The Institute of Biological Engineering

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Summer 2006 Volume 10.2

Mark Your Calendar Now
IBE 2007 Annual Meeting
March 30-April 1, 2007, St. Louis, MO

Meeting Success!

by IBE President, Vince Bralts

The coming year promises to bring success and growth to the Institute of Biological Engineering and to its members. As the 2006 president of IBE, I hope to be a major contributor to that success and growth. But first, I'd like to thank Jerry Gilbert, former IBE president 2005, for his great year of service and stewardship of our organization. Jerry was enthusiastic in initiating several activities during his term as president, including the establishment of several affiliate organizations and the development of the BioNexus, where science and business can meet. Thank you, Jerry, for your service and we look forward to your continued support of IBE over the coming years!

In review, the University of Arizona in Tucson played host to IBE's 11th annual meeting this past March, 2006. Thank you to all of those who had a hand in helping this wonderful and successful meeting come together! Highlights of this year's meeting included a keynote presentation by world-renowned synthetic biologist Jay Keasling of UC Berkley, ten technical sessions on biology-inspired engineering topics, a plenary session on design methods in biological engineering, a general session on bioethics featuring the winners of the student bioethics essay competition, a biobusiness nexus session and a student poster competition. All of these things provided for an innovative and progressive gathering and a great success!

In related matters, plans are also in the works for IBE's 12th annual meeting which will be held March 30-April 1, 2007, in St. Louis, Missouri. The meeting will be hosted by the University of Missouri-Columbia, and I hope you all are planning to attend!

In other news, our organization is now selling IBE Proceedings CD-ROMs. Prices remain in line with last year, $10 for members, $25 for nonmembers. Those members who are interested can order CD-ROMs under the "Members Only" link on IBE's Web site (www.ibeweb.org).

I hope each of you are becoming excited about the opportunities this year can bring! It is an honor to be a part of the leadership team of IBE, and I look forward to many great things ahead for us.

Editor, Art Johnson

The Next Big Thing!

"Technology is neither good nor bad. Nor is it neutral." This quote by Melvin Kranzberg expresses the idea that technology is all-affective. No matter what technological advance we talk about, the advance, once made, changes life for all. The change may be good, and it may be bad, but its bottom line is very often dependent upon how we are willing to use new technology.

At our 2006 IBE meeting in Tucson we learned about artemesinin, synthetic-biology, standard genetic parts, biology-inspired design, and ethics. It was an interesting combination. As you might imagine, lots of people had things to say about ethics, especially when prompted by the winning essays in the student bioethics essay contest that IBE had sponsored. You can read these essays for yourself in this and subsequent newsletters.

Bioethics discussions almost have a life of their own once they get started. The discussion at the IBE meeting was no exception to this, and had to yield to time constraints before it had run its course. Most of the comments were about genetically-modified organisms and how they were either good or bad, acceptable or unacceptable, and there was a certain smug tone to remarks about "others who don't understand about GMOs."

Of course there is really never any resolution to these discussions because absolute right or wrong answers are generally conceded not to exist.

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However, hubris often accentuates irony and many in the room did not really realize that GMO issues were now out of the hands of the developers. GMOs are now able to be patented, so there is nothing we can do about that. Commercial interests have trumped scientific and altruistic interests, so that is largely out of our hands. Promises of less herbicide use have proved to be false, blocks of non-GMO crops that were supposed to have been planted to kill pests in the conventional way (and so delay evolved immunity to genetic modifications) were not planted, and farmers growing plants that show evidence of commercialized genetic modifications must pay whether they planted the crops or not. Legally and commercially the GMO-bioethics game is over.

On the other hand, there are issues on the horizon for which ethical discussion is more than hot air. The case of artemesinin is an example. Our keynote address was about producing this drug to cure malaria by genetically-modified microbes. Producing this drug in this way is not an issue. However, what happens after the drug becomes plentiful and cheap? Will it be abused? You bet! Will it eventually lose its effectiveness? You can count on it! Are there other drugs that can be used in its place? None known. The bioethics discussion therefore, should concern the way the drug is used to maintain its effectiveness for the longest possible time. Biological engineers should know enough about biology (and human nature) to avoid the unintended consequences inherent when dealing with living things.

Or take the winning bioethics essay (appearing in this issue). That essay emphasizes the centrality of human free will. However, recent research results have sown that human actions were actually planned before they were consciously known. The only choice, then, is whether or not to carry out preplanned actions. This has been termed free-won't rather than free-will. Furthermore, there are now being designed prosthetic neural devices meant to correct defects in basic brain processes. It doesn't take much imagination to see where this is headed: with time, higher level brain functions may be performed by complex electronic circuits. At the same time, there are scientists and engineers trying to produce computers with emotions. As the human becomes more machine-like, and the machine becomes more human-like how are they to be distinguished? What are the ethical issues in this Deus ex machina situation?

