tailor curriculum to their own needs, starting from a solid mechanical engineering base and combining a rigorous grounding in core mechanical engineering subjects with an individualized course of study that the you can designs with the help and approval of the faculty advisor (for example, Prof. Linda Griffith). This option is quite popular among course II-A students. In 2005, 35% of students chose this track. If you decide to pursue this option, you must take 7.01 during your freshmen year, as it will conflict with most of your sophomore classes. At the beginning, you will also be required to take a variety of fundamental mechanical engineering classes, such as 2.001, 2.003J, 2.005, 2.009, 2.670, 2.671, 18.03 and then some second level core courses such as 2.002, 2.004, and 2.006. Subsequently, you can develop your biology emphasis by taking any combination of bioengineering classes from course II, such as biomechanics (2.183, 3.052, 2.385J), biomaterials (2.79J) and biological instrumentation or design of medical devices (2.673, 2.782J), quantitative physiology (2.791J) or from biology or chemistry departments, such as 5.12 or 7.05. Course II offers also a unique option of studying medical engineering at MIT. In this case core classes that you will be required to take span a broad range of topics starting from design and manufacturing (2.007), to mechanical design (2.72) to biomechanics (2.183). Afterwards, you are free to take more specialized classes such as Design of Feedback Control Systems (2.14) or specifically Design of Medical Devices (2.782J).

Path 4:

EECS with Biology.

Many revolutionary discoveries in bioengineering were possible only due to extensive use of computer technology, and nowadays computer techniques play an important role in bioengineering and become a separate field known as computational biology. If that is one of your interests, your best option could be majoring in course 6 with biological emphasis. Additionally, if you are not yet certain about your future career path, a major in course 6 will relieve you from the headache of finding an interesting job regardless of your choice of future field. There are two main areas of specialization within course VI. The first one is engineering with a eiving systems component, which focuses on engineering problems which contain a living system component such as biomedical electronics and transducers; image and speech processing; computerized tomography; sensory aids for the deaf and blind; automatic speech recognition, speech synthesis.The second area is more focused on living systems themseves and understanding of them. Examples include: auditory physiology and psychophysics, human speech communication, the transmission and coding of signals in the nervous system; electromechanical properties of biological cells, tissues and membranes; optical properties of tissues; interaction of high-energy particles, laser radiation and ultrasound with living matter; methods for optical biopsy and detection of pathology; ophthalmic imaging; endoscopic optical coherence tomographic imaging. Some great classes in those areas include Control and Signal Processing (6.011), Quantitative Physiology: Cells and Tissue (6.021J, also a CI-M), Psychoacoustics (6.182), Sensation and Perception (9.35) or even as specialized fields as Psycholinguistics (9.59J). Before you take a class, consult the Underground Course VI guide - publication of Eta Kappa Nu Fraternity. It contains unofficial rankings of professors, students opinions and many other useful tips and hints.

Path 5:

Non-standard Applied Sciences Options.

Except of the above routes, there are many non-standard ways to satisfy interests in biological engineering. For example, you could add a second major or a minor in biology or a minor biological engineering on the top of a degree in a more classical engineering or science discipline, for example mathematics or physics. Although doing it the other way round is also possible, you would have to be careful as my personal experiences show that it is easier to teach yourself biology and lab techniques than to master computational techniques or understand differential equations by yourself. If you do it this way, you will enjoy the possibility to plan your degree by yourself (ideally, with your advisor) and take the classes that interest you rather than those that satisfy a departmental requirement. Furthermore, if you plan your degree well you can equip yourself with a set of skills perfectly matching the needs of your future employer or graduate school. However, if you will choose to do so be prepared for scheduling difficulties (departments frequently schedule their core requirements at the same time), troubles with professors not really prepared for the interdisciplinary study (be careful about presenting an amazing piece of coding as you biology project if you cannot pinpoint the biological meaning of its results), and planning, because no one might be there to tell you which classes are important and in that order you should take them.

But whatever your do, always consider...

Research Experience

Try to get some research or industry experience. It might be embarrassing and painful at the beginning--mine was--but it will pay off later. For graduate schools and many companies, the experience you get actually trying to solve questions that no one has answer to, working in the lab, going through its highs and lows, or having to give a presentation to a room of skeptics is likely to be at least as important as your GPA. You might even become a specialist in your field, or the only person in the world who knows why certain processes behave the way they do.

The most common way of getting research experience is through the UROP program, which posts its offerings at web.mit.edu/urop. Additionally, you can simply e-mail the professors who do interesting research and express your enthusiasm and fascination with their research. Other ways of finding a good place for research work include networking with friends, or talking to your academic advisors. Finally, the alumni networks and organized governmental programs have their own offerings, which, however, are rarely on-campus and might require travel during the summer semester or IAP.

