Nano is officially ‘in’. It’s the latest craze. Everybody’s talking about it, if not actually doing it. Trying to impress people at cocktail parties, and talk about electronics is getting a bit too stale? [Alright, maybe normal people talk about different things at cocktail parties, but humor me]. Try nano-electronics. Want to elicit oohs and ahhs among your engineering friends as they excitedly describe their research to you? Tell them you do nano-engineering. Sick of pushy parents trying to convince you to become a doctor? Tell them you work in nanoscale medicine. Nanoscale science is, as one clever headline put it, the next not-so-big thing.

Is the hype justified? We at the Triangle say absolutely. It’s pretty hard to find people who sincerely maintain that nanotechnology is a field that will not have a major impact on the science, technology and society of the coming years. It’s just too incredible. In the past decade, nanoscale research has been a major impetus — some would argue, the major impetus — both for the purist, concerned primarily with uncovering the fundamental principles of physical, chemical or biological systems, or the pragmatist, more concerned with translating the fruits of nanotechnology into new and interesting drugs or devices.

Nanotechnology is not something that has developed by degrees, quietly, over time. Nanotechnology is, as we note later on in this issue, a radical, in-your-face, and ultimately perplexing field whose potential is only beginning to be tapped. It has many leaps and bounds ahead of it. And as this issue of the Pennsylvania Triangle tries to convey, Penn is one of the best places to be right now to get involved in the world of the nanoscale.

Break down barriers is not new to us, whether they be those between different departments or between academia and industry itself. It is this tradition of multidisciplinary research and development that manifests itself once again in a field that by its nature cannot be localized — nanotechnology.

Welcome to the Fall 2005 issue of the Pennsylvania Triangle. We hope you find this publication meaningful, interesting, and ultimately, thought-provoking. Whether you are a starry-eyed freshman, new to the University of Pennsylvania; or perhaps a seasoned upperclassman, graduate student, or faculty member, flipping through these pages on College Green, in a lab somewhere, or administering an exam: if you walk away from this magazine having learnt something new, having come across a unique idea you wouldn’t have otherwise thought of, or simply having seen something you already knew in a totally different light — then we will have done our job right. The many, many days (and many more late nights) that have been put in to this publication will have been worth it.
ABOUT THE PENNSYLVANIA TRIANGLE

Editor-in-Chief: Sujit Sankar Datta
Executive Editor: Debbie Chadi
Faculty Advisor: Dr. Noam Lior

Senior Copy Editor: Michael Young
Copy Editors: Leo Chang, Shawn Dimantha, Janice Gunther, Steven Hershman, Hunter Schloss, Easwaran Subbaraman, Sriraman Subbaraman

Senior Design Editor: Tushar Khanna
Production/Graphics: Neeti Bagadiya, Lauren Carelli, Easwaran Subbaraman, Sriraman Subbaraman, Michael Young

Webmaster: Sujit Sankar Datta
Business Manager: Salima Kassam
Marketing Manager: Leo Chang

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Contact Information:
322 Towne Bldg, 220 South 33rd St
Philadelphia, PA 19104
E-mail: PENN.TRIANGLE@GMAIL.COM
HTTP://WWW.PENNTRIANGLE.COM

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The Triangle encourages submissions from students and faculty alike - just visit us on the web or flip to page 40 for details.

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In 1947, scientists at Bell Laboratories invented the transistor: a device which - at the time - no one could possibly imagine would eventually lead to today’s computer processors, automobiles, home heating systems, appliances, traffic control systems, automated banking machines, wireless communications, medical diagnostic devices, manufacturing process lines, air traffic control, weather prediction devices, and many other such devices that are integral parts of our lives. Transistors are everywhere. And now, rumor has it that nanotechnology – a dramatic and largely unpredictable field that is currently at the same point as electronic technology was back in the early 1950’s – is slated to become a similarly ubiquitous part of our lives as well.

So what is nanotechnology?
According to the National Nanotechnology Initiative, “Nanotechnology is the creation of functional materials, devices, and systems with novel properties and functions that are achieved through the control of matter, atom by atom, molecule by molecule or at the macromolecular level.” In fact, nanotechnology involves aspects of chemistry, physics, and virtually all engineering disciplines. Or as the National Science Foundation states, “a revolution has begun in science, engineering and technology, based on the ability to organize, characterize, and manipulate matter systematically at the nanoscale. Far-reaching outcomes for the 21st century are envisioned in both scientific knowledge and a wide range of technologies in most industries, healthcare, conservation of materials and energy, biology, environment and education.” The anticipation of these “far reaching outcomes”, and the expected $1 trillion/year impact on our economy, has put nanotechnology on the national agenda. The Clinton administration inserted nanotechnology research as a line item in the federal budget and the Bush administration has continued the policy such that now represents $900M. Nanotechnology is already making an impact. Current computer hard disk readers achieve high sensitivity with a phenomenon known as ‘giant magneto resistance’ or GMR, which only occurs in sub 100nm metal films. This technology is touted as being the fastest transition from scientific discovery to product, having taken only 8 years – and rightfully so: after all, GMR is one of the reasons that computer storage capacity grew from 1 GByte to more than 60 GBytes so quickly. Applications of nanotechnology also have effects that can be more clearly seen with the naked eye. For example, current traffic control systems are based on light emitting diodes that utilize quantum mechanics to produce brighter and less expensive lights; or alternatively, the newest stain free clothing is based on textiles with nanometer-thick coatings and is being marketed to the public as ‘nanotechnology’. And this is just the tip of the iceberg.

While these examples are physical in nature, nanoscale phenomena are at the core of biological systems and physiological processes. Cell membranes result from molecules assembling themselves into precise structures. Many functions of the human body are facilitated by protein motors, molecules that cause or use mechanical motion. Think of your muscles flexing as an obvious example. The newest nanoscale measurement probes are being used to advance the understanding of basic physiological processes. Taking this a step further, these principles can be utilized and in fact copied to produce nano-sized devices. Imagine communications based on protein circuits or drug delivery systems that interact only with injured tissue. The possibilities are endless.

Get involved
There are a variety of programs through which undergraduate students at Penn can become involved in nanotechnology immediately. SEAS offers a minor in nanotechnology that is designed to fit into the curricula of all engineering and physical science departments and is available to students in all undergraduate schools (see www.nanotech.upenn.edu/Minor_Nanotech.html for details). The minor offers a series of electives that ensure that students become familiar with basic concepts in nanofabrication, size dependent properties of nanostructures, biological nanosystems, and nano devices. The very multidisciplinary nature of nanotechnology requires that these courses come from multiple departments. Here again, Penn is ahead of the curve in that it is one of the very few universities that offer students the opportunity of a formal program in this vibrant new field.

Penn is one of the very few universities that offer students the opportunity of a formal program in this vibrant new field.

In addition to, and in conjunction with, the Nanotechnology Minor, opportunities for undergraduates to undertake research in nanotechnology exist in all engineering and physical science departments, such as summer programs involving research or geared toward educating future generations of nanotechnologists. Quite simply, there are no barriers to getting involved with the exciting world of the nanoscale.

As noted throughout this issue, nanotechnology abounds at Penn. We invite you to try it!
exploring the trail of the nanoscale

At the heart of science lies the passionate drive to uncover truth, to simplify problems, to dig deeper. Reductionism is the idea that the simplest working parts of a system can always adequately describe a complex system. Molecular motors, self-assembling DNA, and protein synthesis are but a few devices that go to explain the dynamic behavior of a cell. Wave particle duality, teleportation, and zero-point energy fluctuations are all strange phenomena in the quantum funniness that underlie all higher complex physical systems. And in our era of information, scientists at Penn are making pioneering breakthroughs in areas that philosophers can only dream about.

“Space is big. You just won’t believe how vastly, hugely, mind-bogglingly big it is. I mean, you may think it’s a long way down the road to the chemist’s, but that’s just peanuts to space.” It doesn’t take a fan of science fiction to know that this quote from Douglas Adams’ The Hitch-Hiker’s Guide to the Galaxy holds plenty of truth. Astronomers estimate that there is roughly the same number of galaxies in the universe as there are stars scattered through our Milky Way. That’s pretty big. For the human brain, it’s just about impossible to get a grasp of how large that number is, or even find another thing in nature that is that numerous. Scientists studying the world of large—the macro-world—ascend into the heavens and observe the multitudinous stars at the very recesses of the universe. One fact you probably don’t know, however, is that the number of stars in the Milky Way is only about half of the number of cells in the adult human body. In this ferocious new world, hordes of autonomous cellular and nanomachines roam around in an environment that significantly differs from the macro-world. The view of nature at the small level—that of the micro, or nano-world—easily rivals the celestial picture in complexity; and delving even deeper, going even smaller only raises more questions and uncovers more possibilities. Nanotechnology has shown people that technology. The educational goal at Penn then is to trace the evolutionary advances of technology as well as to investigate the feasibility of its revolutionary futurist approaches.

Nanotechnology is not simply the province of one discipline; it demands no less than the efficient incorporation of all sciences. Research on DNA is one great example. “As things in the computer world keep getting smaller, they’re reaching the point where top-down approaches—trying to make big things smaller—are hitting the wall,” says New York University chemist, Ned Seeman, who thinks that DNA provides the architecture for all living things. “What we’re trying to do is building from the bottom up—taking little things and making them bigger. And DNA lets you do true 3-D integration.” Erwin Schrödinger said that DNA is the “architect’s plan and builder’s craft in one.” To the materials engineer, the double helix is the highest degree of well-ordered ‘aperiodic solids’ known to man, more perfect under the microscope than the most uniform crystal. To the biochemist, it is the supreme governing molecule—only being a small fraction of the total molecules in the cell—that controls all cellular mechanisms. To the physicist, it is the paragon of orderliness, the gift to living matter that allows it to escape ultimate decay into atomic chaos.

Richard Feynman was the first to envision the possibility of nanoassembly. Richard Feynman’s seminal lecture at Caltech, “There’s Plenty of Room at the Bottom,” in 1961 was the seed of the revolutionary new idea of nanoscale science. At once he saw the centrality of DNA as a first step to understand the underpinnings of physics and life itself: “This fact—that enormous amounts of information can be carried in an exceedingly small space—is, of course, well known to the biologists, and resolves the mystery which existed before we understood all this clearly, of how it could be that, in the tiniest cell, all of the information for the organization of a complex creature such as ourselves can be stored. All this information—whether we have brown eyes, or whether we think at all, or that in the embryo the jawbone should first develop with a little hole in the side so that later a nerve can grow through it—all this information is contained in a very tiny fraction of the cell in the form of long-chain DNA molecules in which approximately 50
atoms are used for one bit of information about the cell.”

“THE MOST EXCITING THING ABOUT NEW APPLICATIONS GOING FORWARD WILL BE THE SURPRISES I CAN NOT PREDICT. THE MOST IMPORTANT THINGS ARE USUALLY THE ONES THAT PEOPLE WITHIN THE INDUSTRY DO NOT SEE. THEY TEND TO DEVELOP OUTSIDE THE INDUSTRY. I DO NOT KNOW. I JUST WAIT TO BE SURPRISED WITH THE NEXT ONE THAT COMES ALONG.” - GORDON E. MOORE

Over the years scientists have unearthed a tremendous stockpile of knowledge about the Book of Nature. Nanotech, though, is an example of a discipline that poses a peculiar problem to scientists in their timeless and keen longing for an all-encompassing understanding of the world. The multifarious branches of knowledge make us feel as though we are now only beginning to acquire a reliable standard, as Erwin Schrödinger put it, “for welding together the sum total of all that is known into a whole. But, on the other hand, it has become next to impossible for a single mind fully to command more than a small specialized portion of it.” Thus, the need for convergence.

