The Institute of Biological Engineering

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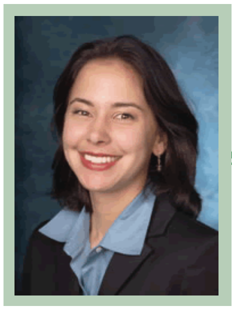
Inside...

Summer 2008 Volume 12.2



President's Message

Christina D. Smolke
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The 21st century presents global challenges in the environment, resources, energy, health, and sustainability. The mission of the IBE is to support the community of scientists and engineers who are addressing these problems through biological systems. We do this through enhancing and promoting biological engineering in the broadest manner through research, education, and professional development.

The solutions to these societal challenges will require broad multi-pronged approaches – spanning engineering, biology, chemistry, materials, computer science, and physics. The breadth of approaches required are well-reflected in the membership of IBE and in the exciting work that was presented at our 2008 annual meeting. From researchers who are taking inspiration from natural biological systems to develop approaches for building new organic-inorganic hybrid materials (as highlighted in our keynote presentation), to researchers who are developing approaches to deploy biology as a technology for information, materials, chemical, and energy processing (as discussed in our Synthetic Biology and Frontiers sessions); biological engineers are transforming approaches to the analysis, design, and programming of biological or biology-inspired substrates.

What unites us as a community is the belief that our ability to use biology as a substrate for engineering for constructive purposes, is a critical technology. It is important to consider what a community of biological engineers is and what your role is in this rapidly growing community. As biological engineering matures, grows, and redefines itself, as new technologies in support of engineering biology come online and as new departments and training programs spring up all across this country and across the world, resulting in the training of rapidly expanding numbers of young scientists and engineers who call themselves 'biological engineers', an effective community framework is more important than ever before. Some of the issues that must be addressed include: How can we best cultivate and support investment and innovation in biotechnology? What should be the new ownership and sharing policies of biological technologies that support innovation and growth? What are the community and professional practices in biological engineering; how can we best support biological ethics, safety and security?

IBE is leading discussions in many of these efforts, as exemplified by several programs at our annual meeting including the bio-business nexus, the bioethics

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Editor, Art Johnson

What Does it Take to Be a Good Biological Engineer?

The story is recounted in the *Phi Kappa Phi Forum* about a Harvard University conference entitled "Keeping Kids in the Achievement Game" (Malone, 2008). John Merrow, President of Learning Matters, Inc., and a renowned education reporter for PBS and NPR, gave a compelling speech about the importance of quality teachers, holistic education, and the care and nurturing of our inner-city students. No sooner had he finished than a male high school student stood up and asked, "Well, if all this is so important, how come my art got cut, and how come I haven't had a music program since the fourth grade?"

How come, indeed! Apparently, the No Child Left Behind policy, with its formal standardized testing and rating of successful and unsuccessful schools has caused there to be increased instructional time in reading, writing, math, and science. What suffered was time devoted to arts, foreign languages, and social studies.

Without science and math, reading and writing, our students cannot be expected to survive in the 21st century world. Aren't they also at a

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contest, and a special session featuring student presentations from the iGEM (internationally genetically engineered machines) competition. As a professional society, IBE needs to look forward and anticipate the frameworks that need to be in place for its community in the 21st century – imaging a world in which biological engineering is a unique educational and professional discipline. What is the educational core of a biological engineer? What is a professional biological engineer, and should there be a license? Are there technical standards and codes by which the work of a biological engineer should be judged? What are the responsibilities or codes of ethics under which a biological engineer should work? IBE is providing a forum for discussing many of these issues within the IBE wiki site (http://openwetware.org/wiki/Institute_of_Biological_Engineering) and IBE's new journal the Journal of Biological Engineering (http://www.jbioleng.org/home).

IBE is on a strong trajectory that is due to the leadership that has been guiding the society, its membership which has been generally very active and engaged in the direction of the society, and the exciting growth that is happening in emerging areas of biological engineering. Attendance at the IBE annual meeting has nearly doubled over the past two years and our membership numbers continue to increase. In addition, we have recently hired a new management company, Symbiotex Management Strategies, that is working actively with the leadership of IBE to develop new strategic plans appropriate with the promise and growth of this discipline and helping us to reach out to industry and educational programs.