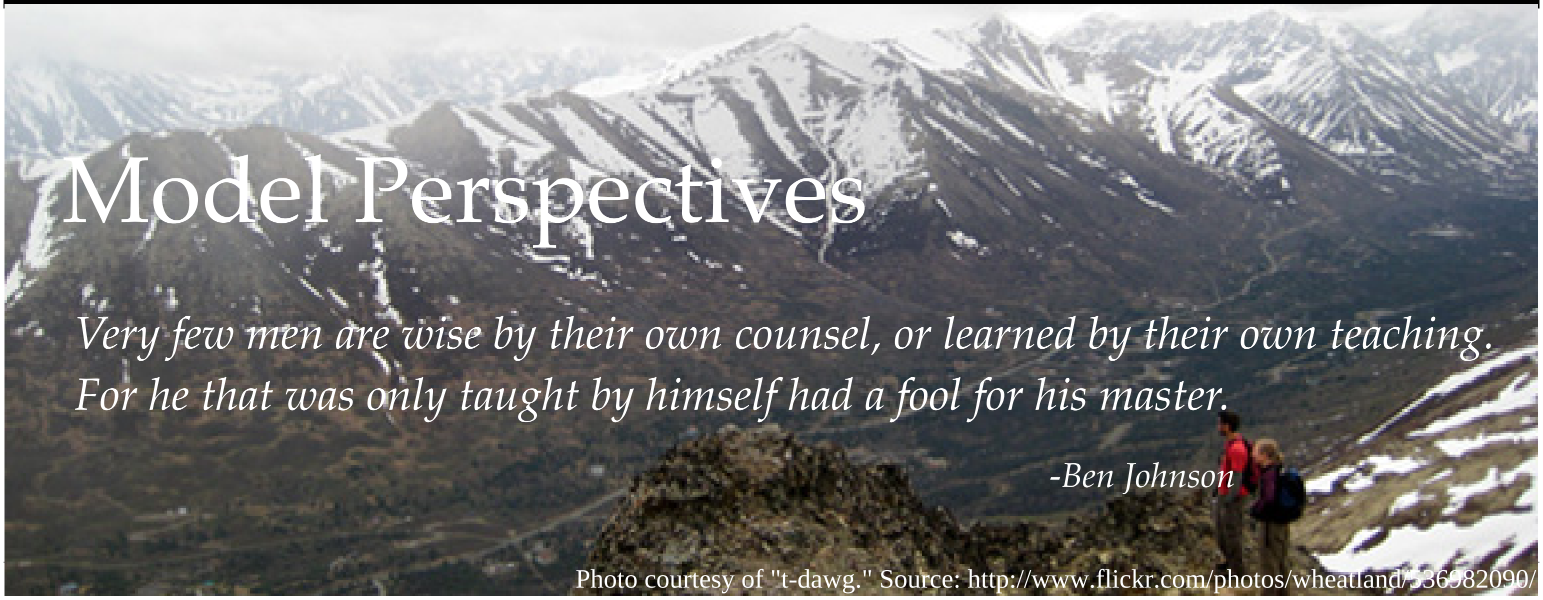
Don't be discouraged if you accumulate only rejections through your freshmen year. MIT professors and graduate students tend to undermine freshmen abilities just due to the fact that they are freshmen, no matter what experiences and potential you posses. The good side is that as soon as you become a sophomore and get some lab experience (for example, through lab classes such as 7.02—take it as soon as you can), virtually everyone will be happy to offer you a UROP position in their lab. During your junior year, in many advanced classes professors will advertise UROP offers in class and companies will have special representatives to collect CVs from juniors during career fairs. If you want to combine your research with a funded stay abroad, you should try the excellent MISTI program, which helps in finding placement in companies and research institutions in Germany, France, China, Japan, Mexico and Spain.

Take your time choosing classes

Make sure you know what is actually offered in the class and whether the class fits your learning style. Some people like to be able to attend lectures, recitations and tutorials, and if you are one of those make sure that you schedule your classes so that they do not overlap. On the other hand, if you prefer to learn by yourself but would like to be able to ask your professor questions as you read through your textbook, make sure to choose a class taught by an approachable one. Some people hate exams, and while most core classes will not allow avoiding this, there are multiple possibilities to take a project-based class as your electives. Finally, if projects are what annoys you most and you would rather have an hour exam to get over it, there are certain classes whose grading breakdown involves purely exams—not even problem sets. Everything will be explained in the syllabus, which should provide you with an approximate grade breakdown between exams, problem sets and projects, and it is the syllabus that should guide your choice of classes. You know yourself know how you learning preferences, so make use of that—choosing the right classes might improve your GPA dramatically.

Ask for help

As much as it seems untrue, most professors are in fact sympathetic creatures that were once in your shoes. If you were sick or had any sort of trouble, go to your professor or advisor and explain your situation. Try to show the way you can catch up after the emergency is over. Most professors want you to learn the class material and if you can show them that you can achieve that goal if given an extension, you are likely to be fine. The policies vary from across departments, and also between professors in the same department, and some places are more "relaxed" than others. The rule of thumb is that the more advanced and technically challenging the class, the more relaxed the professors. Additionally, once you pass the introductory classes, the Mathematics department is well known to give extensions reaching even the very grade deadline.



Model Perspectives

Very few men are wise by their own counsel, or learned by their own teaching. For he that was only taught by himself had a fool for his master.

-Ben Johnson

Photo courtesy of "t-dawg." Source: http://www.flickr.com/photos/wheatland/336982090/

Perspective:
Dr. Bruce Rosen, M.D., Ph.D.

Courtesy of Harvard-MIT Division of Health Sciences & Technology. Used with permission.

BY ALICE CHANG, '10 & TOAN TRAN-PHU, '10

Upon first seeing Bruce Rosen, a person might never know that he's an M.D., Ph.D. who is currently the Director of the Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital, MIT, and Harvard Medical School, as well as a radiology professor at Harvard.

Dr. Rosen's manner is neither overbearing nor intimidating as his accomplishments might entitle. Smiles come easily, and his down-to-earth personality and easy way of talking makes you immediately think of the uncle that all the kids like because he's cool and speaks to them as if they were on the same level. And even though he has more things to do than humanly possible on a daily basis, he always seems to give his full attention to you, never rushing or looking preoccupied.

So what's the secret to his success both professionally and in person? How did he get to where he is today? Curiously enough, Dr. Rosen didn't aspire to be a radiologist when he first started out at school. He was passionate about and received an A.B. in Astronomy from Harvard University in 1977. But when told the projected career options available in the field at the time (totaling to negative one), he went with the flow and decided to change tracks. Moving on to graduate school across the river at MIT, he received an M.S. in Physics in 1980. Two years later, he received his M.D. from the Hahnemann Medical College and Hospital, and another two years after that, returned to MIT and received his Ph.D. in Physics.

The newly titled Dr. Rosen then completed several years of research, eventually ending up at the new fledging Martinos Center whose focus was the newly developped NMR machine. His unique background in Radiology and physics in tandem with his medical degree put Bruce in a unique disposition to have specialized expertise in the technology. Eventually joining their faculty, Dr. Rosen rose through the ranks, becoming the director of the Martinos Center for Biomedical Imaging where he is currently serving in that position.

So enough about what Dr. Rosen did when he was younger, what revolutionary work is he doing today that gave him such renown and recognition? His current research involves the technique development and potential application of functional MRI (fMRI for short), such as measuring metabolic and physiological changes when the brain is activated. He and his colleagues have already made many advances in measuring blood flow in the brain during stimulus. His work also aims to combine MR imaging with EEG and MEG recordings, an ambitious task that is much more complicated than it sounds. With that technology, it would be possible to view the brain as it functions in real time, opening so many possibilities for the study and direct testing of how the brain works and is affected by disease.

Of course, Dr. Rosen's excellent research hasn't gone unnoticed. He was inducted into the MIT chapter of the honorary society of Sigma Xi Scientific Research Society. Already, Dr. Rosen is the recipient of the Gold Medal for the International Society of Magnetic Resonance in Medicine and has been named a Fellow there.

Despite being the director of a world-renowned medical research facility and a senior lecturer at the HST program, Bruce still finds time to help budding scientists and talk to interested parties. During our recent visit to the Martinos Center, Bruce took time out of his day to give us a tour and talk with us afterwards. From the extreme familiarity with which he talked about the projects it was clear that he knew all the research projects that were being conducted. The ease with which he talked stimulated understanding and comfortability; simply put, he was very easy to talk to. This is one of the very important qualities that facilitated his current position. Several guest lecturers have mentioned this aspect of Bruce's success. There are many excellent scientists in the world currently. However, scientists with social skills like Dr. Rosen's are those that rise to head institutions. That was duly noted by the entire group, and was a very memorable message, one that we gladly took to heart.