The Evolution of an Idea

Nanotechnology is the buzzword that launched the global race to the bottom. The word itself, however, has created a deep polarization in the scientific community virtually unknown to the public, which has mainly sprung from confused language and misdirected arguments. The resolution to this debate, however, is meaningless without first grasping what nanotechnology is. “The definition of nanotechnology has three components,” says Dr. Dawn Bonnell, Director of the Nano-Bio Interface Center at Penn. “One is that you build materials or systems with molecular-level precision. In principle you can build them an atom at a time. Second, what you build takes advantage of properties that are specific to their small size. If you have a big chunk of metal, and you make it smaller, it’s not just a smaller version of the same thing, it actually behaves differently when it passes a certain size. And third, it does something functional.”

To understand the origins of this threefold definition requires a solid foundation in the history behind the concepts, terminologies, and fears of nanotech. Renowned Penn physicist Alan T. “Charlie” Johnson says that nanotech “is a field whose time has come from a physics standpoint.” Specifically, its ancestral roots come from Richard Feynman’s famous lecture in 1961. It gave birth to the iconoclastic possibility for a “physicist to synthesize any chemical substance that the chemist writes down. […] Put the atoms down where the chemist says, and so you make the substance. The problems of chemistry and biology can be greatly helped if our ability to see what we are doing, and to do things on an atomic level, is ultimately developed—a development which I think cannot be avoided.”

Feynman’s vision presents several obvious implications, some of which can be seen by biological parallels. A pioneer in nanotechnology, Nobel prize winner Richard Smalley noted: “Every living thing is made of cells that are chock full of nanomachines… Each one is perfect right down to the last atom.”

In 1986 Eric Drexler coined the term nanotechnology and caught the world’s attention. His book, Engines of Creation: The coming era of nanotechnology, convinced the public that building nanomachines was possible, as we ourselves as human beings are living proof that cellular machines are workable. He wrote in his treatise, “We have come far in our atom arranging, from chipping flint for arrowheads to machining aluminum for spaceships. We take pride in our technology with our lifesaving drugs and desktop computers. Yet our spacecraft are still crude, our computers are still stupid, and the molecules in our tissues still slide into disorder […] For all our advances in arranging atoms, we still use primitive methods. With our present technology, we are still forced to handle atoms in unruly herds.” True nanotechnology, according to Drexler, is a molecular technology, not a bulk technology.

Driven by the charismatic personalities of Feynman and Drexler, the excitement behind the buzzword nanotechnology has started a trend. The prestige of the term is tremendous; or as Richard Smalley puts it, “The combination of high -tech gee whiz, high social impact, and economic good sense gives the dream of nanotechnology the ability to inspire out nation’s youth toward science unlike any event since Sputnik.” The Philadelphia Inquirer reported that within a decade, nanotechnology’s global economic impact, now worth about $13 billion, could grow to $2.6 trillion as it upgrades everyday products, transforms electronics and makes inroads into medicine.

A diversity of talent, heterogeneous environments, and daring new ideas from people around the globe will be the lifeblood of nanotechnology if it is to be a successful venture. As Dr. David Luzzi – a professor in the materials science department here at Penn – notes, “we’re really at a tipping point, where all the pieces are in place to allow for an explosion of technological development.” Relevant scientific pieces of the larger multidisciplinary puzzle are scattered all throughout the bioengineering, chemistry, materials science, physics, and electrical engineering realms, just waiting for the savvy scientist or entrepreneur to realize them. There has never been a better time to put them together.
Five years ago in the still budding days of the technology boom, Bill Clinton created the National Nanotechnology Initiative, a federal program that gave a general disbursement of $1 billion to the National Science Foundation (NSF). More important than money though, the establishment of the initiative gave credibility to the emerging field, which all too often suffered from hype and hyperbole thanks in large part to science fiction and market speculation.

Cars, computer chips, and unbreakable golf balls made with new materials engineered down to the scale of individual atoms. With so much attention on commercial applications and other possibilities of nanotechnology, it's easy to overlook the seminal role of research centers, where laboratory interests fuel progress in the field. The University of Pennsylvania looks to play a key role in the nanotech revolution with its state-of-the-art research facilities and connections to industries.

The Laboratory for Research on the Structure of Matter

At the northeast corner of 33rd and Walnut Street sits the Laboratory for Research on the Structure of Matter (LRSM) – an unassuming building that houses the crux of Penn's nanotech facilities, such as the high-tech Shared Experimental Facilities. These shared facilities are used for research work in materials science, nanotechnology, and complementary interdisciplinary exploration. The Polymer Characterization Facility is an example, with a light scattering detector, thermal analysis equipment, and other instruments to analyze various properties of polymers.

LRSM was founded 45 years ago as a unique materials research laboratory. The heart of the research program at LRSM is the Materials Research Science and Engineering Center (MRSEC), established by Penn funding and a grant from the National Science Foundation (NSF). MRSEC supports research involving Penn faculty from the departments of physics, chemistry, materials science, chemical engineering, biophysics and biochemistry. A special focus of this research is on soft materials.

Research at the LRSM is aimed at solving materials problems, as well as developing new materials such as synthetic proteins and carbon fibers with unmatched strength. These new materials could radically change products for consumers and industrial use. For example, major research at the LRSM in microscale soft materials could lead to applications with sensors or switches, both for consumers and for the communications industry. What’s more, research in multifunctional complex oxides explores new materials sensitive to stress and responsive to external electric and magnetic fields. In 2000, the LRSM was granted $17 million by the NSF, which has supported it for 33 years. This MRSEC grant placed LRSM among the very top centers in the country in terms of NSF support.

With this strength in materials, Penn established the Materials Characterization Facility in 1997, which two years ago was renamed the Penn Regional Nanotechnology Facility (PRNF). Dr. Doug Yates, Technical Director of the facility explains, “Penn Nanotech was established to provide nanoscale characterization and fabrication to the Penn community.” This core facility of the LRSM combines Electron Microscopy and Ion Scattering labs with an Atomic Force Microscopy lab. The latter is a favorite among many students who tour the facility, where an atomic force microscopy instrument allows you to manipulate individual atoms and write your name on the nanometer scale! Take a step back and consider that this one capability of using individual atoms to produce a desired structure is itself a huge step towards achieving nanotechnology-based goods for production.

PRNF has a range of tools that make the molecular world visible. Scanning and transmission electron microscopes offer resolutions on increasingly smaller levels. Other tools allow for imaging nanoscale materials, which Dr. Yates describes as “having dimensions or features smaller than 100 nanometers.” For perspective, if you considered a piece of your hair as the Leaning Tower of Pisa, such a nanoscale feature might be the size of a slice of thin-crust pizza.

The materials analyzed at the PRNF include polymers, ceramics, metals, and composites (materials made up of multiple constituents). Samples of materials can be prepared using a variety of techniques such as Ion Beam Thinning, where a focused ion beam images and selectively etches material as required to render a desired sample. Plus you can monitor this material removal as it happens! “Materials research has been increasingly focused on smaller particles and this facility provides a means to study these materials,” notes Dr. Yates.
The Move Towards Interdisciplinary Research – The Nano/Bio Interface Center

Nanotech’s potential is best considered as a merging of different areas of engineering with the natural sciences. For example, new high-tech microscopes such as the ones found in the Penn Nanotech facility use the laws of physics to operate. Scaling down to widths of 20 nanometers brings in problems of unruly physics and tricky quantum effects as well. Arranging atoms and achieving desired structures brings chemistry to play. Nanotechnology is blurring the boundaries separating the areas of science.

To bring this interdisciplinary endeavor to fruition requires collaboration between physicists, chemists, biomedical researchers, and engineers. Consequently, Penn Engineering established the Center for Science and Engineering of Nanoscale Systems (SENS) about four years ago. This center promoted interdisciplinary research based around nanoscale phenomena, and sponsored educational efforts in nanotechnology including seminars for Penn and the community.

SENS bought together Penn faculty from multiple departments, serving as a muster station for these experts of different fields and allowing them a medium to swap ideas and discuss their projects. Nanotech research was no longer being done solely within the bounds of a particular department’s scientific briefs. The center exemplified nanotech’s growing focus that included single molecule mechanics, nano fluids, molecular electronics, and medicine. SENS formed the core of Penn’s nanotechnology efforts.

About one year ago, Penn’s nanotech efforts were given a shot in the arm by a five-year grant of $11.4 million, renewable to $23 million, when the NSF named Penn as one of six new Nanoscale Science and Engineering Centers (NSEC), adding to the eight that have been created since 2001 by the NSF. Other universities receiving similarly prestigious NSEC grants include Stanford University, University of Wisconsin, Ohio State University, Northeastern University, and the University of California, Berkeley.

Dr. Dawn Bonnell, professor of Materials Science and the Center’s director, explains the center’s focus: “We will combine biological principles, molecular synthesis expertise from the School of Medicine, theory from the Physics Department, and developments from chemistry and engineering—like single-molecule probes—to control and study molecular motion.” She commented, “We have a history of inventing some of these technologies. With this center, we will be able to incubate more of these.

Currently housed in the Laboratory for Research on the Structure of Matter (LRSM), NSEC will eventually have its own specialized building, with plans to develop two shared facilities—a distinctive NanoProperties Lab and a Molecular Interface Nanofabrication Lab. The former, when ready, will provide an incubator for explorations in nanostructure behavior, and encourage probe development. It will become a significant resource for analysis of single molecules. The latter will house a large collection of tools, such as lithography and nanoimprinting facilities, for designing structures and modeling interfaces on the nanometer scale. There will be means to combine, purify and pattern nanostructures such as proteins.

As with any new technology, a significant development will be the shaping of a system of ethical principles to govern the appropriate use of the new abilities. Consider that the ability to put together atoms to create new, specific and synthetic structures could lead to results that are neither planned nor wanted. Furthermore, mull over fears of self-replicating nano-robots running amok. A nanotech pioneer once coined the term ‘grey goo’ to refer to a hypothetical situation where nano-robots would replicate beyond our control and consume all life on Earth, which should be enough to alarm any nanotech novice.

Dr. Bonnell maintains a close partnership along with the Penn’s Center for Bioethics to “lead the national discussion on the ethical considerations surrounding nanoscale science and its potential impact on humanity.” Accordingly, the NBIC plans to address such concerns as it becomes a hub for nanoeconomics and nanotech education for the general public. Look out for discussions led by some of Penn’s distinguished bioethics professors, as the NBIC works with the Center for Bioethics at Penn to tackle ethical issues and discuss potential influences of nanoscience.
The NBIC will also work with the School District of Philadelphia to help bring the exciting forefronts of research to high schools. The center will maintain nanotech education at Penn, supporting the Doctor Certificate program in Nanotechnology, and the Minor in Nanotechnology for undergraduates. The Engineering School introduced the nanotechnology minor to the Penn curriculum in Fall 2003, which requires a multidisciplinary course load of two required classes and four electives. Students who want to get involved in nanotechnology can take Professor Karen Winey's popular class “Introduction to Nanotechnology,” which focuses on the particular applications of the emerging field. In addition to these two programs, undergraduates and graduate students from across the University established the Penn Nanotechnology Professional Group, a student-run extracurricular club started up after the announcement of the “Introduction to Nanotechnology” class and minor.