Are technology advances, and especially advances in bio-technology always good? How do we know? What will give us the ability to judge?

IBE as an organization should be looking for those issues and those realms for which ethical discussions could make a difference. There are the issues of tomorrow, the realms largely unknown to an unimaginative public, the questions where real leadership is necessary to guide the directions of bio-technology. It is here that IBE can make a real difference.

IBE Chapter/Branches Committee Report

Lalit Verma, Chair

The committee met on March 9, 2006 and makes the following recommendations:

1. Dual student membership should be pursued with other professional societies, with about $10 additional fees, for the dual student membership. Such an arrangement, for example, with ASABE for a fee of $35 would be attractive to students. The fee should be the same for graduate and undergraduate students. This could be pursued under the associate membership MOA's with other professional societies.

2. Student Chapters should be required to submit annual reports by February 15 of each year to Ardel. These reports must include student club officers, faculty adviser, summary of activities for the past calendar year and plans for the current year. These reports should be maintained for five years.

3. Each student chapter should have at least one representative at the IBE Annual Meeting and meet as a group of chapters to discuss progress, activities, plans, and ideas.

4. The Chapter Committee should review the chapter reports and provide a status report to the Executive Committee by March 15. Chapters delinquent in providing reports should be contacted by March 1 to obtain a report.

5. The IBE Poster Competition should be divided into undergraduate and graduate categories.

6. A block of time should be allocated at the IBE National Meeting for inter-club chapter activities, starting with the 2007 meeting in St. Louis. The Chapter Committee should assist in coordinating the program for this part of the program.

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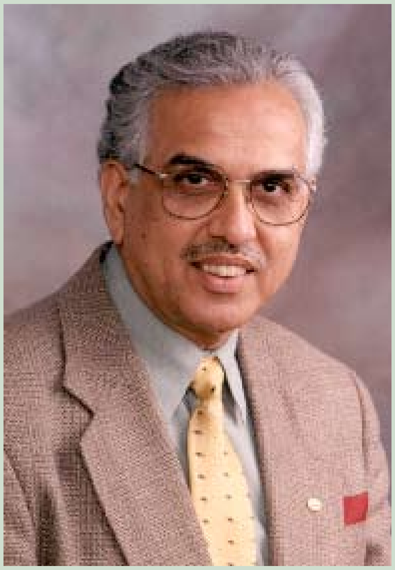


Brahm Verma Recipient of New Vision Award

The IBE Recognition/Awards Committee made a recommendation at the October 2005 meeting of the IBE Council that a new vision and leadership award be established. The award was established to recognize an IBE member who has made significant contributions to the field of Biological Engineering and who has exhibited action and vision in advancing the field. The award is to be presented periodically and only when deemed appropriate.

At the banquet of the 2006 Annual Meeting of IBE, the Council presented the first award to Dr. Brahm Verma, Professor of Biological and Agricultural Engineering at the University of Georgia and the founding president of IBE. In future years, the award will be called the Brahm Verma Lifetime Visionary Award. The naming of the award in Dr. Verma's honor is in recognition of the fact that Brahm Verma was the driving force behind creating IBE and that without him, the organization would not exist today. The inscription on the 2006 Award reads:

"*On behalf of all the members of IBE, the Executive Council makes this Lifetime Visionary Award to Brahm Verma. He has positively impacted the past and present members of IBE, and his influence will continue to impact members long into the future. He has provided the visionary focus and driving motivation to form IBE, and he continues to articulate a future of engineering and biology so that others can join that future. He served as president of IBE in 1997 and has taken on numerous roles since then to ensure the success of IBE.*

With this award, we express our sincere debt, gratitude, and appreciation for his unselfish commitment to the engineering profession, to the field of biology, and to IBE."

IBE President Makes Citations

At the annual meeting, citations were given to five other individuals in recognition of their exemplary service to the IBE professional organization. The recipients are listed below.

Art Johnson has served as the editor of the IBE newsletter since its inception in 1995. Over the years, he has been an advocate and faithful ambassador for IBE in his involvement with other societies.

In addition to serving as president in 2004, **Lalit Verma** has provided leadership in reaching out to other professional societies in interfacing with affiliate societies of IBE and in service on the Executive Committee.

During the 2005-2006 fiscal year, **Terry Walker** served as co-chair of the Meeting Committee and put forth a significant effort in helping organize the presentations for the 2006 Annual Meeting of IBE.

Mark Riley served as local arrangements coordinator for the 2006 Annual Meeting of IBE in Tucson, Arizona. The success of the 2006 Annual Meeting is due in large part to his hard work and dedication.

In addition to serving as president in 2003, **Roy Young** has provided leadership in reaching out to other professional societies as the liaison to the American Institute of Medical and Biological Engineering and in interfacing with affiliate societies of IBE.