IBE is an organization that welcomes participation from its membership, at any age or stage of training. As a member, you are IBE and should be leading and participating in discussions and actions on issues and challenges that inspire you. Your energy and effort can have a real impact on what we as a society is doing. As a place to start, IBE has nine committees that span education, chapters/branches, meetings, membership, public relations, recognition/awards, website and communications, nominations/elections, bylaws and publications committees. These committees represent an excellent first step in getting involved with IBE, either informally or as committee members. To learn more about these opportunities, please contact committee chairs as listed on the website (http://www.ibe.org/about/committees.cgi). In addition, we encourage you to organize community discussions on the IBE OpenWetWare wiki site; the wiki site provides a forum for discussion that anyone can openly contribute to.

As president of IBE, I have identified several goals on which I will focus my efforts over the next year. First, we will reach out to new members (new departments, emerging research communities) and international contingencies to build a broader biological engineering community base. Second, we will transition IBE to take better advantage of global community building and information sharing through interactive internet hubs. Third, we will emphasize a directed effort on education in biological engineering, by leading discussions around the foundational core of this discipline. Fourth, we will develop new initiatives directed to the support and development of IBE's student membership base. Our student membership is the core energy behind IBE and certainly the future of biological engineering. The executive committee has discussed several exciting initiatives that we will be implementing later in the year to support more active student chapters, activities and resources for these chapters, and to broaden IBE's base of support. Finally, we will begin developing partnerships with other organizations to participate in framing discussions around professional practices in biological engineering.

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disadvantage without art, history, music, and social and cultural legacies? The world is facing globalization: shouldn't we prepare the next generation to adapt with languages, global history, and appreciation for foreign contributions?

Emil de Cou, Associate Conductor for the National Symphony Orchestra, has said, "I have yet to meet a teacher who thinks excluding the arts is a good idea. If you just memorize facts and figures, you're not contributing to society. You're a maker of widgets. The arts can be a divine spark that grows." (Express, 2008).

Biological engineering, as some of us like to think, is a very broad integration of science, engineering, and biology. Not only do we expect biological engineering practitioners to be familiar with principles from fundamental physics, chemistry, engineering sciences, mathematics, and biology, but also much more. Biological engineers who truly represent the entire profession, and not just a small segment of it, should also know about ethics, aesthetics, emotional satisfaction, group dynamics, ecology, history, music, art, economics, and law. In other words, they should have some holistic view of the world; some systems concept of the grand scheme of things and how various parts fit together.

We have had several successful IBE meetings with myriad technical papers that reflect the reductionist segmentation of the field. I have gone to many of these presentations and wondered exactly what the speakers were talking about. I wondered why I was there, when I expected perspective and yet got only detail. Perhaps that is the nature of the game, but it makes me yearn for something more complete.

Perhaps that is what we can expect in the future as more and more of our high school students become more and more proficient in math and science, and less and less in cultural diversity. With art and music squeezed out, what chance do we have to maintain a broad view of biological engineering? How can we expect future biological engineers to be adept enough to anticipate reactive maneuvers and unintended consequences characteristic of living things?

Perhaps art and music do not directly contribute to versatility, but they help people to break the chains of constrictive thinking. The box that biological engineers need to operate in should have walls that are far removed from one another. Outside the box thinking should be the norm rather than the exception. If biological engineers cannot do this, then who can?

My Biology for Engineers course reflects this philosophy. It is not a cellular biology course; it is not an ecology course; it is not biomechanics, electrobiology, genetics, or biophysics. It is all of these and more. The reason for this is that just a little exposure to group ecology, beauty, human factors engineering, language, and others goes a long way toward expanding the box. Understanding of genes as only one possible intergenerational information legacy, and of birth as a resetting of a chaotic system to a common starting point gives new perspective on biological details repeated so many times in other courses that one loses a sense of the wonder about the completeness of the biological world. Looking at biology as a source of solutions to be worked with rather than a source of problems to be conquered offers hope that biological engineers can truly add to universal progress rather than to false starts and technological pitfalls.

We want us to be positive contributors. We want us to be appreciative of all the world around us and what it can offer. We need those who come after us to maintain this legacy of hope, vitality, and expression. We need to impart to them familiarity and appreciation for a broad education. We can do this in the home, in school, and in life, but we cannot condone extremism that excludes cultural appreciation.