Collaborations between the NBIC and other principal nanotech initiatives will include work with The Center for Integrated Nanotechnologies of Los Alamos National Laboratories, The Technical University of Dresden in Germany, and nearby Drexel University.

**Bridging the Gap Between Academia and Industry – The Nanotechnology Institute**

These research centers are located on Walnut Street at the eastern end of the Penn campus, between the heart of campus and the businesses of center city, typifying how these centers form an avenue that will transform laboratory findings towards applications for the marketplace. This ‘avenue’ is better represented by the NanoTechnology Institute (NTI).

The NTI is co-directed by Dr. David E. Luzzi, from the University of Pennsylvania, and Dr. Kambiz Pourrezaei, from Drexel University. “With nanotechnology, we seek to emulate the natural world, where millions of years of evolution have worked to maximize efficiency while minimizing waste,” says Dr. Luzzi. “In humans and other animals, a couple of cells give rise to an amazingly diverse array of tissues and organs. Similarly, nanotechnology seeks ways for single atoms to assemble themselves into complex structures.”

Created by a $10.5 million grant from the commonwealth’s Pennsylvania Technology Investment Authority (PTIA), the new Regional Nanotechnology Center (renamed the Nanotechnology Institute aims to reinvent the Delaware Valley as a high-tech hotbed coined “nanotech valley” – a collaboration between industry and academia akin to what Stanford University did for Silicon Valley in the 1950’s. The institute will help create additional incentives for research and development, focusing energy on emerging innovations that will be useful to local companies, facilitating the transition between academic discoveries and industrial applications. This will help bridge the economic gaps between scientific understanding, technological application, and product commercialization, and will mark the region as a nanotech breeding ground, paving the way for the next era of products and jobs.

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**Research at the Nano-Bio Interface Center: An Overview**

Research at the NBIC is structured around two major themes (Biomolecular Optical Function and Molecular Motion) and two cross-cutting initiatives (Single Molecule Probes and Ethics of Nanotechnology). The experimental facilities (The Molecular/Nanostructure Innovation Lab) will be a national resource for single molecule probes.

**Biomolecular Optoelectronics**

A unique (and essential) feature that characterizes the NBIC is its focus on interdisciplinary work, and coordinated collaborations amongst multiple faculty members spanning many different departments. For example, in the Biomolecular Optoelectronic Function Group, a new lithography process recently developed in the materials science department here at Penn - Ferroelectric Nanolithography - can be used to produce complex patterns of nanostructures. Researchers in the chemistry department use this to synthesize molecules with the most extreme optical properties produced to date, which are then incorporated into peptides (simple proteins) in the biophysics department. Physicists and materials scientists study the materials of these individual molecules and are currently working towards incorporating these into complex structures.

**Molecular Motion**

Molecular motion is being examined at the single molecule level by researchers in the physiology dept who use polarization resolved near field optical reflectance to watch motor proteins walk along fibers. Together with mechanical engineers and materials scientists, microfluidic channels are being used to control local chemical environments and surfaces are being tailored to control the molecular motion.
The Future of Nanotechnology at Penn

The NIH granted $9.5 million to Penn recently as a part of the National Screening Network to discover active molecules. This money will go to create the Penn Center of Molecular Discovery for the next three years. The privilege of receiving this NIH grant is that Penn will be able to access readily the immense electronic repository of chemicals held by the NIH, a database that will be soon open to the public.

Private institutions like Penn are becoming more active in ultimately determining future academic and commercial successes resulting from nanotechnology.

Dr. Amos Smith, a professor in the chemistry department, currently leads trailblazing research in the fields of biology, medical imaging, and pharmacology. His excitement for the project is clear, noting that “in time, these exciting new molecules with known biological activities will be a mouse-click away for chemists, biologists and drug designers to use, all supported by an extensive database.”

The Center for Molecular Discovery will be a part of the Institute for Medicine and Engineering. Yet another truly multidisciplinary endeavor, the Center will draw from talent pools in the Engineering School, the School of Medicine, and the Penn’s department of chemistry from the School of Arts and Sciences. As Dr. Scott Diamond, director of the new center as well as a professor in the department of chemical and biomolecular engineering, notes, “small molecules come in an astronomically large variety of shapes and sizes that dwarfs the number of genes in the human genome. Finding the important ones within the NIH repository is a classic needle-in-the-haystack challenge.”

Armed with a new Center for Science and Engineering of Nanoscale Systems and the Penn Center for Molecular Discovery, Penn will undoubtedly emerge as a nanotech research leader, and Philadelphia its node of innovation. Nevertheless, the public should not get too carried away with nanotech’s possibilities. History of science scholars will often compare the emerging field of nanotech to the development of the transistor fifty years ago. It took decades for the semiconductor industry to finally generate a practical benefit to the market. “Nanobusinesses” may very well follow the same measured growth trajectory, so investors will be prudent to adapt an attitude of patience. As of 2005, the primary driving force for innovation in nanotechnology in the US is the federal government. The speculative and whimsical capitalist bazaar is still no match for the government’s deep pockets and long-term outlook.

Although the overall annual federal funding for nanotech in the US has

Single Molecule Probes

There are those who believe that the nanotechnology era began with the invention of the scanning tunneling microscope by Binnig and Rohrer in 1986. This was the first time that atoms and molecules could be imaged in real space, picked up individually and moved around, and that their properties could be locally determined. It is difficult to overstate the excitement in each of the labs around the world as research groups ‘saw’ atoms for the first time. This instrument technology itself represents a small part of the field, but opened a window that enables scientists and engineers to imagine new horizons in nanoscale behavior.

The original invention represented a platform upon which an entire class of probes has developed that access electrical, chemical, optical, magnetic, and thermal properties. Of course these are not the only tools available for characterization. Electron microscopy, a variety of scattering tools (based on x-rays, neutrons, and ions), optical microscopy with fluorescent labels, etc., are also brought to bear on nanostructures. In spite of these advances, one of the real challenges in understanding and exploiting nanostructures is the ability to measure properties of individual molecules. Penn faculty across the campus have been pushing the limits of molecular and nanostructural probes. The NBIC is building a Molecular/Nanostructure Innovation Probe Facility to house the newest inventions in small scale measurements. The facility will be located in the Edison Building on Walnut and 33rd until the new nanotechnology building is constructed.

Ethics of Nanotechnology

Any new technology raises questions about when, where, how, and even if it should be introduced into society. Nanotechnology is not different in this regard. We can think of nanotechnology as divided into advances that are evolutionary or revolutionary. Evolutionary changes arise from the continued improvement of a current technology, as for example when particles used in paint are made smaller to improve optical properties. Revolutionary technologies introduce a new paradigm that overturns current solutions, as would quantum computing should it ever become a reality. Ethical issues surrounding evolutionary technologies are likely already considered in existing societal structures. Ethical issues arising from revolutionary nanotechnologies are not. It is critical to examine these issues and come to consensus at early stages in the development of the field. These studies are an integral part of NBIC activities.
successful academic discoveries with progress towards eventual commercial products. In fact earlier this year, Nanomix introduced its first product—chemical sensors made of carbon nanotubes for use in medicine and industry. NanoOpto CEO Barry Weinbaum says in TechReview that the rise in nano-deals reflects how nanotech companies are slowly maturing into real businesses, shipping real products, generating real revenues.

Nanotechnologists are sometimes labeled as ‘contemporary alchemists.’ It wouldn’t be far fetched to compare nanotechnology to alchemy, though that is not to say that the potential of nanotechnology is scientifically outrageous. The heart of this analogy lies in the wondrous and far-reaching prospects of nanotechnology, much like those of alchemy. Nanotechnology won’t turn base metals into gold or discover life-prolonging elixirs, but it will transform the future of materials and have profound impact on medicine. While alchemists worked in rooms lit by lamps, Penn’s contemporary alchemists are conducting nanotech-related research in state-of-the-art laboratories with advanced instrumentation.

The impending impact that nanotech research will have everywhere is mind-boggling. Yet take comfort and pleasure in knowing that Penn is set with key research centers for doing much to realize prospects of nanotechnology, in what could really turn out to be among the greatest accomplishments in science and engineering.

Throughout time, scientific and technological advancement have served as the catalyst for societal change. From the printing press to the personal computer, technology and the science behind it have altered the very fabric of our lives. Very rarely, however, has a technology come along that has threatened to change almost every single facet of our lives. Nanotechnology promises exactly that. And as history has proven, all technologies can be used for ill as well as for good.

Speculators worry, for example, that nanotechnology may go haywire and lead to the inevitable destruction of society, through uncontrolled release of “nanoparticles” in the air, or by an unstoppable proliferation of “nano-robots” or nanites that would eventually cover the Earth in “grey goo”. Many scientists and engineers in the field of nanotechnology today dismiss such possibilities - that nanocreations may have uncontrollable, and potentially drastic effects - as being mere worries to be dealt with in the future.

If we are to adopt and accept nanotechnology as a field that will revolutionize science, technology, and society, then we must be willing to pay as much attention to its ethical implications as we do to the actual science itself.

Too frequently for comfort, scientists and engineers working in nanotechnology choose to ignore the societal implications of the field.

But this will get us nowhere. If we are to adopt and accept nanotechnology as a field that will revolutionize science, technology, and society, then we must be willing to pay as much attention to its ethical implications as we do to the actual science itself.

The important thing in all of this is to recognize that nanotechnology is still taking its first steps as an enfant science, and as its caretakers we must be very careful about how it progresses. Too little control and we may lose the science to those who wish to abuse it, a process that could very well lead to catastrophic results. Too much control and we stifle what could be the most revolutionary science of the 21st century, something that has the potential to change almost every facet of our lives.

is premature. But Caplan can already identify several emerging ethical issues, and there are likely to be more. The best way to identify them and perhaps shape their outcome, he says, is to work closely with the people who are pushing the technology forward.”

It is important that in these early stages the growth of nanotechnology is supported not only by government research grants, but also by young engineers willing to take a chance and explore the new field. It is also important that society does not give in to fear and reject nanotechnology, but instead simply treads carefully, much as it has through the ages.

Indeed, the path to nanotechnology may very well be a careful tiptoe through a mine-field instead of a stroll down easy street, but that’s never stopped scientists before. Cliché as it may sound, armed with the fresh and capable minds of our generation of scientists and engineers to push the revolution forward, what was once thought to be impossible may soon very well become a reality.

Dr. Arthur Caplan, Director of the Center for Bioethics at the University of Pennsylvania, is one of those scientists who have recognized the importance of addressing nanotech’s ethical quandaries now rather than later.

Samuel Moore, who wrote an article in an IEEE publication about Caplan’s views on nanotech explains, “Since there are precious few nanotechnology-based products on the market or even in late-stage development, it might seem that having an ethical discussion about them
Alan T. ‘Charlie’ Johnson came to Penn in 1994, and has been making enormous strides in the fields of nanotechnology and condensed-matter physics since then. A native of Massachusetts, Prof. Johnson received his bachelor’s degree in physics from Stanford University in 1984, his Ph.D. from Harvard University in 1990, and was a postdoctoral fellow at Delft University of Technology and the National Institute for Standards and Technology before coming to the University of Pennsylvania. Prof. Johnson recently sat down with the Pennsylvania Triangle’s editor-in-chief Sujit S. Datta and talked to him about his research in carbon nanotube electronics, the interdisciplinary nature of nanotechnology, quantum computing, and the secret to good teaching.