Nevertheless Dr. Rosen was a big part of the seminar, being one of the two leaders. He was the one with most of the connections who invited the speakers to talk. In this way he got to choose most of the selection, choosing most of the time from Martinos Center faculty. This explains the heavy Martinos tilt of many of the speakers and is also because the focus of the seminar ties very well into the objectives of the Center.

Field Trip:
Athinoula A. Martinos Center for Biomedical Imaging

Article on Athinoula Imaging Center removed due to copyright restrictions.

MRI machine, similar to that used at MGH. Photo courtesy of NASA.

Perspective:
Maria Angela Franceschini, Ph.D.

BY TIFFANY YEE, '10

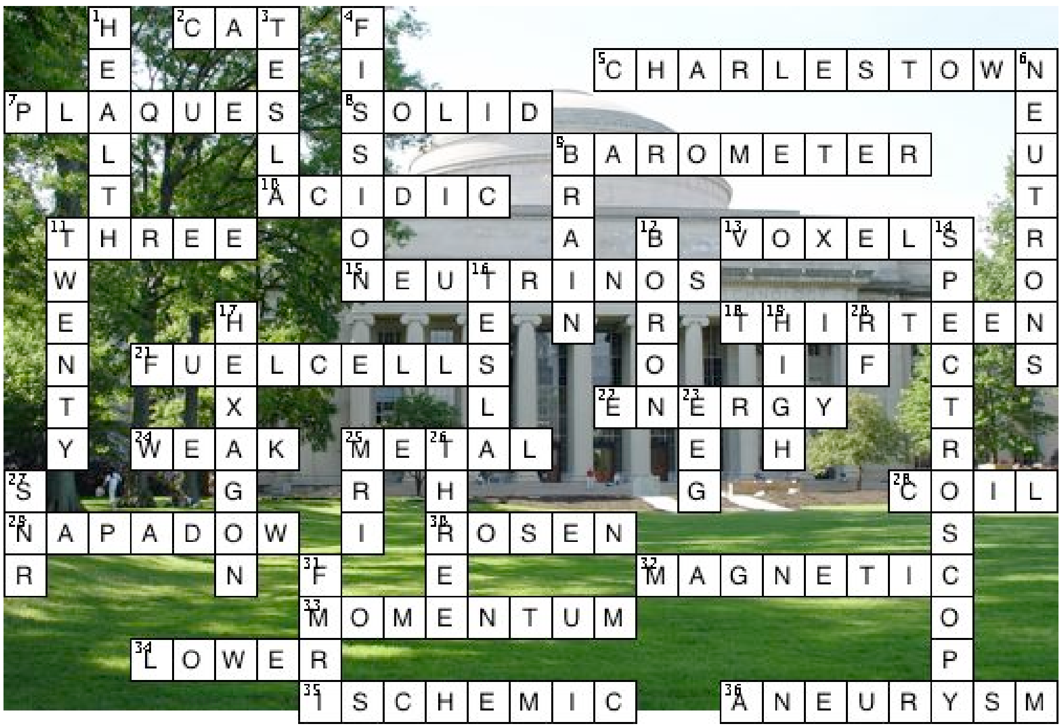
Maria Angela Franceschini was born and raised in Italy to a family with many members working in medicine. She, however, decided to take a different path and first attained her doctoral degree in physics at the University of Florence in Italy. After that, she came to America and worked as a Post-Doctorate Research Associate and research physicist in the Department of Physics at the University of Illinois in Urbana-Champaign for seven years. Moving to Boston to be with her husband in 1999, she was a research assistant professor at Tufts in the Electrical Engineering and Computer Science Department for a few years. Soon she realized that physics just wasn't her biggest interest in life, and in 2000 found a way to incorporate her mechanical background with studies in medicine by being an assistant physicist at the NMR Center in Charlestown. She's been working with imaging parts of the body ever since. She was also an instructor for a year at Harvard Medical School and now is an assistant professor there. Currently, as an associate professor, she plans to make a few more publications with hopes for a new grant to continue her research and may eventually become a full-time professor.

Current work/presentation

Maria Franceschini shared with us her work in brain physiology and imaging. Through studying neurovascular coupling and baseline hemoglobin fluctuations with data interpreted from imaging, it has been made possible to learn more about brain development/aging, strokes, and psychiatric syndromes. FMRI (functional magnetic resonance imaging) is a method of taking high-resolution pictures to map parts of the body by means of a magnetic field and emission of a specific radio wavelength. DOI (diffuse optical imaging) is a way of using light absorption and reflection to scan changes in blood volume and hemoglobin oxygenation. With integration and application of these two techniques to the brain, specific areas can be identified that are affected by stimulation like thoughts, perception, or movement. Maria has done research in cerebral oxygenation in infants as well as in noninvasive techniques for optical imaging of the brain that measure the effect of stimuli on oxygen concentration. The eventual hope for imaging technology is finding a way to see what we think, although currently there hasn't been much progress besides attempts to pinpoint face recognition and lying.

My Personal Commentary

Maria's presentation on optical imaging was very helpful to myself and my peers. She gave us a basic overview of her career path and current work in intriguing and unprecedented research taking place at the Martinos Center. Another side topic she talked to us about was grant writing, a critical part of her career that determines her salary and job. She has a great deal of experience in this process and has written many, many grant proposals. Each can be as long as 50 pages or more, with half of that just to budget and outline of the plan, and other parts covering goals, background information, preliminary studies, and similar projects. It can take a lot of strong preceding data to prove that your plan will be useful and is necessary. You can submit grant proposals up to three times a year to the National Institute of Health, where a panel of 20-30 people discuss 100+ grant ideas. Each gets a score before it is considered; no more than 10% will be funded. Ideas that need revision are provided suggestions and can be submitted up to twice more before one must start again from scratch. It's a good idea to sit on grant panels when possible to understand what the organization is looking for and see how the process works. The money has to be divided up evenly between the different fields of medicine, so often the chances of getting the money are purely a gamble. Maria's inside scoop on the workings of grants was very helpful information that will probably apply to many of us as we move on to pursue careers in biomedical research, whether it be in medical imaging or other fields.