Very few of us will win the Nobel Prize. I haven't given up hope yet, but there is nothing that I have done thus far to deserve such an honor. And it's not likely that I will ever achieve anything even close. But, as Arlo Guthrie has said, "everyone's good for something." I think it is more likely that the something that someone is good for depends strongly on the education and experiences they have in their formative years. Perhaps the something that we can be good at is to help the next generation to achieve greatness.

References:

Express, 2008, Pr. George's Kids Take Time for Art, *The Washington Post Express,* p12 (18 April).

Malone, H.J., 2008, Educating the Whole Child: Could Community Schools Hold an Answer? *Phi Kappa Phi Forum,* 88(1):16, 25 (Winter/Spring).

Mark your calendars NOW! IBE 2009 Annual Conference **March 19 – March 22** in Santa Clara, California at the Santa Clara Marriott. More details this fall.

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IBE Meeting a Success

The IBE meeting held 6-9 March in Chapel Hill, NC was a rousing success. Attendees numbered 298 and 187 papers were presented on topics ranging from synthetic biology to synfuels. Meeting rooms were crowded with interested listeners, and student enthusiasm was on display for all to see.

Winners were announced at the Awards Banquet for the Poster Contests (see page 6). Undergraduate student Bioethics Essay Contest winners were also announced. They were:

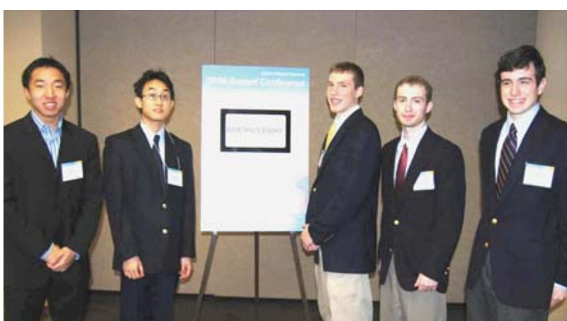
Zachary Russ, University of Maryland – first place
Nansen Yu, Cornell University – second place
William Richbourg, University of Maryland – third place
Stevephen Hung, University of Maryland – honorable mention
Brian Hofferbert, University of Maryland – honorable mention

Four IBE members were elected as the first class of Fellows. They were Roy Young ,Jerry Gilbert, Brahm Verma, and Tom Richard. Art Johnson was given the Brahm and Sudha Verma Lifetime Visionary Award. His citation read as follows:

Before biological engineering was popular, he worked to make people notice; when biological engineering needed to be explained, he wrote about its philosophical foundations; when biological engineering needed a home, he helped establish organizations where it would feel comfortable; when biological engineering was overlooked, he stubbornly reminded others of its importance; when biological engineering needed an educational base, he created a curriculum; and when biological engineering needed flesh, he wrote original textbooks about the field. No one has worked more assiduously on behalf of the biological engineering vision.

The Awards Banquet was capped with an IBE American Idol skit presented by students present from Purdue University, Mississippi State University, University of Virginia, and Utah State University, who acted as contestants. The three judges were played by Mark Riley (Randy), Sabina Jedlicka (Paula), and James Warnock (Simon). All did a wonderful job and kept the audience delighted and laughing. All-in-all, it was a very successful meeting. We thank Marshall Porterfield and his cohorts for arranging this great event.

Bioethics essay winners—from left to right: N. Yu, S. Hung, B. Hofferbert, W. Richbourg, and Zachary Russ



IBE Fellows—Roy Young, Jerry Gilbert, Brahm Verma and Tom Richard

IBE Council meeting

Bio Technology Development in North Carolina—Welcome Seminar presented by Bill Little and Preston Linn

BioBusiness Nexus reception

IBE awards banquent

Executive Director's Report
Sarah Clements

It has been an active first quarter for IBE. The year kicked off with the 2008 Annual Conference in Chapel Hill, North Carolina. IBE experienced many firsts at the conference including the largest number of attendees and presentations in the association's history. In addition, during the conference, the IBE leadership met and continued strategic planning discussions that started in late 2007.

The meeting was energetic and produced innovative ideas for the organization's future. Implementation of the programs and member benefits will span the course of this year and into 2009. Please visit the IBE web site (www.ibe.org) often and check your email for updates.

We encourage and want all members who are interested in sharing their expertise with the association to consider joining an IBE committee. The committees will be instrumental in implementing new opportunities and benefits for you. To join a committee, please send an email to the committee chair listed on the web site at www.ibe.org or contact Sarah Clements, IBE Director at sclements@ibe.org.
Do you know the IBE mission statement? Do you want to contribute to the development of a new mission statement? The current IBE mission statement is posted on the IBE Wiki and is waiting for your comments. Please visit www.ibe.org, click on IBE Wiki, log in and provide your feedback. The leadership is dedicated to putting a mission into action that reflects its dedication to its members and the profession.