PT: What are the main areas of your research, and what are your future directions?

CJ: My group has a lot of work going on in the science, physics and applications of carbon nanotubes, particularly in electrical devices but also in their optical applications. We are mostly focused on molecular electronics, so we look at nanotubes as molecular electronic objects; and we also have a newer project, which is based on looking at the opto-electronic properties of single molecules, in particular proteins and other molecules that are related to proteins. For the protein project, all the chemical synthesis is being done at Penn, as part of the work done in the NBIC [Nano-Bio Interface Center].

“Over time, it became clear that the next step in small electronics was to look at things that were like molecules.”

I would say that the nanotube stuff has been around a while – we’ve been doing it for almost 10 years. The single protein work is much newer, we’ve only been doing it for a year or two, and for the next four or five years that’s where I see my group working, on both those fronts. Over time, I expect the nanotube work will become a little more applied, because I think it’s more closely connected to doing something useful, while the single molecule will be more on the basic science end. Maybe over the course of time, say in five or ten years, we’ll start looking at possible applications of the molecular electronics.

PT: Were you doing this as an undergraduate or graduate student? How did you get involved in this, and what were you doing before that?

CJ: I have always been working on the electronics of small things. When I was a graduate student, I worked on the electronic properties of small superconducting devices – so no molecules; these were made out of little bits of metal. Then as a postdoctoral fellow I started to work on the properties of small semiconducting devices. I worked on a system called a two-dimensional electron gas, which is in gallium arsenide; so it’s connected to the semiconductor world.

When I came to Penn, I planned on continuing in the area of gallium arsenide, and we worked on that for a while; but you really need a lot of infrastructure to work in that area. I was the only person at Penn working on this. And over time, it became clear that the next step in small electronics was to look at things that were like molecules. A carbon nanotube is a little bit like a molecule, but maybe not exactly like one – they’re almost intermediate.

In fact, we started working with carbon nanotubes because Jack Fischer, who is in the Materials Science department - who had never met me - heard from some physicists that I could make small electrical devices. So one day, he came into my office and dropped a vial of black soot on my desk and said, “You should be interested in this.” And those were carbon nanotubes, the first ones that I had ever seen. That was late 1995, 1996; and Rick Smalley’s group [at Rice University] had just produced large quantities of single walled carbon nanotubes - it was material from his group that Jack had given me. So it became clear to me that this would be another way to make very small electrical circuits; and it was new, and exciting, and we had the opportunity to be one of the first groups working in the area of single nanotube electronics. So we decided to move in that direction.

In fact, the first year and a half of my very first graduate student’s research was on two-dimensional electron gases – but when he finished, his Ph.D. thesis was about his work on carbon nanotubes.
PT: So if nanotubes are just an extension of small electronic systems, why the peptides and proteins?

CJ: On some level we started off working on things that were more like the silicon industry’s ‘top-down’ systems; however, you could say that carbon nanotubes are not really molecules. They’re very close to being molecules – you could argue about it. But proteins really are molecules.

The other thing about proteins which I find intriguing, and which isn’t characteristic of nanotubes, is that they’re much more complicated. A nanotube is a geometrically perfect structure – they are all carbon, all bonded in exactly the same way, except for maybe the ends. You could imagine trying to make nanotubes more complicated, but in general, that’s how they are. Protein molecules, on the other hand, are extremely complicated. They have an amino acid backbone which is like an electrical insulator; and then they have incorporated into that, held into position by that scaffold, other molecular groups which can perform other functions. They can have optical absorption; they can have ‘free’ electrons living on them, which can then tunnel from one location to another.

So an individual protein molecule is in fact much more complicated than a nanotube; and now we’re ready to begin working on these much more complicated systems than nanotubes – even though we think nanotubes are still very interesting and potentially very useful.

PT: Let’s talk about nanotechnology for a bit, then. How has the field of nanotechnology grown and progressed over the years, and what role does Penn play with regard to it?

CJ: First of all, it’s just an enormous field – you’d probably have trouble getting two people to agree on exactly what it is. It’s very broad, and so it encompasses everything from the physics department, to the chemistry department, to many parts of the engineering school. Eventually I think we’re going to interact more strongly with the biology department and the medical school.

Penn is one of the leading institutions in nanotechnology. If you look at what’s
happening on campus that’s part of the ‘nano-initiative’, it’s a tremendous amount. More and more people are realizing that this is what they’re interested in. Many different aspects of science, engineering, and soon medicine, are converging at the molecular scale. I think it’s fair to say that in 1994, for example, the number of people at Penn who would’ve said they were working in nanoscience, or nano-scale systems, was incredibly small. It might’ve been, say, three. Very tiny. But now, we see that this is becoming an increasingly important part of the physical sciences, and what you might call the physical and the biological part of the physical sciences, and what you might call the physical and the biological side of engineering – materials science, electrical and systems engineering, mechanical engineering, and bioengineering.

CJ: This is a very dangerous question – it’s quite likely that I’ll be completely wrong! Most of the basic sciences, and most of the engineering that's focused on what you might call “the physical layer” are being pulled into this. I think you’re going to see more and more from higher up on the ‘foodchain’ - from more systems-oriented people, resulting first in integrated systems of individual circuits, but then systems and whole networks of devices based on nanoscale technologies.

I think we could generate some very strong groups around the idea of sensors and networked sensors, and eventually couple with the GRASP [General Robotics, Automation, Sensing and Perception] lab and their robots. We have a lot of strength in that area.

If [nanotechnology] is what you’re interested in, I say get in there, get your hands dirty, and really do the research yourself. Just figure out what department, what person, and try to make it happen.

So how did this develop? Here at Penn, it has been a “grass roots” process where faculty have chosen to come together to work on problems of common interest. We influence each other’s research development, and if things go well, we move towards more dynamic and influential research areas. Penn is a natural place for this because we have a very long history of interdisciplinary research. It’s much longer than I’ve been here, so to me, it’s a sort of “historical mythology” – it’s the stories of what happened here long before I arrived.

The LRSM has been an interdisciplinary institute since its inception around forty years ago, and interdisciplinary work is the heart of nanotechnology. So it’s natural that we would embrace it, which we have; it’s natural that we would take on a leadership role, and we have - for example, one of the areas where we are focused is at the nano-bio interface, with the inception of the new NBIC.

PT: So where do we go from here? How do you think nanotech at Penn is going to develop after the NBIC?

CJ: By nanotechnology in computing, I mean something that we’re doing having an impact in the field of computing. So quantum computing would be one way in which this might happen. We have a little bit of work going on in that field at Penn, but it’s not what you would call a real focus here. But maybe someone will show a practical application of quantum computing, by which I mean really having a quantum computer that improves on what one can do with conventional computing technology.

Similarly, you might say to yourself (and people do think about this): could I replace parts of a microprocessor with nanotubes? Quantum computing on one hand would say, forget about the microprocessor – let’s do away with it and approach this in another way, using quantum “q-bits” instead of classical bits. Another strategy would be, let me make my existing microprocessor better.

So what do you have in there? You’ve got semiconductors, and you’ve got metals. By some measures, a semiconducting nanotube is a much better semiconductor than those in a microprocessor; by other measures, a metallic nanotube is a much better metal than the copper that you have in your microprocessor. So if you could just replace them all, it would work better.

The trouble is that just replacing them all is an extremely difficult task, because there are hundreds of millions of them, all in exactly the right spot. This is really what makes it difficult to have an impact in high-end computing (like what’s in a laptop). Nanotubes may be useful in schemes for computation on non-traditional substrates. For example, why not have an integrated circuit built right into clothing or embedded in a transparent plastic windshield?
At Penn, we don’t have that many people working in the part of nanotechnology that might impact computing. But there’s a huge amount to gain in all those other areas – sensing, treatment, medical diagnosis… there are a lot of ways we can improve and build on the research strengths that already exist.

PT: So how can undergraduates - who are not directly thrown into this - how can they tap into the nanotech revolution here at Penn?

CJ: There are many mechanisms by which students who are really interested can get involved in research. Already, there is huge amount of it going on. If that’s what you’re interested in, I say get in there, get your hands dirty, and really do the research yourself. Just figure out what department, what person, and try to make it happen. For example, the engineering school has these senior design projects, which are a good opportunity for students to do work on a problem and have an impact.

These opportunities do demand a lot of the students who get involved with them, they’re not as simple as picking up a book and reading it for a few hours and feeling like you really did something – they require a significant time and energy commitment.

Then of course, you also just want to be informed about what’s happening, what the basic ideas are that people have in this field. There are a growing number of classes that address various aspects of nanotechnology and nanoscale science. There’s a nanotechnology minor in the engineering school which looks to me like a very strong program.

Here at Penn, we don’t have a separate department of nanoscale science or engineering, and I doubt we will anytime soon. We think that nanoscale science and nanoscale engineering is work that’s at the interface of two or more existing disciplines. It’s not really a separate discipline.

PT: Speaking of classes, then - in addition to your research, you also actively teach, and students consistently know you as being one of the best instructors in the Physics department, and the university as a whole. What is your secret?

CJ: I can’t tell you my secret, because then I’d have to kill you, right? [Laughs]. I really don’t know; I think that everybody who teaches has to somehow connect to the students and motivate them in their own way. We have excellent students here, both undergraduate and graduate students. For the undergraduates, I find the biggest challenge is to get their attention. If they pay attention, and if they’re interested in a class, and if we select a textbook and material that is appropriate, then they will learn a lot and they can make themselves excited about what they are doing.

My goal is to try to make people feel interested in what we’re doing. Physics is an interesting subject – at least, I believe so – I’ve spent my whole adult life working on it, so all I want to do is convey some of that interest and excitement. I realize that not everybody is going to think that Physics is the most interesting thing, and that’s not what I’m aiming for – I just want them to think it’s a bit more interesting than they expected. I find that if I have that attitude, then good things happen on their own.

PT: So then to wrap up with one more question - on top of your research and teaching, you also recently became the proud father of a baby girl. What do you do to balance all these different aspects of your life?

CJ: Well, they’re completely not balanced right now! [Laughs]…because she’s only two weeks old! I think this is a challenge for everybody, and if you spoke to some of our women faculty you’d find that it’s even more of a challenge. But for me, it’s decide what’s important, decide what you can do that nobody else around can do – you have to pick and choose things to do. Do the things in which you’ll have the biggest impact that not anyone else can do, that somehow can leverage your own individual strengths. But in terms of balancing things, I’ll have to let you know.

Image information: The image on this page is a graphic rendering of a micron-scale functional electronic circuit made of carbon nanotubes. This is based on a recent paper, “Electronic Devices Based on Purified Carbon Nanotubes Grown By High Pressure Decomposition of Carbon Monoxide” - to be published in Nature Materials - resulting from a collaboration between Prof. Johnson and Prof. Arjun Yodh, also from Penn’s Physics department.
**Proteins are pervasive throughout the cell.** Enzymes that catalyze chemical reactions, ion channels that allow the passage of important ions, and repressors and activators of DNA that control which genes are expressed and which are turned “off” are all proteins. By making subtle changes in the amino acid sequence of a protein, scientists are able to make molecules that are more stable when subjected to high temperatures and harsh chemicals. Down the road, a better understanding of proteins will enable us to interfere with proteins involved in virus growth and replication and to disrupt vital processes in bacteria with medications that are nontoxic to humans. Since gene expression is essentially a method of turning on and off the synthesis of certain proteins, we may also be able to correct for harmful mutations in the genetic code through a better understanding of biological proteins.