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29 NAPADOW
30 ROSEN
32 MAGNETIC
33 MOMENTUM
34 LOWER
35 ISCHEMIC
36 ANEURYSM
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3 TESLA
4 FISSION
6 NEUTRONS
9 BRAIN
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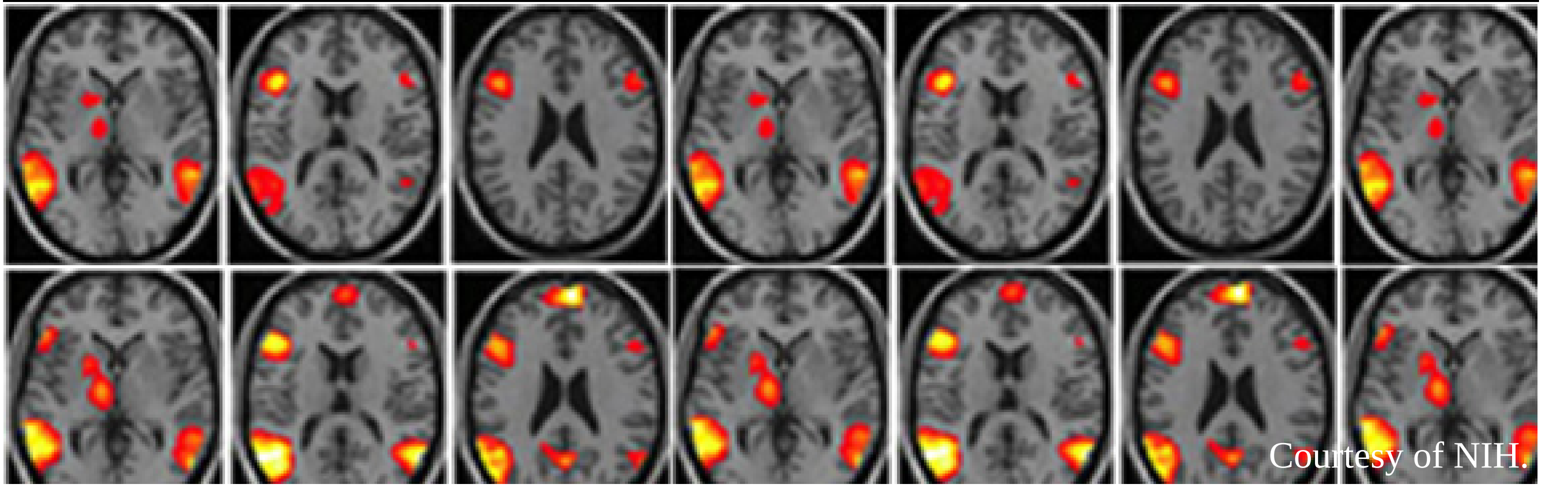


Courtesy of NIH.

Perspective:

Dr. Denise Hinton, Ph.D.

BY ALICE CHANG, '10

Denise P. Hinton, PhD., will tell you that it's all about the Tesla.

Clinical magnetic resonance imaging, also known in short as MRI, has changed the medical world for early detection and diagnosis of various diseases. While MRI has been universally recognized as a tool for studying the brain, enormous progress has also been made recently in cardiac MRI. Cardiovascular disease and malfunction is the number one killer of Americans today. With cardiac MRI, radiologists have studied various cardiovascular structural abnormalities such as valvular and congenital diseases.

Tesla are a unit of magnetic induction. The higher the Tesla, the stronger the field strength and ultimately, the better the picture. Most hospitals' MRI machines operate at 1.5T, the standard for field strength used clinically today.

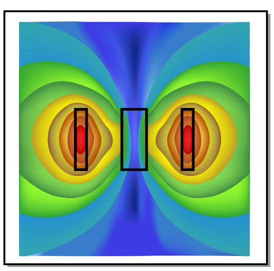


Figure by MIT OCW.

But there are problems that arise with the conventional 1.5 Tesla resolution that is clinically available. For example, images of the beating heart tend to come out blurry due to its movements. In addition, though the major trunks of the coronary arteries are clear, smaller arteries are invisible in 1.5T prints. As research explores increasingly complex cardiovascular issues with MRI such as myocardial perfusion and functionality, it becomes even more essential to have a good picture of what's going on.

It's all about the Tesla

That's where Denise P. Hinton comes in. Besides working with the MGH/MIT/HMS Athinoula A. Martinos Center for Functional and Structural Biomedical Imaging and Mass General Hospital, Boston, she is also a radiology instructor at Harvard Medical School.

Hinton has been studying cardiac MRI at ultra-high fields, primarily at 3.0T. Direct comparisons of images at 1.5T and 3.0T show significant differences, some of which include better contrast between tissue and blood and better signal-to-noise ratios (SNRs). That means that such measurements as vessel diameter can be more accurate, thus improving the diagnosis of various ailments.

One priority is the development of plaques, which are an abnormal accumulation of inflammatory cells, lipids, and sometimes connective tissue within the walls of arteries. The progression of the disease is called atherosclerosis. Plaques are so hard to track because heart arteries are very small and hidden deep within the chest. Slices as thin as 2 mm and in-plane resolution of less than 0.5mm is needed for plaque imaging. 3.0T MRI makes plaque detection much more efficient and can acquire plaque images in half the time 1.5T scanning could.

But optimizing 3.0T scanning isn't as easy as it sounds. Hinton remarks that, "In order to take full advantage of the SNR gain provided by high magnetic fields, both hardware and software optimization are critical. The higher field tends to be more sensitive, and we have to invest more time at the outset of a 3T body examination to remove field inhomogeneities."

The necessary technology is available, it simply needs to be adjusted and fine tuned. Radiofrequency coils needed for scanners of high-fields are not as broadly ranged as lower-field scanners. In addition, cardiac MRI is not as popular as say, brain MRI. Hinton, who works at the Martinos Center, acknowledges that the MRI scanners there are primarily adjusted for the brain. Coils that are optimal for studying the heart are still being developed and it will take time to be more widely available.

The ultimate goal would be to make 3.0T scanners available for clinical use. Hinton, along with many others, are sure that the benefits will be well worth the cost.

22.A09

Seminar Participants

I. **Students**

- Olga Botvinnik, '10
- Anna Labno, '07
- Alice Chang, '10
- Toan Tran-Phu, '10
- Troy Rurak, '10
- Ke Zhang, '10
- Richard Lin, '09
- Tiffany Yee, '10
- Richard Yau, '10
- David Li, '10
- Jennifer Chu, '10

II. **Coordinators**

- Sidney Yip
- Bruce Rosen

III. **Student Coordinator**

- Xin He, '09

HST

Division of Health, Sciences, and Technology...

Education beyond M.I.T.