Your support and involvement are necessary to accomplish these goals. Please feel free to contact a council member, a committee chair or Sarah Clements with any ideas, thoughts, or comments. We look forward to a successful 2008 and to hearing from you.

Biology in Engineering

Suretha Potgieter
Pretoria, South Africa

Isn't it wonderful how intertwined disciplines have become? Who ever thought you could combine acting with politics or biology with engineering? Why, you may ask, would engineers be interested in biology?

Nature has a harmonious, wasteless way of doing things that engineers could benefit from adapting. Learning the principles of bottom-up design and applying nature's ingenuity in their work could lead to completely new ways of thinking about mechanical systems or complex structures. Swapping our destructive human behaviour for the self-sufficient, self-healing one of nature could only benefit all involved.

On the other hand, applying engineering principles to biological matter can lead to wonderful, almost sci-fi like discoveries. The engineer's tools of standardization and simulation, their drive to understand the underlying principles of a system and their knack for creating new gadgets out of old spares holds great promise for creating biological systems with previously unheard of functionality.

Also, humans are biological creatures. Our health and well-being are functions of biological processes. Investing some effort in biology means investing in ourselves.

The role of biology in engineering should thus be to provide both the foundation and the building material, with engineering as the cement, shaping new structures and holding them together.

These are exciting times indeed, and who is to say what will be next? It is like seeing two rivers meet for the first time and predicting the course they will take.

IBE 2008 Annual Conference

Undergraduate Poster Competition Winners

FIRST PLACE
Omega-3 Fatty Acid Production from Crude Glycerol
Daniel Nelson, Sridhar Viamajala, Ronald C. Sims, Utah State University

SECOND PLACE
Optimizing Vascular Morphogenesis in a Self-Assembling Peptide Hydorgel
John P. Casey, Vernella V. Vickerman-Kelly, Roger D. Kamm, Louisiana State University and Massachusetts Institute of Technology

THIRD PLACE
Design of processing Conditions for Conversion of the Purple Sweet Potato to Useful Sugars
E. Nicole Hill, Mari S. Chinn, Craig G. Yencho, V. Den Truong, North Carolina State University

Graduate Poster Competition Winners

FIRST PLACE
An optimized Interdigitated Array Microelectrode Based Immunosensor for Detection of Avian Influenza Viruses
Yun Wang, Ronghui Wang, and Yanbin Li, University of Arkansas

SECOND PLACE
Acoustic Radiation Force Impulse Ultrasound for Monitoring Hemostasis in Femoral Artery Puncture In vivo
Russell Behler, Timothy Nichols, Melissa Caughey, Melrose Fisher, Caterina Gallipi, University of North Carolina at Chapel Hill

THIRD PLACE
Automatic Characterization of Focal Adhesions in TIRF Microscopy Images Matthew Berginski and Shawn Gomez, University of North Carolina at Chapel Hill

Biological Engineer at Work

Beth Brokaw

Alexander Nguyen graduated with his B.S in Biological Resources Engineering from the University of Maryland in 2007. He is now working for GE Medical Systems.

1) How did you choose your major?

I started out in aerospace engineering but was interested in the biological aspects of engineering, which lead me to biological engineering.

2) How did you get your job?

I interned at GE healthcare between my junior and senior years. I really enjoyed the experience. They gave me a job offer and so I knew where I was going to go after graduation before the start of senior year.

3) What does your job entail?

The Operations Management Leadership Program involves rotations around the country for two years with new locations every 6 months.

The first rotation was in Milwaukee and involved management of material suppliers for MRIs and MRI testing.

The second rotation, which is taking place in Cleveland, involves managing a team of around thirty people with production and servicing of equipment. For example the team gets broken surface coils from hospital MRIs that have to be repaired as quickly as possible so that patients get the care that they need in a timely manor. This requires knowledge of mechanical and electrical aspects of the devices.

4) Are you considering an advanced degree to help with your career?

Yes, I am not certain about what type of graduate work but am looking into MBA and medical school programs.

5) Do you find that what you learned at the University of Maryland applies well to your job?