Hence, protein design has an enormous range of applications, from the development of novel therapeutics to new materials and nanoscale systems. While protein design can be done experimentally, the use of computers greatly speeds up the search. This method of designing novel proteins aided by computer algorithms is called computational protein design, with the goal of designing stable, well-folded proteins with novel sequences that mirror a design target’s structure using methods that are both fast and accurate.

Techniques geared toward the creation of general design algorithms are being developed by many laboratories across the world, both in academia and in industry. These include the computational biophysics labs within the School Of Medicine at the University of Pennsylvania. Dr. William DeGrado, the director of one of these labs, originally coined the phrase de novo protein design, which is “the construction of a protein, intended to fold into a precisely defined 3-dimensional structure, with a sequence that is not directly related to that of any natural proteins.”

In de novo protein design, one often starts with a desired backbone conformation, a shape for the protein's ultimate tertiary structure. All twenty naturally occurring amino acids, or residues, have the same components: a central carbon atom to which is attached a carboxyl group (COOH), an amino group (NH₂) and a hydrogen atom; it is the side chains attached to the central carbon atom that differ among the residues. Given a fixed backbone, an enormous number of amino acid side chain combinations are then considered for the sequence that will fold in the desired manner.

In attempting to solve the structure, scientists are often unsure if a given backbone will be designable. Therefore, they sometimes allow their computer algorithms to consider a range of similar backbones, for which they alter each backbone position by a few degrees. This is called considering a flexible backbone, as opposed to a rigid backbone.

A major concern in de novo design and protein design in general, is conformational specificity, or the ability of a protein to fold into a unique three-dimensional structure. There are four levels at which conformational specificity is apparent.

First, the designed protein must have the correct oligomeric state; for instance, if the target protein is a tetramer, the designed protein must also be a tetramer.

Next, the folds and topology (i.e., clockwise or counterclockwise turns) of the protein must be preserved. Topology is important because the interactions between two clockwise interfaces, such as two helices, will differ from the interfacial interactions in their counter-clockwise correlates.

Third, the orientation of elements of secondary structure (i.e., alpha helices, beta barrels) must be observed. Thus, a shift in the relative location of an element of secondary structure with respect to the target protein violates conformational specificity. Finally, side chains in the core of the protein must be packed favorably, or in the minimum energy conformation. In thermodynamic terms, a stable designed protein must have a large free energy gap between the native state of the protein and the various non-native folded and partially folded states. A lack of conformational specificity can spell disaster; a single Glu-to-Val mutation on the surface of the protein hemoglobin, for example, will change the correct oligomeric state, resulting in sickle cell anemia. According to a review by Blake et al., “a single well-designed loop can stabilize a protein by several kilocalories per mole relative to a randomly chosen or poorly designed sequence.” Besides thermodynamic stability, kinetic foldability, or the ability to fold reversibly on a timescale comparable to that of natural proteins, is also important. For most proteins this means anywhere from microseconds to minutes.

In order to ensure a large free energy gap between folded and partially folded
states which may be similar to the folded structure, some algorithms include information about competing structures explicitly in the sequence design structure. This process, which considers not only the energy of the designed protein but also the energies of similar, partially folded states, is known as “negative design.” The group of Jin et al. used this method successfully to design a three-helix bundle. They compared the size of energy fluctuations among denatured states of the protein relative to the difference between the energy of the denatured states and the target in order to find a protein that would possess the required free energy gap.

Negative design is especially useful in the design of protein-protein interfaces, for which specific interactions between residues of nearby proteins play an important role in the overall structure of the protein.

In protein design, energy function optimization is another method used to find the optimal sequence for a given backbone. This method looks for low-energy sequences by minimizing a carefully weighted and parameterized energy function. In general, the energy function includes standard terms associated with molecular mechanics potentials and database-derived propensities, with reference energies for each amino acid. One of the potential functions that may be included is pairwise interaction energies, the energy differences that occur when two atoms interact, a term derived from the probability of the atoms interacting.

Other energy potential functions that are often used include electrostatics, van der Waals forces, hydrogen bonding, and solvation terms. Hydrogen bonding occurs frequently in proteins and correct modeling of these interactions is important in designing functional sequences. Solvation is the role of the solvent and its interaction with the protein. Incorporating the protein-solvent interaction is very difficult because determining the configuration of a solvent for each attempted sequence is time-consuming. Therefore, scientists often make crude approximations.

Statistical design methods, which are alternatives to sequence search methods, involve estimating the site-specific probabilities of amino acids in sequences that are structurally consistent with the target structure. Structural consistency is quantified by energy functions that address rotamer-rotamer, rotamer-backbone, and rotamer-solvent interactions for specific atoms.

Constraints may be added to limit the combinations that undergo consideration. For example, the residues in a solvent-exposed region of an aqueous protein may be limited to only polar residues, and certain residues will not be considered because of stereochemical considerations (i.e., because they would not fit in the space available). The most likely set of amino acid probabilities are those which maximize an effective entropy function.

The main problem that scientists face when cycling through various combinations of amino acids is the torsional flexibility of amino acid side chains which allow a discrete set of conformations, called rotamers. The number of rotamers that the amino acids can form is around $1.9 \times 10^{27}$.

The first time a computer program was able to successfully design a protein was in 1997. Drs. Stephen Mayo and Basil Dahiyat used a computer algorithm to create a protein that was very similar to the target, a protein motif based on the polypeptide backbone structure of a zinc finger domain. They sorted through all possible combinations for the protein to arrive at the optimal amino acid sequence for the target. In considering all rotamers for each possible amino acid at each residue position, their program went through a mind-boggling $1.1 \times 10^{62}$ combinations.

Although rotamer sequence optimization poses problems in terms of size, search algorithms such as dead-end elimination and Monte Carlo minimization can be used to address these problems. The first method quickly eliminates rotamers that cannot be members of the minimum energy sequence, while the second method, also called “simulated annealing,” is a tool that can be used to estimate an energy minimum.

Designing proteins for particular functions sometimes necessitates a great deal of creative thought. For example, to design metalloproteins, proteins that are capable of holding metals, scientists have more than one option. They can use an algorithm to graft a metal-binding site into the structure of a natural protein whose structure is known. Alternatively, they can opt to design small, flexible peptides that are able to fold around metal ions. A third method is to design a protein that binds to a metallic cofactor, a substance that then associates with an enzyme, enabling the enzyme to function. With multiple solutions to each problem, protein designers can adopt the methods that best fit their needs.

In de novo protein design, scientists try to design novel proteins, aiming for high conformational specificity and thermodynamic stability. Complex computer algorithms which incorporate features such as negative design, energy function optimization, and statistical design methods have led to impressive results in the computational branch of protein design. The use of design constraints and of search algorithms such as dead-end elimination and Monte Carlo minimization cut down the amount of time needed to cycle through the enormous number of rotameric positions formed by the amino acids side chains, enabling scientists to tackle an otherwise impossible task.
the mystical elixirs

A look into Alternative Medicine by Tushar Khanna

Ever been prescribed meditation by your doctor? You soon may be, according to researchers. Dr. Andrew Newberg of the University of Pennsylvania’s Radiology department actively researches the neurophysical correlates of alternative treatments like acupuncture and meditation – esoteric areas of medicine (or as some would argue, pseudo-medicine) that are only beginning to be probed by researchers for their potential to benefit physical and mental health.

Imaging studies done of Tibetan Buddhist monks meditating reveal that decreased activity in the superior parietal lobe of the brain may explain why these subjects witness an alteration of space and time during meditation. But meditation doesn’t sound like the conventional treatment a physician would prescribe to a patient. What is going on?

Burrowing outside the mainstream of accepted biomedical doctrine lies the field of complementary and alternative medicine (CAM). Infused with controversy and viewed with skepticism, alternative medicine has been denounced by many leading scholars and doctors as counterfeit. However, it now becomes noteworthy to Penn affiliates because the School of Medicine at the University of Pennsylvania will further adopt CAM into its curriculum, aiming to start a program to teach medical students about such ‘alternative’ forms of medicine in conjunction with the Tai Sophia Institute in Maryland, in August of 2005.

While complementary medical techniques simply bolster methods of modern healthcare, alternative medicine purports to be a total replacement, and has evolved through an interesting history. Its inception can be traced as far back as 6000 years ago in the ancient Vedic culture of India, where herbal compounds were used through a Hindu belief in holistic treatment, stemming from “qualities of nature” and five elements of the material world. Similarly, 5,000 years ago in the ancient culture of China, herbal remedies were rooted in the concept of balance from Taoist philosophy, incorporating emotions, spirits, and the Yin and Yang.

In western culture, developments were slightly less grounded in religion and spirituality. From hydropathy techniques of ancient Roman spas, to folk healing during the witch hunting period, treatments came in many varieties. As pollution and the Plague rampaged across the lands, monasteries and churches garnered substantial control of what could be practiced in treating sickness. The age of Heroic Medicine was quick to follow – a time when physicians would use such forceful therapies as draining blood, inducing vomiting or sweating, and even purging the intestines through mercury chloride to cure patients. These practices were often dangerous, and settlers to the American colonies from England tried to reform them through the Popular Health Movement. Soon after America became more civilized, modern medicine and pharmaceuticals began to come into existence.

There is an assortment of alternative medical techniques still in popular use today. Acupuncture involves penetrating the skin with electrically stimulated needles at specific anatomical points. Ayurvedic medicine involves using yoga, meditation, massage, and herbs, and it is believed that the seeds of the Mucuna pruriens plant have been curing Parkinson’s disease in India.

Homeopathy revolves around the idea of broadly treating the patient as a whole instead of just the particular disease. It uses natural minerals and chemicals, and incorporates the theory of “fighting like with like,” meaning administering to a patient small doses of something that is known to cause similar symptoms in already healthy patients – a process slightly different from vaccination in that active pathogens are used to cure a disease already contracted.

Aromatherapy is the use of fragrances and oils derived from plants to promote relaxation and mental and psychological well being to cause convalescence.

Naturopathy is grounded on the principle that the human body has the ability to heal itself, and the doctor’s task is to simply facilitate the process. It incorporates unique diets, exercises, massages, chiropractic methods, as well as homeopathy and herbal remedies.

Ultimately, the various techniques of alternative medicine employ more natural means, and perhaps incite the placebo effect in patients, whereby the immune system is duped into healing itself due to a non-reactive stimulant.

Alternative medicine is hotly contested for a slew of reasons. The first and foremost is the lack of scientific,
controlled, clinical trials proving the efficacy and consistency of natural methods, as opposed to simply providing temporary relief. Renowned biologist Richard Dawkins of Oxford University has described CAM as “that set of practices that cannot be tested, refuse to be tested or consistently fail tests.”

The salient problem appears to be reliability, as these methods have not been shown to have an acceptable success rate in a professional setting. Safety is another concern. Since there is an insufficient amount of biomedical research corroborating the theoretical validity of CAM techniques, cases arise where herbs or natural substances ingested by the patient are actually harmful or potent to the human individual’s body for reasons unrelated to the patient’s sickness. This can occur due to poor diagnosis from a CAM practitioner.