Perspective:

Dr. Frederick Bowman, Ph.D.

BY TROY T. RURAK, '10

October 17th was the day my love came home to me. Well, no. Actually, it was the day Dr. Fred Bowman came to chat. Our advising seminar 22.A09 entitled "Career Options for Biomedical Research" typically hosts a guest speaker on a weekly basis in order to promote awareness and to give us a sense of what the biomedical field beholds, should we decide to pursue it further with simple curiosity or as a potential career. Dr. Fred Bowman, Ph.D., works in the Division of Health Sciences and Technology (HST), the collaborative child of Harvard Medical School and the Massachusetts Institute of Technology. "(HST) is dedicated to integrating medicine, science, and engineering into an educational program that carries these disciplines from the laboratory bench to the patient's bedside, and conversely, brings clinical insights from the patient's bedside to the laboratory bench" (hst.mit.edu). This motto of "bench to bedside" exemplifies their mission to integrate technical learning with physical interaction and application to the medical world in order to better the understanding of both fields.

Dr. Fred Bowman, a self-proclaimed "farm boy" grew up in the heartland of the United States, always fascinated by the way things worked. When the time came, he ventured on to college: a venture new to the Bowman family. He entered the Pennsylvania State University hoping to learn about engineering, but when asked which field of engineering most interested him, Dr. Bowman replied, "You mean there's more than one?" To keep his future options open, he elected to study mechanical engineering, the most general of all fields. Along the way, a few of his professors and colleagues saw that he was doing good work, and suggested he look into nuclear engineering. He wasn't too sure what it was or why they wanted him to do it, but he figured he'd give it a shot; several years later, he left the MIT graduate program with a degree in nuclear engineering. Since then, he's spent time on the biomedical engineering faculty at Northeastern University* and, during his stay at MIT, has developed the Bowman Perfusion Monitor (BPM) through an application of thermal properties to blood flow. Thermal diffusion technology can be applied to address and facilitate all sorts of bodily processes and procedures such as neurosurgical and cardiovascular monitoring, organ transplantation, and reconstructive surgery. Appropriately named, the Bowman Perfusion Monitor displays historical and immediate information on a patient's blood flow and tissue temperature using a diffusion probe that connects to the BPM via an "umbilical cord." "The… probe, which is a flexible, medical grade catheter, is inserted into the target tissue using the appropriate surgical hardware to measure focal temperature and tissue perfusion…." This minimally invasive method of monitoring perfusion and temperature in small volumes of tissue has been sought after for years, and will likely play a key role in critical surgeries and treatments where such information is essential for the patients' vitality and well-being.

During his talk, the one thing he emphasized more than any other was the web-like quality of biology, medicine, and engineering, thus stressing the importance and usefulness of biomedical engineering in our ever-changing world. Each field bears a facet of the same gem, and without just one of these sides, the gem is not whole, and the understanding of each is diminished. *Aside from his Chairman and CEO positions at Hemedex—the company he founded to manufacture the Bowman Perfusion Monitor—Bowman is a lecturer on Radiation Oncology at Harvard Medical School and has served for twenty-five years as a faculty member in the Mechanical and Biomedical Engineering program at Northeastern University. Dr. Bowman is the Senior Academic Administrator and UROP Coordinator at HST and has served the National Science Foundation where he plays a prominent role as Program Director for Biomedical Engineering. He has published nearly one hundred fifty articles and abstracts, many examining his principal research interests of "microprocessor-based instrumentation for the quantification of perfusion, thermal properties and cardiac output, 'bioheat' and mass transfer based problems in clinical research, thermal physics of hyperthermia, and thermometry."

Dr. Bowman has certainly come a long way from the farm boy he once was, though in many respects, I'm sure he has been left unchanged. He still shows that innate curiosity for the human body and figuring out "how things work," only now, he has the means and the education necessary to change the way the world thinks and to better the lives of all those who've benefited from his technological advances. I'm sure, as a kid, he'd wonder what he'd be doing when he got older. Now, he probably asks himself the same question. The door for opportunity has been left open, and the people who choose to venture outward will change our world and our knowledge forever. Dr. Fred Bowman is one of these people.

Nuclear Reactor Tour

Courtesy of William McGehee. Used with permission.

Field Trip:
M.I.T.'s Nuclear Reactor

By David Li, '10

It may seem as if the MIT nuclear reactor would be irrelevant to career options in biomedical research, but in fact, the MIT nuclear reactor is relevant since the neutrons it produces are used for research, especially medical research. On November 21, 2006, the students in the Career Options in Biological Research Class went on a tour of the MIT nuclear reactor. Before the tour most of the members of our class met in room 24-105. In this room, Professor Yip explained to us the basics of how a nuclear reactor works. A nuclear reactor works by a fission reaction of Uranium-235. Fission is the process in which an Uranium atom absorbs an external neutron, which causes it to split into two parts and release two or three neutrons. The released neutrons induce a chain reaction by bombarding the surrounding Uranium atoms. Thermal energy is generated each time a Uranium atom is split. Normally, this energy is used to convert water into steam, which drives a turbine to produce electrical energy. At the MIT reactor, the excess heat generated by fission is carried away via heat exchangers to cooling towers. As mentioned before, the neutrons produced at the MIT reactor are used only for research.

After Professor Yip's presentation, we headed to the nuclear reactor. The MIT nuclear reactor has been operational since July 1959. The reactor is located on Vassar Street behind the Johnson Athletic Center. Inside the reception area there was a counter to our left and sofas to our right. Toan and Jennifer had arrived earlier on their own and were sitting on the sofas. The lady behind the counter asked us to sign in. I signed in first and the lady gave me a scintillation counter. The scintillation counter was approximately one centimeter in diameter and ten centimeters long. I put it in my pocket. This counter was used to measure the amount of radiation exposure that I received while touring the reactor. After we finished signing in, we waited in the lounge for a long time.

At around 4:30 pm, a guy named Ed Lau came and said that he would be our tour guide. Before we began, he gave us some background info on the MIT reactor using a small metal model of the reactor in the reception area. The model of the reactor had small Christmas lights on it at specific components of the reactor. Beneath the model, there were labeled buttons that corresponded to each of the lights; when one of these buttons was pushed, the corresponding light would light up.

The core of the reactor consists of 27 bars, 24 of which have fuel elements. Each bar costs around $50,000. Each bar has a rhomboid shape and consists of fifteen fuel plates. Each fuel plate is sandwiched between sides of aluminum cladding. The fuel is a uranium-aluminum mixture called cermet. The 27 bars are arranged in a hexagonal formation. For each hexagonal side there is a corresponding boron-stainless steel shim blade. When all the blades are dropped into the core, the reactor is shut down. The reactor can be shut down in less than one second. Surrounding the core, there are various layers of material that shield against radiation. There is a layer of water, a layer of lead, a layer concrete, and layers of other things.