Yes, I feel I was well prepared by the program. The information from my electronics course has been very useful at GE, as has mechanics of materials.

6) Is there any course or skill you wish you'd learned before entering the field?

Once again, I'd say I felt prepared. It's possible more electronics would have helped with my job but each rotation at GE is different and other jobs in the field will certainly require very different skill sets.

7) Do you have any advice for the up and coming biological engineers?

I recommend that students learn as much as they can about the field. Biological Engineering is a very broad field ranging in topics from imaging to pharmaceuticals. It is important to have a wide scope of general biological engineering knowledge.

8) What types of pre-graduation experiences make a recent graduate more desirable for a company?

Previous work experience is very helpful. However, how the person acts at the interview is the most important thing. The interview tells us how well the interviewee gets along with people and is able to express himself or herself.

iFAQ

iFAQ is a new column to appear in the IBE Newsletter, and we intend for it to appear regularly. Questions concerning almost any topic related to Biological Engineering, student life, professional interests, career management, or other issues of concern are invited from the readers of this newsletter. Answers will be contributed usually from older and wiser IBE officers and Council members, and sometimes from students or others in the field. The intent of this column is to give useful advice on topics that are not always discussed among peers. If you have a burning question that you would like to have answered by our distinguished panel of experts, then send them along to Art Johnson, Editor, artjohns@umd.edu. Include in the email subject line the words "iFAQ Questions".

I am an undergraduate student in biological engineering who is going to graduate next year. At this point I really don't know what I am going to do after I graduate. I will probably try to find an interesting job, but don't know what I'd like to do. My advisors keep telling me that I have a wide choice of careers that I can follow, but that is just making it more confusing for me. Can you give me some advice about how to go about looking for the right job?

You really do have a lot of choices as a Biological Engineering graduate. You can pursue jobs in a lot of different fields with every expectation of success. Graduates from the University of Maryland, for instance, are taking jobs in prosthetics, patent offices, biotechnology, medical devices, and environmental and ecological engineering consulting. A significant number of our graduates are applying to medical school, and some are going to law school or dental school. Others are pursing graduate work in environmental engineering, biomedical engineering, or food engineering. One student even said that now that he has satisfied his parents' expectations that he get his engineering degree he was going to follow his dreams and go into music. And just to show you that your first choice of job doesn't necessarily determine your professional career for the rest of your life, one alumnus who I just talked to worked for FDA for a year, decided he wanted to do something else, and is now working in environmental engineering.

Some of our current graduates are looking to take temporary jobs to see what they like and what they don't like, and then either change jobs or go to grad school later. As a matter of fact, it used to be said that engineering graduates spent only a year in their first job, and then they moved on to better jobs somewhere else. You might want to try that approach. According to the AIMBE job placement survey of medical and biological engineering (MBE) students (www.aimbe.org), roughly 40% of MBE graduates found jobs, 35% went to graduate school, 20% went to medical school, and 5% were still looking. Each year the survey is updated, and these percentages don't change much from year to year.

So, what you have to do now is to start finding out what possibilities exist for you. Go to your school career office, and find out what they have. Ask your faculty advisors what they recommend. Find out where graduates from the last few years at your school have gone to work, and contact them. Find out how they like their jobs, what they do, and whether or not they know of positions open in their companies. One of the best ways to find an interesting job is by networking, and your fellow alumni are great people to work with. There are *Biological Engineer at Work* interviews in many of the previous IBE newsletters (available online at www.ibe.org), and these may be helpful and give you some ideas.

In all of this you have to know about yourself: what you like to do, what you are good at, and how serious you are. If you are looking for something ordinary, then find a comfortable job and try it on for a while. Remember, you can always change later when you know yourself better. If you are looking for something different, try an overseas job, or working for an insurance company (they need engineers to suggest solutions to clients' potential risks), or teaching or training. Working in rehabilitation engineering will have you working closely with individuals, and the need is growing as the population ages. Working in biofuels is certainly a hot area these days.

Your vast numbers of career choices, while a problem for you just now, will be a strength for you later. The world is becoming a closer, and flatter place. You will need to be versatile in order to thrive in the new economy. So, you have chosen a great profession to study (see the editorial in the Spring 2008 issue of the AIMBE newsletter, online at www.aimbe.org).