Availability can also be an issue, as many herbs are rare and can only be found in exotic foreign locales, whereas the useful substance within the herb can be easily synthesized on a mass scale. Moreover, many techniques and sets of therapeutic conditioning are so individualized that statistical testing might be irrelevant to any specific patient. The sporadic nature of testing results might be attributed to imprecise measurements between test subjects.

Alternative medicine as a scientific field is still very much in development, and Penn is revolutionary in that it is one of only two institutions in America that has been given grant funding through the NIH for CAM research training. However, the CAM research that goes on at Penn is targeted towards alternative treatments that are adjunct to traditional methods, as opposed to complete replacements – we want to be able to use such alternative treatments to perhaps supplement modern medicine, as opposed to doing away with it. And the need to study alternative forms of treatment is a pressing one - current surveys show that consumers spend over 27 billion dollars per year from their own pockets on CAM physicians that aren’t covered by healthcare insurance plans. Pseudo-science or not, alternative forms of medicine need to be studied.

Also, in terms of specific research projects, Dr. Steven Thom heads Penn’s NIH center for CAM research, investigating unconventional uses of hyperbaric oxygen. Some other examples include exploring the treatment of knee arthritis by acupuncture or yoga, fields being researched by Drs. John Farrar and Sharon Kolasinski respectively. Since acupuncture has been approved by the NIH as an effective form of treatment for certain ailments, its investigation is fully active at Penn.

The most popular CAM treatments remain to be dietary supplements, however, a category incorporating vitamins, minerals, and botanical substances. In fact, Penn just recently conducted an intensive study of an extract called guggulipid, which comes from an ancient Indian herb, and yielded both positive and negative results as to its effects. Such projects will certainly be benefited by Penn’s recent collaboration with the Tai Sophia Institute, which specializes in clinical applications of CAM treatments. Combined with Penn’s research focus, this collaboration will serve to accelerate and broaden approaches to progress in CAM. Penn already offers courses in comparative and alternative medicine as electives to medical students. However, the Penn-Tai Sophia affiliation will further integrate CAM into the medical curriculum, and also allow medical students to be officially certified in a CAM related disciple, as well has perhaps pursue a Master’s Degree in complementary and alternative medicine in the future.

Although modern conventional treatment is working reasonably well for a healthy society, there still seems to be gaps and places where something is missing, and this is where CAM may fill the cracks.

Despite the abundance of criticism regarding alternative medicine, there have been cases where patients have been healed from these non-traditional, highly experimental and somewhat intangible techniques – at least, supposedly. Acupuncture has been shown to heal chronic back pain, osteoarthritis, migraines, and strokes. Scientists have postulated that stimulation from the needles may prompt the extensive release of brain chemicals like endorphins, serotonin and prostaglandins which eradicate pain and accelerate convalescence.

Furthermore, many of our modern treatments today were once herbal remedies. Aspirin comes from the bark of a white willow tree, morphine is derived from the opium poppy, and penicillin is produced by fungus.

Knowing this, it is commendable for Penn to be branching out of the mainstream and taking complementary and alternative medicine under its wing. While many of these techniques are historically rooted in magical potions, alchemy, and spiritual healing, there have been cases of success, and this is crucial.

Our duty as scientists and thinkers is to continue to probe and investigate just why and how these methods have sometimes worked. Doing so will advance our biomedical knowledge repository and expand our breadth of healthcare and treatment. The sporadic effectiveness of CAM reveals that we still have a lot to learn.
Before her freshman year at Penn, Mazell interviewed on-campus with professors. She eventually decided to work in an immunology lab at the Wistar Institute. Because she had no prior experience with immunology, Mazell spent freshman year and the following summer learning procedures and working around the lab. She is currently researching Systemic lupus erythematosus (SLE), an autoimmune disease in which a body attacks its own cells. In patients with Lupus, some B cells secrete antibodies that bind to double stranded DNA and chromatin, the proteins that hold DNA. Using mice models with mutations that increase the production of these antibodies, Mazell and other scientists can begin to answer questions regarding how these antibodies form, why these destructive B cells are not kept in check, and how can T regulatory cells be induced to keep these auto-self cells suppressed.

Mazell enjoys scientific research and thinks that more students should get involved. “E-mail professors, but read their research first,” she advises. “You want to have an idea of what’s going on [in the lab]. Professors appreciate it if you show interest...[you should not be afraid of e-mailing as] most professors are really nice.”

As for Penn students in general, Mazell offers this advice: “Don’t assume college is as easy as high school.” With that said, do not study too much. “Enjoy life. When you’re in graduate school, you can put in 24 hours [a day]; Undergrad is when you learn about life.”

### What are your favorite classes?

CHEM 101: General Chemistry I with Dai, the introductory class for chemistry majors. Dai teaches it in a way that is not a typical introduction to chemistry, he teaches it with physical chemistry in mind.

MATH 114: Calculus II with Crotty. He’s a humane professor who wants you to succeed. If you have a problem, he will listen. He doesn’t doubt every word you say.

SOCI 275: Medical Sociology with Joyce. Take this course if you’re interested in medical health care. Dr. Joyce puts no emphasis on grades, just learning. The classes focus on the American health care system but also touch on European and Japanese systems.

ANTH 247 (summer) or 219 (school year): Archaeology Laboratory Field Project. You count pieces of glass, rusted nails and tin cans in the summer and excavate a site in Vineland, New Jersey during the school year. If you participate, you get an A and fulfill the history requirement. Can you ask for a better deal than that?

### What are your favorite campus eateries?

Hemo’s is the best food truck. They have awesome chicken sandwiches of all types. Au Bon Pain and Così are also good.

### What’s your favorite study spot?

4th floor Weigle room in Van Pelt. There’s a really cool table, Knights of the Round table-style, but with a hole in the middle. It’s quiet and there’s internet. access Also, there are always science majors studying there.

### Any advice for freshmen?

Don’t buy books from the bookstore. It’s a ripoff. Use Amazon, Ebay, or other alternative sources.
triangle exclusive:

**Using GlobalSpec in the Classroom**

Edited by the Triangle’s Michael Young; original article by Abraham Michelen and Gary Kardys

Adapted from an article that appeared in the proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition Copyright © 2005, American Society for Engineering Education.

You’re an engineer living in today’s turbocharged information age. Your favorite invention born from technology within the last thirty years is Google. That defiantly gallant, and wildly successful, startup has waged something of a holy war with Microsoft. It has literally introduced a destabilizing force into the computer industry, giving 300 million users direct accessibility to the net. Search engines are gatekeepers in that respect. Search engines like Google ultimately aim to control the organization, search, and retrieval of all digital information. The engineering world can thank a popular new search engine, GlobalSpec, which has been the Google for engineering technologies to a growing base of 2 million users.

GlobalSpec offers a unique, specialized, searchable database of parts, components and services along with innovative, engineering-only information retrieval capabilities, both of which are unmatched by any other search engine.

As such, GlobalSpec’s utility is threefold. Technical buyers use it as their number one online destination to locate products and services, learn about suppliers, and access comprehensive technical content on standards, patents, specifications, designs and application notes. GlobalSpec’s SpecSearch technology lets users search by detailed product specifications in the world’s largest parametrically searchable database of technical products, services and related industrial catalogs.

Founded by and for engineers, GlobalSpec has built what it calls the “Engineering Search Engine.” To achieve this, it has crawled, filtered, and indexed the World Wide Web and focused solely on engineering-related information. Included is access to the hidden Web, content protected by firewalls requiring registration or fees to access. This content is not readily available to mass-market search engines.

Nearly two million engineers and technical buyers have registered for free access to www.globalspec.com, giving the search engine the world’s largest registered community of its kind. GlobalSpec continues to add new registered users at the rate of 18,000 to 20,000 per week, thus giving it a leadership position in the engineering-only vertical search arena.

Since its inception in 1996, GlobalSpec has become a one-stop location where technical buyers meet, and can search for products, services, technical articles, standards, application notes, and more. Nowadays engineers and technical professionals use the Web throughout their work process to search for and locate products and services, learn about suppliers and access comprehensive technical content on standards, patents, design, specifications, materials, application notes, and many other important activities in the daily life of an engineer. Without GlobalSpec, or a tool similar to it, the essential task of locating a specific component for a design would take many hours of browsing in manufacturer’s catalogs.

All these tasks are accomplished by just linking to the GlobalSpec site. This is the reason why many engineers at important industrial manufacturers as well as research laboratories use the GlobalSpec site for all engineering tasks. Organizations where GlobalSpec is used include Companies such as IBM, Motorola, Boeing, Cisco, NASA, Fermilab, Nokia, and Intel have already caught on.

The engineering community, represented by engineers at these companies require a specialized search engine offering precise, relevant results and easy access to the comprehensive engineering-related information to succeed in these times with shortening product design and development cycles.

“Learn more about” pages: By digging down deeper into specific categories and selecting a “Learn more about” link for an area, students can delve further into a particular component, service or product type. “Learn more about” pages provide a more in-depth description with additional details of the product or component.

The young engineer, scientist or technologist can gain a better understanding of the specifications or attributes for a particular component or product by accessing Specifications pages located at the bottom of the “Learn more about” pages.

**Engineering WebSM Searches:** Web searches using the GlobalSpec search engine will return results more pertinent to the young engineer compared to the general-purpose search engines. An Engineering WebSM search for “Pumps” will return links on industrial pumps, while a search on a general-purpose search engine returns results high heeled shoes. An Engineering WebSM search for “strippers” will return links on cleaning agents or chemicals as one would expect, while a search on a general purpose search engine returns results, which educators hope are not of interest to good engineering students.

Engineering hubs and search engines such as GlobalSpec provide a wealth of tools to enable engineers to perform their jobs more efficiently. The GlobalSpec website also contains many useful resources for educating engineering and technology students. Proficiency in online
searching of industrial components is a useful skill for new engineers to acquire and can be integrated into engineering curricula. Further study is required to quantify the impact of search tools like GlobalSpec in enhancing engineering education. Anecdotally, several graduates now in industry have reported back that they use GlobalSpec frequently and instruction in using the search tool was an advantage. A system that speeds access to technical information should be a beneficial resource for engineering students as well as practicing engineers.

Abraham Michelen is a full professor in the Engineering Technology Department at Hudson Valley Community College. Abe has a Ph.D. in Electrical Engineering from Rensselaer Polytechnic Institute as well as M.S. degrees in Nuclear and Electric Power Engineering.

Gary Kardys is an adjunct faculty in the Engineering Technology Department at Hudson Valley Community College. Gary has M.S. and B.S. degrees in Metallurgy and Materials Engineering from Rensselaer Polytechnic Institute.

Ah Philadelphia. What do you think of when you hear the name of our beloved city? Maybe liberty? Or Independence? Brotherly love? Even cheese steaks? There is another word coming to Philly that may well be just as important by our modern tech standards as the timeless notions of liberty and independence—wireless.

Why should wireless and Philadelphia go together? It is because city mayor John Street launched Project Wireless Philadelphia last year. In it the city outlined a controversial proposal to invest in the creation of a new wireless mesh network based on Wi-Fi, or Wireless Fidelity. This will allow people to connect to the internet free of charge at select sites in Philly, while others must pay for the service. The staple sites that will come fully web enabled include LOVE Park, Benjamin Franklin Parkway, Philadelphia Reading Terminal, Philadelphia Convention Center, and Headhouse Square Plaza, to name a few. The Project believes that “for centuries cities have been the early adopters of new technology, and it is by investing in these new technologies that cities became the great creative engines of commerce, culture, and society.”