The reactor is refueled three or four times a year, and each refueling involves either replacing two or three fuel elements or rearranging the fuel elements. A typical fuel element stays in place for three years. The reactor is operational twenty four hours a day, seven days a week.

After Ed finished telling us the background on the reactor, we began the tour. First, we walked lengthwise into a large cylinder, whose dimensions were approximately three meters in diameter and six meters long. Both sides of the cylinder were sealed airtight. Then the side of the cylinder leading into the main reactor chamber opened. The main reactor chamber was very bright. The reactor was located in the center of the room. Ed explained to us that the reactor core is kept at a lower pressure compared to the outside chamber so that if an accident happens, clean air from the outside will flow in and not the other way around. After walking around in the main room for a bit, we went down a flight of stairs and into the control room. The control room was about two meters by four meters by two meters and was full of dials, lights, and TV screens. There was one person in the control room monitoring the reactor. After seeing the control room, we went back upstairs and walked around the reactor. The most interesting part of this walk was seeing one of the medical research rooms which had four inch thick yellow glass. The yellow color of the glass comes from doping with lead. There are also many other research facilities scattered throughout the facility. On the way out we tested for radiation using a Geiger counter. Then we signed out and I returned my scintillation counter. The actual tour only lasted for about 12 minutes.

Personally, I enjoyed the reactor tour a lot. I had never visited a nuclear reactor before. I was surprised to learn that the MIT reactor is used only for research and is not used to produce energy. Our tour guide, Ed Lau, was knowledgeable and friendly.

Links:

http://web.mit.edu/nrl/www/index.html

This is the official website of the MIT nuclear reactor laboratory.

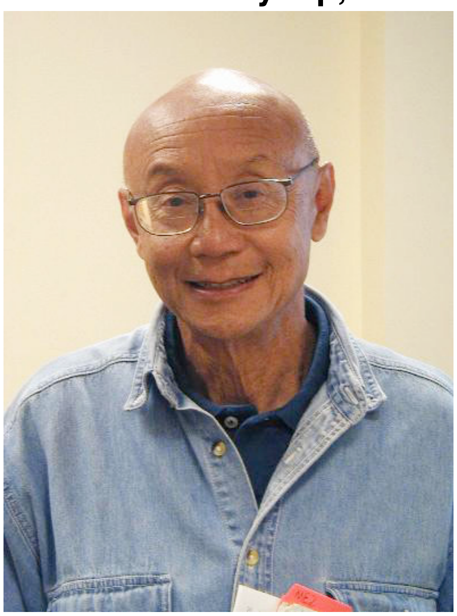
Model Perspective

Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning.

-Albert Einstein

Courtesy of "Uncle Jerry in Golden Valley, AZ." Used with permission.
Source: http://www.flickr.com/photos/uncle_jerry/162852753/

Perspective:
Professor Sidney Yip, Ph.D.



Courtesy of Kavli Institute for Theoretical Physics. Used with permission.

BY TOAN TRAN-PHU, '10

Professor Sidney Yip holds a special place in all of our hearts. To us, he will remain our beloved seminar advisor. His years of wisdom were soundly encapsulated into advice that he would periodically give. We were thus treated to an enlightening and engaging lecture on both snippets of motivational advice and a background on his current research.

Professor Sidney Yip came to the US from Beijing as a kid and attended different high schools in the US, graduating from high school in 1953. He then attended the University of Michigan, earning a BS in Mechanical Engineering and then a M.S. and Ph.D. in Nuclear Engineering, and after a year as a postdoc and a brief stint as a Research Associate at Cornell, was offered a faculty position on the Nuclear Engineering Faculty at MIT. Earning his Professor status in 1973, he has since taught many classes and has received a secondary appointment in the Department of Materials Science and Engineering.

Currently, he teaches several undergraduate and graduate level classes in nuclear physics in topics like neutron physics, nuclear and atomic collision phenomena, and statistical processes and atomistic simulations. He has also co-led this very seminar for many years now, focusing on career options in biomedical research, a departure from his traditional field.

This varied background prompted a stimulating and varied talk, which was duly attended by both his seminar and a guest seminar group, supplemented by absolutely delicious pizza.

Professor Yip's current research deals with computer simulations of atomic interactions. True to Morse's Law, computational power has been exponentially increasing. This affords ever increasing sheer computational power and makes it more readily available and accessible to many more researchers. Supercomputers are becoming more ubiquitous, allowing just about any researcher to have computing time on these computers.

The challenge is therefore to find uses and make the best use of this newfound power. Yip's work is one such example of computer usage. In order to design and understand materials better, we need to figure out interactions between the actual materials and the molecules therein. We want to be able to predict how materials will hold up to different strains and stresses. We know that different materials behave differently under varying conditions, and react according to their state.