And, finally, don't forget those who come after you. They will face some of the same problems that you now face, only they will confront them a few years down the road. Keep in contact with your school, give talks there, and look upon those graduates as potential employees for your company. Remember that the struggle that you are going through right now will help to make you a better advisor later. -ATJ

STUDENT NEWS

Hello all,

My name is Craig Barcus, the Undergraduate Council member for IBE. I was asked to write a piece for the newsletter, and before I go into what happened on the undergrad end at the conference, I would like to write something about myself. I am currently a junior at Purdue University majoring in Biological Engineering. I have been doing research in nano-materials with biological applications since the beginning of my sophomore year and am currently working on the first part of my Master's thesis. I am the current President of the IBE chapter at Purdue and the iGEM team.

Enough about me, let's look at what happened at the Annual Conference. At the conference, many undergraduate students presented their work from across the country. Students from Utah State, Mississippi State, Louisiana State, Cornell, Virginia, Purdue, and North Carolina State Universities to name a few were represented. To my knowledge, over 30 undergraduate students attended the conference and we hope more will attend next year. The undergrads also put on a little show at the awards banquet, a la American Idol. Five different Universities were represented at the First Annual Undergraduate Entertainment Ceremony, with three distinguished professors as the judges. I am sure this will continue to be a large part of the ceremony, and was definitely worth the price of admission.

In other news, four universities will be hosting a teleconference for Undergraduate chapters in October. Purdue University, Mississippi State University, Utah State University, and Cornell University will be the satellite sites. Live, virtual networking will be utilized to meet and greet with other undergraduates and discover new techniques to increase awareness and membership in the Institute of Biological Engineering.

I hope that everyone has a great summer.

Thank you,
Craig Barcus

1st Place Essay, IBE Annual Meeting

Synthetic Biology: Enormous Possibility, Exaggerated Perils

Zachary Russ, University of Maryland

Nobel Laureate and physicist Richard P. Feynman once wrote, "What I cannot create, I do not understand." In the field of biology, this quote is very apropos. Bioengineering, for all of its accomplishments, still has yet to create life to fit the same sort of precise specifications that chemical engineers have done with molecules and mechanical engineers have with machines. Life is too unpredictable and poorly understood to reach its full engineering potential. The newly introduced field of synthetic biology (synbio) represents a response to that problem. Synbio is epitomized by the BioBricks project, which attempts to create life from scratch with clearly defined and understood interactions between each engineered gene. One success of the BioBricks approach is the complete rewrite of the T7 bacteriophage, which behaves much like the original, but in a very predictable fashion. Synbio, much like genetic engineering in general, is not without its critics.

Many of the public's fears are reflected in *The Guardian* columnist Madeleine Bunting's "Scientists have a new way to reshape nature, but none can predict the cost." Bunting writes that synbio "is a frightening science," that

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New Student Chapter at Purdue

Jenna Rickus

Students at Purdue University established a new student chapter of the Institute of Biological Engineering during the fall of 2007. The chapter was founded by students who were originally brought together by the international Genetically Engineered Machine (iGEM) competition. Participating in iGEM will continue to be a major activity for the chapter. The department of Agricultural and Biological Engineering (ABE) serves as an administrative and supportive home for the chapter, but students from many other engineering and science majors are members. Craig Barcus, a junior in ABE, is the chapter president. He is also the undergraduate student representative on the IBE council. The chapter's next major activity will be to host the first annual Midwest regional student IBE conference in the fall of 2008.

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it "has the potential to be highly accessible ... making the task of regulating its use extremely difficult," and synthetic organisms can "get out and cross with their wild cousins, mutating into organisms we had never foreseen." She expresses concern over the "massive and momentous consequences," comparing synbio to the Industrial Revolution. Professional scientists' concerns are more limited to feasibility, suggesting that it's unlikely humans can design a better biological machine than nature.

Many of these concerns stem from a misunderstanding of synbio. Synbio is a new approach to genetic engineering that knocks out the byproducts of evolution out of the genome either by designing the organism from scratch or removing all of the nonessential DNA from an existing organism. The BioBricks project takes the former approach, and, by designing organisms using standardized building blocks, makes genetic engineering easier and much more efficient. BioBricks provide the potential to quickly and easily make biochemicals and pharmaceuticals without having to worry about unforeseen interactions between the drug genes and vestigial genes. Life effectively becomes predictable and can be modeled by equations. All nonessential processes can be removed in synthetic organisms, so more energy and resources go towards making the product. In the process, engineers gain a greater understanding of life and its mechanisms.