Philh is not the first city to dream up of the risky idea of mass providing free public internet connectivity. Cleveland, operating in conjunction with Case Western Reserve University, installed over 1,500 wireless enabled access points in its downtown metropolitan district. Like our Wireless Philadelphia project, theirs is the so-called OneCleveland project, the stated goal of which according to a description of the project is to “connect more than 1,500 institutions and organizations and every member of the community to the internet.”

Mayor Street made it clear in 2004 when he drafted the business plan for Project Wireless that his overall objectives were to boost economic development, to help overcome the digital divide, and to improve quality of life. “Today is a great day for Philadelphia and the thousands of businesses and tens of thousands of families and children who will benefit from our Wireless initiative,” he spoke. “Just as roads and transportation were keys to our past, a digital infrastructure and wireless technology are keys to our future.” Wireless Philadelphia projects that it will sign up 94,000 subscribers in the first year of service, and reach 162,000 in five years.

A Brief History of Wireless

Wireless has come to mean basically any technology that transmits signals without cables, wires, or waveguides. It uses various means to get transmit and receive information, including radio frequency, microwave transmission, or even free-space optical systems. The Federal Communications Commission (FCC) and other regulatory agencies require federal approval and licensing of transmitters in many frequency bands, such as radio, television, and telephony broadcast bands.

Wireless is the healthiest part of our healthiest industry in telecommunications, though it is still nursing a hangover from the tech bubble. It has a firm lock on mobile communications, and it has allowed millions of people everyday around the world to talk, listen, send, and receive messages without strings attached, literally. Wi-Fi devices are based on the IEEE 802.11 family of standards, and are the dominant technology in the market for wireless. The most common types operate in the 2.4 GHz band range shared with microwave ovens and other unlicensed short-distance networks like Bluetooth, a short ranged wireless technology that come enabled in some portable devises like laptops and PDAs. Wireless developers herald advantages over those using cables, such as easier installation, lower...
Installation cost, and flexibility of relocation. Fiber lines, however, remain the vertebrae of the global telecommunications network. Current wireless technologies in the market cannot compete with the immense bandwidth, low attenuation, reliability, and distance communication of cable. These naturally give fiber optic and wireless each its own comfortable market niche.

A battleground, though, has been drawn. Its borders lie in the midst of the telecom industry and a handful of cities around the globe have begun the war. This battle between wireless and cable will ultimately decide the new world order, although no matter what the outcome the victors will always be the consumers. A new force will emerge over the horizon by the beginning of next year that will rise to command and unite the armies of wireless developers against cable. This new force is WiMAX.

The Worldwide Interoperability for Microwave Access (WiMAX) standard is a wireless metropolitan-area network, also known to tech geeks as IEEE 802.16. This speed demon will enhance your internet surfing experience to a blazing 70 megabits per second. When you think of WiMAX, think WiFi on steroids. They are both similar in that they create connectivity in laptops. The future looks secure for wireless mobile communications. And WiMAX promises to be one technological race horse that is sure to drive innovation.

Economies of Scale

Even though publicly owned infrastructure may be at first glance a socially beneficial means of providing internet services in the future, not everyone likes the idea of municipal networks. Telephone and cable companies are two examples. In fact, the announcement of the Wireless Philadelphia Project had its share of controversy, and even met with litigation from Verizon. Internet and telecommunications companies such as these tend to think it is unfair that municipal networks do not have to pay taxes, but instead are paid for by the taxes that telephone companies, cable services, and the population give to the city. Some states have agreed with these companies, banning municipal networks. Last summer the Supreme Court held that it is perfectly legal for states to do this.

FACTS AT A GLANCE:

• A wireless mesh to serve the entire city will be deployed based upon the current Wi-Fi 802.11b standards.
• Individual Wi-Fi cells can be mounted on streetlights creating a self-organizing wireless mesh. 8 to 16 units are needed per square mile.
• It costs $60,000 per square mile. Philadelphia is 135 square miles.
• Wireless connectivity could be provided for the entire city for $7 to $10 million.

In the United States, where the telecom industry is not government-owned but is still subject to economic regulation, competition in companies providing these services know that regulation is an imperfect mechanism that often fails directly to serve consumer interests. While federal deregulation of telecommunications continues in many countries including the United States, curiously there has been a growing trend in the opposite direction at the local level. Aggressively laying down more and more optical fiber lines, city, state, and local municipalities have increasingly made it their goal to provide broadband that is unavailable to citizens from the private sector of the industry.

Thus, we must ask: is this business proposal socially optimal and efficient? Is the Project really a plausible remedy for “market failure”? There does not seem to be sufficient evidence to show that there is a paucity of broadband and wireless services offered by the already intensely competing companies for Philadelphians. Perhaps one reason why the private sector has not invested in city-wide Wi-Fi networks is that it is a technology that was made for local applications. Project Philadelphia, according to some who don’t mind throwing it under thorough financial analysis, may very well be technologically obsolete.

This is not to ignore WiFi’s impressive past record in the market however. Businessweek reports that 2003 was WiFi’s golden year, as growth in sales
It has been four years since the release of the Nintendo’s Gamecube and Microsoft’s Xbox, and five years since the release of Sony’s Playstation 2, the most successful video game console to date. With computer technology advancing in leaps and bounds, the time has come for the major console developers to step up to the plate, and step they have. Sony, Microsoft, and Nintendo have all announced and released details about their new next-generation gaming consoles. With some release dates set as early as next year, it is clear that none of these three companies want to be left behind in a 24 billion dollar market that is forecasted to double in size by 2008.

So what can we expect from these new gaming consoles? Well, for avid video game players, these consoles promise everything from amazing graphics and sound to compatibility with previous consoles’ games. Console developers aren’t forgetting the non-console gaming crowd either, hoping that a new host of media features including Blu-ray and HD DVD technology, advanced online networking, music playability, and picture tools will help to expand the console gaming market.

Some Specifics:
It is important to note that currently, details about Nintendo’s next-gen console, the Revolution, are few and far between. Nintendo execs have been tight lipped as to its specifications, stating only that its power should be comparable to that of the PS3 and Xbox. Many expect that Nintendo is looking to take a very different approach to gaming with the Revolution than that of Sony or Microsoft, but little more than speculation is available as to what that approach entails.

With this in mind, comparing and contrasting the specs and approaches of the PS3 and Xbox 360 give the best idea for what the future holds. The PS3 makes use of a Blu-Ray rom drive for its gaming media while the Xbox 360 will contain an HD-DVD drive (see article on Blu-Ray vs HD-DVD on pg __). Both share almost equivalent processing power, and it is unclear whether the PS3 or the Xbox 360 will end up with the strongest graphics performance, although the PS3 boasts an NVIDIA chipset with performance greater than two of the newest and most powerful graphics cards available for PC’s combined. Memory-wise, the Xbox makes use of technology that allows its graphics card and central processing unit (cpu) to share a combined 512 MB of memory, while the PS3 has 256 MB for graphics and 256 MB for its processor. Most expect that the systems will offer about the same performance where memory is concerned.

So far the systems seem like two sides of the same coin, right? However, each offers a different set of advanced features to differentiate themselves from the other, and hopefully, to garner the larger part of the video gaming audience. The PS3 offers complete backwards-
compatibility with the Playstation 2, meaning that you can play any PS2 game on the PS3. Furthermore, it offers 6 USB 2.0 slots, support for flash drives, and space for a removable 2.5 inch hard drive. Sony hopes that the PS3’s ability to support many different types of media will allow it to transcend the label of “gaming console,” making it more of a media center.

The Xbox 360, on the other hand, focuses mainly on its networking abilities, hoping to build on the success Xbox Live has had with games like Halo 2 and Ghost Recon, whose online multiplayer components have become immensely popular in the gaming community. Supposedly, players will be able to use the advanced networking options of the Xbox 360 to create a novel multiplayer experience that even allows remote access to computers with Windows installed, allowing at the very least for media sharing. Of course, the ability to play with and compete against players from across the country and around the globe currently offered by Xbox Live is expected to come with a few enhancements as well, but Microsoft has not made any announcements as to what these would be. Microsoft also has a host of game developers already producing games for the Xbox 360, something both the PS3 and Revolution currently lack. This, in large part, seems to be its trump card until the PS3’s release, as it can promise what most console buyers will want: next generation games to go along with their next generation consoles. Although the Xbox 360 will only support some backwards compatibility with Xbox games, the panoply of new games being produced for the 360 should more than make up for this shortcoming.

In the end, Sony, Nintendo, and Microsoft are expecting a fierce battle between the next-generation consoles, and although it may be a little unclear currently as to which console is the “best,” this is something that is sure to be threshed out come next year when all three have arrived in stores. One thing is for sure, though; regardless of who wins the next-generation console war, consumers and gamers can expect their gaming experience to be taken to an entirely new level.

**Optical Media Technology: The Latest Craze**
by Sriram Subbaraman

Thinking about finally getting a DVD-burner or player? Think again, because the next generation of optical media is almost ready to sweep CD-Rs and DVDs into obsolescence. By the end of the year, Bluray will replace as the standard optical media.

Bluray technology dumps the conventional 650 nanometer wavelength red laser that is used to burn today’s CDs and DVDs in favor of a 405 nanometer wavelength blue laser. Swapping a red laser for a blue laser decreases the pit length, which is the length of a pit made in the disc, as well as the track pitch, which is the difference of radii between concentric circles of pits. A smaller pit length and track pitch corresponds to a greater amount of pits per circle and circles per disc, and thus, a greater storage capacity. In fact, Bluray discs will have capacities starting at 15 gigabytes and going as high as 200 gigabytes.

What does that mean to the consumer? Think the entire set of Lord of the Rings DVDs on a single Bluray disc. If that doesn’t interest you, think an MP3 Bluray Disc that holds ten times more music than your IPod. If that doesn’t impress, thing backing up your entire hard drive on a set of 2 or 3 Bluray discs. Or think of the games that will be made for next-gen consoles on bluray discs. Bluray represents a great leap forward in storage media and can revolutionize the way in which data is stored.

So, just go out and buy a new Bluray burner or player, right? Unfortunately, it’s not that simple. Advocates of the Bluray media format stand in two opposing camps. In one corner, Toshiba and NEC have created the HD-DVD media format. Alternatively, Sony and other electronics manufacturers have developed the Blu-ray Disc (BD) media format. Both media formats promise more than 40 times the storage capacity of a normal 700 megabyte CD-R and at least 8 times the storage capacity of a 4.7 gigabyte DVD. Both also use blue-wavelength lasers instead of red-wavelength lasers to increase storage capacity. So the question is what’s the difference? Here’s the breakdown:

**hd-dvd**

What it is: The High-Density (or High Definition) Digital Versatile Disc a.k.a. HD-DVD optimizes the existing format for a DVD. It is burned with a blue laser and was designed with the intention of being able to meet demands for larger storage capacity media needed to record high definition television.

**How it works...**

**Burning:** Using Bluray technology, the HD-DVD operates using a 405 nanometer blue-wavelength laser. However, the pit length of the HD-DVD is a constant at 204 nanometers. This restricts the size of one layer of a HD-DVD to be exactly 15 gigabytes. Thus, HD-DVDs have possible capacities of 15, 30, 45 and 60 gigabytes with a dual-layer, dual-sided disc.