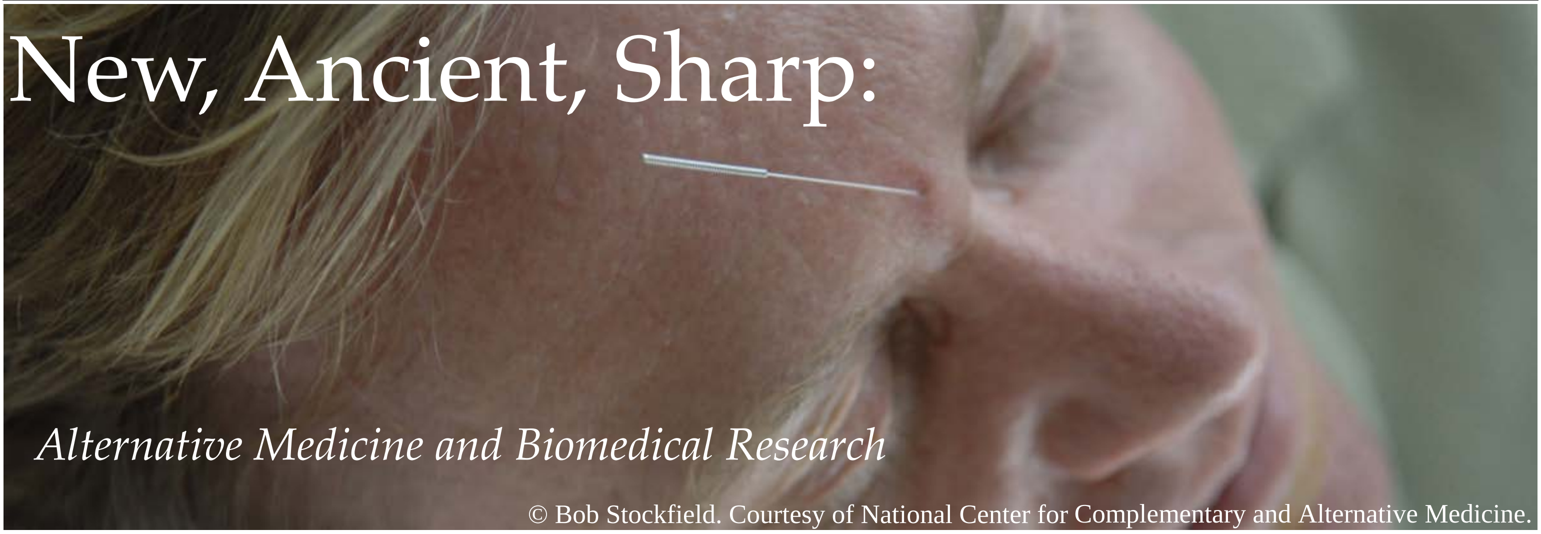
For example, refractory carbide will cleave at low temperatures when exposed to a stress, and will begin to cavitate when at high temperatures and exposed to a stress. This cavity will expand through the material as additional strain is applied, eventually causing a rupture. Similarly, a carbon nanowire will simply break in half at low temperatures but will break down string by string until separated at high temperatures. This is useful in applications like bridges and other structures where advanced warning of degradation would be beneficial and could save lives and reduce costs. These behaviors were observed in the lab in carefully controlled experiments.

Professor Yip managed to predict these behaviors in his computer simulations with the simplest assumptions and behaviors. Using elementary Newtonian mechanics, he modeled many thousands of particle interactions and came up with behavior that matched observed behavior. Nanoindentation and stress wave behavior was also seen in some of his models. He also was able to explain the physical mechanics of the weakening of quartz immersed in water at the molecular level.

The second part of the lecture was devoted to disseminating tidbits of wisdom accumulated during Yip's forty year stay at MIT. His summary of the research life at MIT is best put as "It's not what we know. It's what we don't know." A professor can become the absolute expert on a subject matter, but MIT would not be interested. Knowing a lot about something does not further the human understanding of science. MIT, according to Yip, is a research institute. A professor needs to be able to do competent and relevant research. Teaching is secondary and an added bonus.

The beauty of this institution as a school is that it will not teach formulaic responses. Instead, it focuses on teaching students how to respond to situations. Unexpected obstacles and circumstances will undoubtedly arrive in one's career, and we are taught to surmount it. Four qualities especially will serve us: excellence, perseverance, boldness, and optimism. We should all excel at our classes and work, persevere in times of trouble, be bold and daring and never hold back, and be optimistic and have a bright outlook for the future. We are indeed "way too young to be cautious." And how to approach life? Have a mission and stick to it: "Vision without Action is a Dream. Action without Vision is a Nightmare."

We hope Professor Yip continues to continue to impart his wisdom for many more freshman by continuing to offer the seminar. We are very grateful for his time and energy in helping us find our roots about us in this seminar.



New, Ancient, Sharp:

Alternative Medicine and Biomedical Research

© Bob Stockfield. Courtesy of National Center for Complementary and Alternative Medicine.

Perspective:
Vitaly Napadow, Ph.D., Lic.Ac.

Courtesy of Vitaly Napadow. Used with permission.

By Jennifer Chu, '10

Dr. Vitaly Napadow is currently a neuroscience researcher in Massachusetts General Hospital's Department of Radiology. Yet what is so intriguing and unique about his choice in careers is that he is also a licensed acupuncturist. Dr. Napadow combined his acupuncturist background and his knowledge of biomedical imaging to enhance his research on the effects of acupuncture in the brain. He works as a clinical acupuncturist once a week at Brigham and Women's Hospital's Pain Management Center and spends the rest of his time investigating the scientific evidence behind the effects of acupuncture.

Interestingly, if you had asked Dr. Napadow as a college freshman where he saw himself in the future, his reply would be light-years away from anything to do with acupuncture. As a freshman at Cornell University, Dr. Napadow had his mind set on pursuing a career in the aeronautics and astronautics engineering field, with the ultimate goal of becoming an astronaut. He majored in Mechanical Engineering, as there was no Aeronautic and Astronautics Engineering major at Cornell, and sought out a summer internship at NASA's Johnson Space Center. Dr. Napadow described his internship as a fantastic learning experience. But at the same time, it also led him to the conclusion that he did not want to work for NASA or the government.

Dr. Napadow saw it as a good thing to have been disappointed early on and realize that he did not want to continue in the aeronautics direction since he had more time to adjust his plans and search for a new interest. Unsure of where to turn next, a girl he was interested in was taking classes in biomechanics, so he decided to try it out. As a result, Dr. Napadow became interested in biomechanics, which integrated a human element into engineering. He continued with his new interest and did his undergraduate research projects in biomechanical engineering.

After graduating from Cornell, Dr. Napadow continued to pursue his interest in biomechanical engineering, obtaining a Ph.D. through the Harvard-MIT Health Science and Technology program. Yet during that time, he also became interested in acupuncture and started as a part-time student at New England School of Acupuncture. Eastern medicine and acupuncture were 180 degree turns from his engineering background, and it provided an entirely different perspective and interpretation of the biomedical field. Nonetheless, Dr. Napadow was intrigued by acupuncture and continued as a full-time student, graduating with a Master of Science in Acupuncture.