But what of the drawbacks? What will happen if a synthetic organism escapes a lab? Most likely, nothing. With complete control over the genomes of their organisms, synbioengineers can introduce specific weaknesses into their organisms, such as a dependency on a particular amino acid, so that lab experiments have little chance of surviving in the wild. Without the noise data that natural organisms have in their genomes, synthetic organisms will also be very limited in genetic variation and virtually unable to adapt to new conditions. The probability of them hybridizing with wild varieties is also limited – they are synthetic organisms that have little in common with natural life and thus even less chance of recombinants surviving. Compared to organisms created using previous genetic engineering methods, synthetic organisms are much safer, not only because they lack the survival techniques found in nature, but also because they are better understood. Every gene in the organism is there intentionally with a specific purpose and a known function. This greatly lessens the risk of unknown genes triggering allergic reactions, one of the major fears in genetically modified food.

While accidental harm is significant, in the age of terrorism we live in, malice is also an important factor in technologies. While the accessibility of BioBricks makes regulation difficult, synthetic biology is (and will probably continue to be) a long way from a basement technology. Those who would wish to visit destruction on the human race have much easier, more convenient tools available. Nature has already provided massive numbers of harmful organisms, and deadly chemicals are easier to manage and create. With so many variables, the human body is a far cry from the controlled lab environment that synthetic biology addresses. Scientists would have enormous difficulty in creating a virulent pathogen instead of a simple microbe designed to produce a chemical in a sterile, stable environment. Even the advent of computer programming provided an easy route to destruction, much easier than the slight advantage BioBricks provides, by allowing individual computer crackers to cause billions of dollars of damage with a few days of work, but few would argue against the information revolution for this threat.

There is even more risk to not using synthetic biology. Synthetic biology can produce organisms to clean up pollution and provide clean energy. Proteins and food can be created without wasting energy on a full-sized organism, providing cheap ways to make nutritious meals for millions. Without the help of synthetic biology, the Earth may just become uninhabitable for humans as pollutants build up and the climate changes. The dangers posed to the human race are not from genetic engineering so much as they are from well-understood technologies and mechanisms – wasteful energy use, inefficient land use, and straightforward destruction. In many developing countries, respiratory problems stemming from pollution are a persistent and growing problem. Synthetic organisms hold the potential to cleanly and efficiently manufacture products with minimal waste and some may even alleviate the threat of a poisonous atmosphere by breaking down specific toxins.

Ultimately, synthetic biology is about complete understanding. Synbio is the opportunity to gain power over life and achieve the ultimate goal in engineering – to be so familiar with a part that its behavior can be modeled, predicted, and used; and the uses are limitless. Already, a synbio project is close to producing large quantities of artemisinin, an antimalarial chemical; other projects are aimed to make biosensors, anticancer microbes, and clean petrochemicals. Synbio is the next step in the growth of genetic engineering, and it offers a great hope for not only helping humanity but also minimizing the potential pitfalls of genetic engineering. Synthetic biology should be embraced, not feared, for the immense potential it has. As the MIT AI Lab's Tom Knight said, "the genetic code is 3.6 billion years old. It's time for a rewrite."

The Dangerous Social Impacts of Genetic Engineering

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The ability to frame ourselves in terms of our genes is both a blessing and a curse. Since the completion of the human genome project, there is no doubt that genetic research has permeated throughout the scientific world. Most current clinical research includes genetic tests or epidemiological studies to determine genetic factors at play [1]. This type of research can help individuals at risk of carrying a gene for inheritable diseases make informed decisions about how to avoid passing the gene on to offspring. Understanding genetic factors can also allow afflicted individuals to comprehend their situations and make informed decisions. However, genetic research has also illuminated various metaphysical aspects of humanity. Predisposition for addiction, previously perceived as a personal vice, has now been identified to be genetically linked. Even virtues, such as patience can be framed as an absence of a gene for aggressive behavior [1]. Research is going beyond just understanding genes. Manipulation of genes has limitless potential to impact the world. Gene therapy, a treatment that uses non-virulent vectors to deliver genes to cells, has been a popular subject of research for the past decade. While there had been some setbacks, evidence of gene therapy as a successful treatment for Parkinson's disease has demonstrated the potential for this technology [2]. The recent discovery of RNAi and siRNA represents additional methods for controlling gene expression. Phase I clinical trials are already underway for several RNAi and siRNA based treatments. While the genetic engineering technology is still far from reaching the clinical consumer market, the risk for using the technology for applications other than treating diseases is real and can change the fiber of society. It is a practice that must be avoided at all costs.