**Physical and Copy Protection:** The HD-DVD has the same structure as a DVD. It possesses a 0.6mm surface layer to protect the disc from scratches and fingerprints alike. The HD-DVD will be encrypted with the latest upgrade to the standard CSS (Content Scrambling System) encryption found on today’s DVDs. Unfortunately, this upgrade,
known as Advanced Access Control System or AACS, has an additional and possibly annoying feature. AACS has as its first line of defense a database of model names. Any player that tries to decrypt a particular HD-DVD must first find its model name in the AACS database on the HD-DVD before it can continue. If a model is reported as having played pirated material, the industry can remove that model’s name from the database, rendering any player of that model useless. While this does pose a stultifying defense against pirates, it also means that your player could at some point be made into the equivalent of a doorstop due to the malicious piracy of some kid down the block.

Supporters: Toshiba, NEC, and the DVDForum, which consists of movie studios whose DVDs make up 40% of the total market. This makes the HD-DVD a strong runner in the competition for the storage media of the next generation.

### Blu-ray

**What it is:** The Blu-ray disc, or BD, is a disc that uses variable pit length and a higher numerical apertures to gain higher storage capacities than its opponent, HD-DVD.

**How it works..**

**Burning:** The numerical aperture (NA) of an optical lens defines how focused a laser is at a specific distance, so a high numerical aperture in addition to a shorter wavelength laser correspond to a smaller track pitch. The BD has a NA of 0.85 nanometers compared to 0.65 for a HD-DVD, in addition to a variable pit length of around 160,000 nanometers compared to 205 nanometers for the HD-DVD. This all sums to a greater storage density for the single layer, single sided BD, anywhere from 23 to 27 gigabytes. The BD uses the same 405 nanometer blue laser as the HD-DVD burner, but has its write layer only 0.1 mm from the surface of the disc, allowing for the much higher NA.

**Physical and Copy Protection:** Due to the slim 0.1 mm surface layer protection, the BD was thought to be extremely vulnerable to data loss due to scratches or to fingerprints. But BD manufacturers came up with a hard coating that is supposed to make BDs more resistant to scratches and fingerprints than both today’s DVDs and CD-Rs. In terms of copy protection, BDs use 128-bit Advanced Encryption Standard encryption key that is different for each 6kb of data, making cracking an entire BD a very hard endeavor.

**Supporters:** Almost the entire electronics industry. However, only a few movie giants have signed on with the BD format. Nevertheless, the BD is gaining support on the grounds that it is clearly the better format in terms of both flexible storage capacity and large storage capacity.

**And the winner is...?**

It is not so easy to say which media format is “better”. While the BD seems to have a clear technological advantage because it is able to store more data/information, (TDK recently announced the production of the 100 gigabyte BD), its production comes with its own price.

Because of the different structure of the BD, all conventional DVD production lines would have to be retooled to make BDs, making BD production more expensive in fixed costs. Additionally, BDs cost more to make than HD-DVDS. But the price might be more than worth the rejection of HD-DVDS, with their 60 gigabyte maximum storage capacity. After all, the HD-DVDS certainly don’t provide the leap in storage capacity that BDs can. BDs also seem to come with a better encryption system less fraught with annoyances to the user.

In the end, if the choice isn’t made, the consumer will suffer, having to buy two different players and two different burners along with the different media. All in all the BD clearly stands as the technologically superior product. Even if today’s high definition programming can fit on a 60 gigabyte HD-DVD, the cost of an upgrade of media 5 years down the road will more than outweigh the cost of just switching to BDs now. Besides, the idea of having a storage disc with the storage capacity of most medium-high end storage drives seems fantastic to me. But let’s not get ahead of ourselves. Although the first HD-DVDS will hit the markets by the end of the year, you won’t have to chuck the brand new DVD player you have bought just yet. As with most brand new technologies, until High Definition television and movies become the norm, movies are likely to be released both in Blu-ray format and in normal DVD format. And even when released, hybrid players will be released that will play both Blu-ray and normal DVD formats so you do not have to sweep all your DVDs into the garbage can.

So don’t panic if your house contains walls of DVDs and piles of CDs, while the switch to Bluray is inevitable, it will occur gradually and will be compatible with older formats. In the end, the choice is up to you the consumer as to which format to support, and when to make the switch. Choose wisely.
philadelphia happenings:  
THE PENN SCIENCE CAFÉ

“
A mathematician is a device for turning coffee into theorems.
"  
- Paul Erdős

The Penn Science Café - started in January, 2005 - is in essence based on a very simple idea: the notion that science, coffee, and public discourse mix well. The lecture series “that takes science out of the laboratory and treats it to a night on the town”, the Science Café presents members of the Penn community and the greater Philadelphia area to scientific research and discourse in its most plain-language and accessible form.

Held at the Marbar at 40th and Walnut streets, in the heart of Philadelphia’s University City, each event begins at 6:00 pm, with doors to open at 5:30pm.

Previous Science Café topics have been on Gene Warfare (David Roos), Einstein and the Answers to Life, the Universe and Everything (Vijay Balasubramanian), Understanding the Tsunami (Benjamin Horton), Hunting Dinosaurs (Peter Dodson), Safecracking for Computer Scientists (Matthew Blaze), and Love at First Sight (Robert Kurzban).

The next Penn Science Café will be on Monday, August 29, entitled “Will Teaching Evolution Become Extinct?” with Professors Paul Sniegowski (Department of Biology) and Michael Wiesberg (Department of Philosophy).
In the wonderful weeks of summer preceding my second year in the DeGrado computational biophysics lab, I have devoted my time off from proteins to my other passion: culinary arts. While attempting to whip up the perfect chocolate mouse and making mango lassi’s has been pure fun personified, neither concoction has been as surprisingly smooth as my research experience in the protein laboratory. Over the past year, I entered a field in which I knew very little and managed to be productive and to enjoy myself a great deal at the same time. Here, I offer my humble recipe for making your own research experience as smooth as crème caramel.

**Recipe for a Delightful Research Experience**

_by Debbie Chadi_

In a lab where you will have to interact with many other people, the best advice I can extend is to adopt a positive attitude towards your coworkers and an “I can do it” mentality. Everyone appreciates a pleasant person and one who contributes to the work ethic of the lab is the cherry on top of the sundae. “I can do it” means that you step up for projects when they are put on the table and are willing to spend time learning new techniques to get the job done. A boss who suggests doing something you have never tried before will generally understand if you don’t get it right immediately and will appreciate the effort and enthusiasm you put towards getting it done.

Showing that you are committed to your work is another key ingredient. Although staying current with developments in the field and putting in extra time to finish projects and learn job-related techniques will certainly help you, the main way in which you can demonstrate your devotion to your job is through timeliness. Forget the fact that you have never woken up before the end of your first class: make it to lab on time or risk the wrath of your boss. Most college professors are extremely busy supervising the work of numerous graduate students and postdoctoral students. If yours takes the time to show up in your office or cubicle and you’re not there, your chances of promotion from coffee carrier or beaker washer will be near zero. This brings to mind two other points. Since many graduate students take the liberty to arrive late, your punctuality will afford you the perfect opportunity to schmooze with the professor or discuss that problem that’s been bothering you. And speaking of dish washing and coffee services, before entering a lab that will require you to do menial tasks for months before starting any real projects, ask what you will be doing should you accept the job. If you have the chance, speak to other students in the lab to find out the nature of the environment and think about whether or not you can see yourself working there.

Let’s say your professor comes by to check up on your project. Of course, since you arrived on time, you’re already busy producing the next round of results. If you are smart, you are avoiding the Internet. And most importantly, you have been keeping track of what you’ve been doing. An integral part of research is to document your steps because your supervisor and other people will ask detailed questions about the procedures that led to your results and as your projects become more complex, it will be increasingly difficult to remember exactly what you’ve done. It is also necessary to keep track of your results and the challenges that you haven’t overcome so that when the boss comes around, you will be prepared to discuss them. Not being prepared is as distressing as starting a cake only to realize that one has a shortage of flour; laying out the ingredients before hand saves time and gives one greater control over the process. Last but not least, if your research becomes fit to publish, proper documentation will be an enormous aid in preparing “Methods” and “Results” sections.

In a social lab, there will be an enormous temptation to speak to other people and to take frequent coffee breaks. If everyone else goes, then feel free to join them, but don’t distinguish yourself by being the one to initiate all of the breaks. When it comes to sharing stories, be sympathetic of others but stay focused on your work. Everyone understands that you have been hired to get work done and are responsible for its completion. Furthermore, be careful about sharing details of your personal life or they may come back to haunt you. Similarly, avoid mockery of your coworkers openly or in private as backstabbing stories tend to spread; it is easier to worry about your success without the additional worry of sabotage or, at the very least, having to soothe hurt egos.

As your research starts to take off, you may find that you have shouldered so much responsibility that your work is starting to creep into your nightmares. In this case, it may be time to cut back to only one project or to one aspect of it. Although this may seem as difficult as separating egg whites from the yolks, the upside potential is that the project you are left with will blossom under your undivided attention. In addition, you will come to appreciate your decision to sacrifice the additional work for the sake of your mental sanity once school begins and you start to straddle the research in addition to class work and extracurricular activities.

My recipe for meaningful research has many variations, and you may wish to add additional ingredients to spice up or sweeten your own experience. While this may be the case, successful research entails more than just good work; as in most other endeavors, a positive attitude combined with enthusiasm, effort, commitment, promptness, and self-control make all the difference as to whether the experience turns out sweet and smooth—or goes sour.
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about the *pennsylvania triangle*
(No, we’re not a Drexel publication.)

In a nutshell, the *Pennsylvania Triangle* - not to be confused with Drexel University’s student newspaper, also named the *Triangle* - is a student-run science and technology publication of the School of Engineering and Applied Science at the University of Pennsylvania. The *Triangle* has been around since 1899, making us the oldest continuously-published periodical at Penn. We’re convinced that if you have the slightest interest in anything to do with science or technology, you'll find something that fascinates you here.

“The Triangle” originally stood for science, engineering, and architecture – the three main arms of the engineering school in the early 1900s, and has gone through as many names, from starting off as being the *Journal of the Whitney Society* (1899), to the *Towne Scientific Journal* (1913), to its current name, the *Pennsylvania Triangle* (1924). Obviously, engineering and the nature of science and technology have changed since 1899, and so have we.

**How have we changed?**

In the past, the *Triangle* has somewhat limited both its staff and audience to SEAS students. Beginning with this issue, future *Triangle* magazines will be written by students from three main groups including engineers, scientists, and anyone else interested in science and technology. We’d love to have you join us even if you’re not in SEAS.

We’re also expanding our intended audience from just engineering students to three main groups: students, faculty, and the greater Philadelphia community (alumni, visitors, prospective students, etc.). The issues we address will not be limited to SEAS or even Penn topics but also interesting events and news that happen outside our campus.

(Articles that have been written or are in the development stage include an exposition on the relationship between science and religion, the nature of stem cell research, the politics of science/technology, biographies of famous scientists, and profiles of the technology used in museums and stadiums, to name a few.)

Whether you’re a professor reading this magazine while proctoring a final, a student skimming through before (ok fine, during) lecture, or a prospective student trying to get a taste of Penn, welcome to the new *Pennsylvania Triangle.*