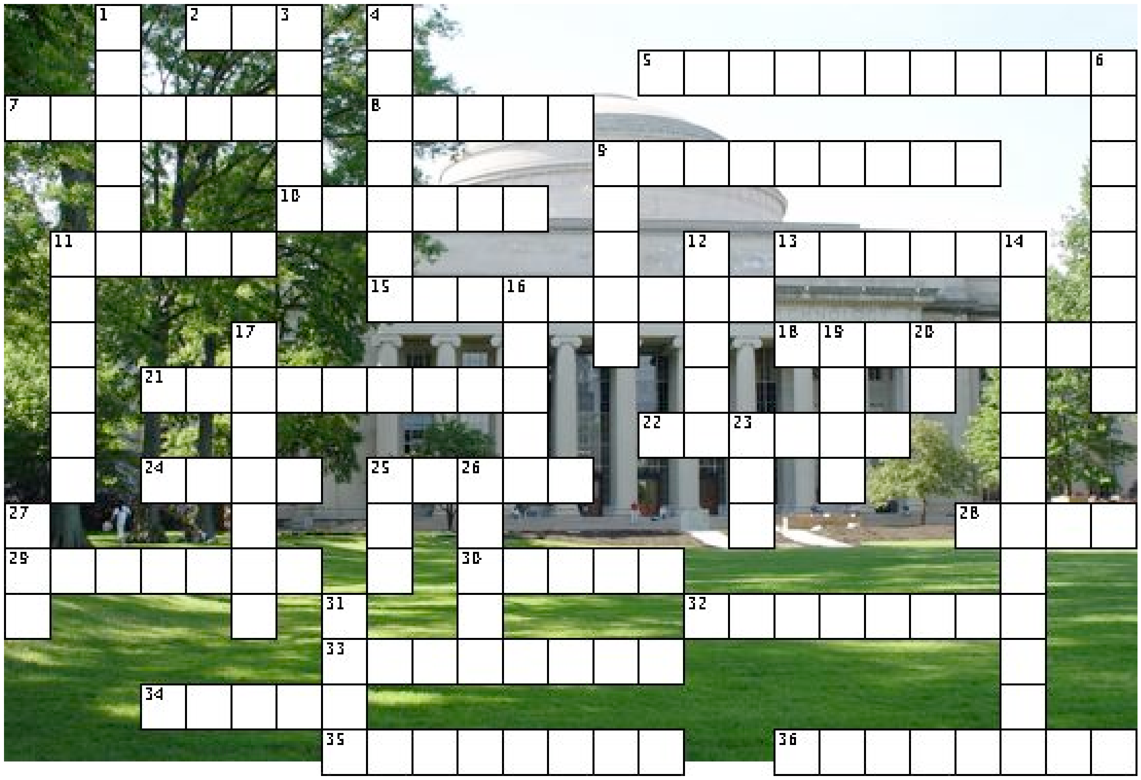
Then he was in a dilemma. Dr. Napadow did not know whether to continue with his Ph.D. into research or become a clinical acupuncturist. In 2002, he went to China for an internship in outpatient acupuncture clinics to explore his options as an acupuncturist. In the end, he found his path lying on the line between the two options. Dr. Napadow became an acupuncture researcher, using his MRI imaging background to study the effects of acupuncture in the central nervous system, while adding his acupuncturist perspective to the field. He also continued to be a part-time acupuncturist to maintain the patient-contact aspect of acupuncture. As an acupuncturist, Dr. Napadow treats his patients with the conviction that acupuncture works, while as a researcher, he remains open to the idea that perhaps acupuncture is just a very effective placebo effect.

Acupuncture research is a relatively new field, dating back to over 30 years. It was only recently that acupuncture research increased in popularity and funding, though acupuncture has a history of over 3,000 years. Currently, a popular scientific explanation for the mechanism of acupuncture is the "opiate hypothesis" which attributes the effects of acupuncture to the release of endogenous opiates due to needle stimulations.

Yet because of the conflicting views between Western and Eastern perspectives on acupuncture, it has been hard to design experiments that represent both sides fairly. One particularly tricky area is in designing controls for clinical trials. From the Eastern perspective, each acupuncture treatment is individual-based and different patients with the same Western symptoms could be diagnosed differently and given entirely different treatments according to Eastern acupuncture theory. This idea strongly conflicts with the Western ideology of developing standardized treatments in which all patients with the same general symptoms get the same, equivalent treatments. Western science also tends to investigate phenomena by breaking them into core elements, but acupuncture would lose its meaning since it was meant to be taken as a whole according to the Eastern perspective. There is also the presence of skepticism to the idea of acupuncture. Even at MGH, where there are acupuncturists on the anesthesia staff, acupuncture is yet to be recognized as a mainstream medicine.

The future of acupuncture research is bright, with lots of opportunities available since it is a growing, new field with a lot of unchartered territory. Learning about how acupuncture works in the brain can also lead to discoveries and insights into the somatic, central and peripheral nervous systems. It is not uncommon now to see MD students go into research or look into alternative medicines like acupuncture. And for all students, Dr. Napadow gives the advice to keep your options open and not be afraid to pursue the things that interests you when you happen to stumble upon them.

Course A09: Crossword



Across

2. computerized axial tomography scan
5. the Martinos Center is in this town
7. build-up in arteries
8. crystallography is performed on molecules in this phase
9. atmospheric pressure reader
10. Not very basic
11. one can submit grants to the National Institute of Health this many times a year
13. volume picture elements
15. Primary products of the MIT nuclear reactor
18. most commonly used nuclei in NMR are hydrogen-1 and carbon-
21. What uranium is incorporated into (2 words)
22. this has many forms, but can't be used up completely.
24. use this force, luke.
25. don't wear it when you go into an MRI machine
28. electrons flow around a ___ to generate a magnetic field in a given direction
29. Practices acupuncture and does brain research
30. the director of the Martinos Center
32. all nuclei that contain odd numbers of nucleons have an intrinsic ___ moment
33. integral of force
34. the MIT nuclear reactor core chamber pressure, compared to the outside pressure, is ___
35. strokes can be categorized into two types: hemorrhagic and ___
36. the rupture of a vessel wall

Down

1. the H of HST
3. unit of magnetic induction
4. Nuclear reactor reaction
6. what the MIT nuclear reactor sells
9. most focused on organ for MRI
11. bioengineering at MIT
12. neutron-absorbing metal
14. a principal NMR technique
16. 7 is better and stronger than 3 of these
17. shape of nuclear core reactor
19. this kind of magnetic field gives better resolution than low fields
20. radiofrequency
23. electroencephalograph
25. Imaging Technique
26. years that a fuel element in MIT reactor can be operational for
27. signal-to-noise ratio
31. functional Magnetic resonance imaging

Thank You:

Olga Botvinnik, Anna Labno, Alice Chang, Toan Tran-Phu, Troy Rurak, Ke Zhang, Richard Lin, Tiffany Yee, Richard Yau, David Li, and Jennifer Chu would like to extend a most grateful thanks to **Professor Sidney Yip** and **Dr. Bruce Rosen** for being amazing seminar coordinators. Your guidance and advice catalyzed a smooth transition to M.I.T. for all the freshmen in the seminar. We certainly hope you continue the tradition of 22.A09 and allow the future classes to experience what we did.

Of course, none of this would have been possible without the help of **Xin He**, '09. Thank you for always being there with advice, an open ear, and copious amounts of food.

Last, but most certainly not least, we would like to thank all the speakers of 22.A09 for presenting their research, sharing their life stories, and giving us a perspective of M.I.T. that undergraduates rarely see.

Thank You.