Society has already started to sense the impact of discovering certain genes that affect aspects of our human behavior including smoking addiction, alcoholism, drug addiction, obesity, anorexia, homosexuality, aggressive behavior, and dangerous decision making. The embracing of genetics may be a result of wishful thinking more than the willingness to accept scientific truth. With the discovery of the obesity gene, people have begun to rationalize their weight gain and look for alternatives to diet and exercise. [1] The notion of willpower has started to be challenged by the medicalization of human behavior. The large-scale social effect is still not known since very few people undergo gene tests for non-illness related conditions. In relation to obesity, on one hand, the social stigmas could dissipate because people will no longer view it as a lack in willpower. On the other hand, all overweight people could start being viewed as genetically inferior. If we consider the gene for aggression, the issues become even more controversial. While studies have shown that violent criminals possess the gene more often that normal people, the presence of the gene is not necessarily predictive of criminal behavior. Should we be more accepting of violent criminals or should we lock them up forever because they are inevitably bound by nature to repeat their behavior? Medicalization of what we previously considered to be variabilities in human behavior has led to more questions than answers, as people wonder how much control they have over their vices and virtues.

It is important to realize that the debate of nature versus nurture has not changed significantly. As a result of gene-linked behavior, the debate now exists on many new fronts. However, the notion that one is simply a product of one's genes must be rejected. Research has shown that, while having a certain set of genes that make one prone to alcohol addiction significantly raises the risk of alcoholism, personal choices are just as important. While treatment for disorders such as drug and alcohol addiction is warranted, genetic engineering is far from being a panacea for these disorders. On the contrary, I believe how we perceive disorders such as addiction has a much greater impact. Those who believe that there is nothing to prevent them from battling addiction or obesity are more willing to face their problems head on. Modern medicine already has numerous technologies to help these types of people. Others who realize their conditions have genetic bases would have no reason to fight nature if genetic engineering represents an easy way out. However, the change in perception that stems from this kind of thought could create a society in which each person is not accountable for his or her actions. It is also a slippery slope that can result in genetic engineering being used to introduce favorable genes, instead of to treat medical problems.

Even now, the technology exists to abuse genetic engineering. Through preimplantation genetic diagnosis (PGD), parents worried about passing on genes for inheritable diseases are selecting for the healthy embryos by utilizing *in vitro* fertilization. [3] While no clinic would allow parents to select embryos based on gender or other non-medical criteria, a deterioration of society's moral fibers due to the unregulated availability of gene therapy could lead to changes in social attitudes toward PGD. In a similar way, I feel that the availability of plastic surgery in the U.S. has adversely changed our attitudes of beauty and accountability. The availability of PGD for detection of genes for inheritable disease has also brought up economic issues. Since the procedure is not covered by insurance, over the long run, it could lead to wider disparity between the healthcare options available to the rich and the poor.

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Although somewhat paternalistic, it is necessary to restrict certain applications of genetic engineering based on moral grounds before the economic and political influences complicate the argument. Gene therapy should only be used to treat diseases with no other treatment options, never for introducing any favorable qualities not present at birth. As for disorders such as addiction, all other methods must be exhausted before gene therapy can be considered. Economic sanctions are not enough. The government must be able to draw the line and take a moral stand. Genetic research and genetic engineering are fields with limitless potential. However, emphasis should be placed on research with the most utility. Research that links character traits to genes causes more uncertainty and compels people to make irrational decisions because they often do not discuss the "nurture" effect. This is different from research that finds genetic basis for diseases, which allows those afflicted to understand their health situation and make more informed decisions. The solution is to put more research funding into research with practical application such as genetic engineering, or into research that delves into the influence certain genes actually have on behavior. It is scary how we considered the movie Gattaca, seen by nearly all high school science students in America, to be science fiction just 10 years ago. Now, genetic inferiority is a serious bioethical issue that must be addressed. While genetic engineering is still far from commercial application, it is important to discuss the issues early on. Precedence has already been set. Even before the human genome project was completed, the Genetic Information Nondiscrimination Act circulated through Congress, aiming to prevent discrimination by employers and insurance companies based on genetic information. [4] The same type of discretion must be taken with genetic engineering technology.

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