Technology and the World's Problems

Thomas Cathcart

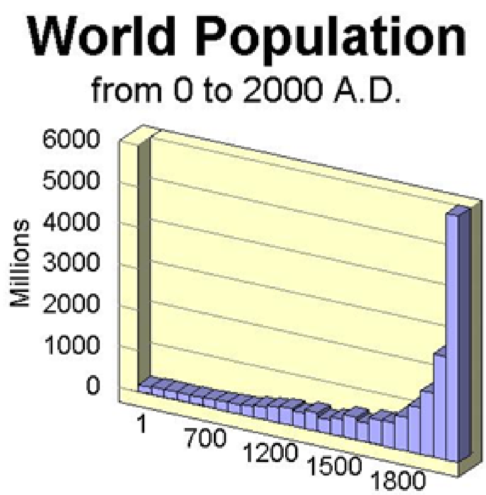
At the recent IBE meeting in Tucson, there was an interesting discussion about the advantages and disadvantages of producing genetically engineered crops. The discussion mainly centered on the potential for feeding the hungry of the world versus the potential for initiating a genetic catastrophe by creating new types of plants that have not been naturally selected.

An important element in this discussion was only mentioned in passing (by me, as a matter of fact). Individual technologies do not exist in a vacuum. They emerge as part of a mosaic of all related technologies, providing the opportunity for synergistic relationships that can be either helpful or harmful. An example of this is the relationship of genetically engineered crops and world population.

Thomas Malthus said that population increases exponentially while our resources to support population can, at best, increase arithmetically. He contended that any positive exponential function will inevitably outstrip any arithmetic function at some point and he used this contention to explain the poverty-induced misery that he observed.

If you look at world population since the beginning of the Christian era, population growth appears to have a significant exponential component and we are in the middle of a period of rapid growth. I would go further and say that we have, through our technological development, increased earth's carrying capacity for humans, allowing exponential increase to continue and accelerate. Projected population values for 2050 are 9-12 billion people at the current rate of increase.

If we return to the desirability of increasing resources using genetically modified crops, two scenarios emerge. The first is that this technology could be used with continued exponential population growth. I have not seen any evidence that Malthus was wrong. Any exponential function will eventually surpass any arithmetic function. If we assume that we will not be eternally able to increase carrying capacity, then eventually the crash will come. If we assume a global famine that results in a 1/3 die off of earth's human population, then at the present time, 2 billion people would die. If we assume that it will happen some time in the future (say when the population is 9 billion) then 3 billion people will die. That's 1 billion more deaths, more misery, more starving children. In this case, the application of this technology would have made the results more horrific.



The second scenario is that increased food production via genetically modified crops accompanies a determined effort by the world's population to reign in population growth. In this scenario, the technology may help us to engineer a soft landing as world population closes in on carrying capacity, reducing misery and the potential for famine.

Most technologies are neither inherently good nor bad. Whether they help us or hurt us depends upon their inter-relationships with other elements within the population. With regard to population and carrying capacity, I would like to finish with an analogy close to the hearts of good engineers. We have gotten very good at building what amounts to a cantilevered beam. One might even say we have become spectacularly good at it. We have, however, forgotten that a cantilevered beam cannot go on forever and we are building as though it can.

The Academic Profession

by Jerome Gilbert

At the 2006 annual meeting of IBE in Tucson, I had the opportunity to be engaged in a number of interesting conversations and discussions about biological engineering, careers, and life in general. The subject of careers was particularly appropriate because we had so many undergraduate and graduate students at the meeting, and they were quite naturally poised to make decisions about their futures. Around half of the 150 or more attendees were students.

The focus of one of the career discussions was satisfaction with the choice of going into a career in academics. It has been my position for my whole career that there is no better occupation than that of a university professor (and that has been about 25 years). With the exception of owning your own business, there is no career where you are afforded so much independence and freedom to make as much success for yourself as you can handle. There are your research endeavors, your teaching in the classroom, and your service to the university and your profession. All of these go into the responsibilities of a faculty member. But the excitement of the job is, in large part, due to the fact that you are in the business of knowledge, creating knowledge and sharing knowledge. Being at a professional meeting, such as the IBE annual meeting, where we share new knowledge gives us time to think about where we are in our professional development and to perhaps reflect on the future. It is intellectually and personally satisfying to interact with colleagues and to be recognized by our peers as we add to the body of knowledge.

While talking to one of my colleagues between sessions in Tucson, we both came to the conclusion that the real payoff in the academic profession is the interaction with your students. The impact that professors, and all teachers for that matter, have on developing minds is one of the greatest impacts that you can hope to have in your life. In the end, when it is time to reflect on the impact that my life has had, I will not think of the positions or journal articles or conferences, but of the times when parents and students have come up to me and said "thanks for making a difference in our lives." The touching of lives and subsequently making a difference in people's futures are what makes academics a truly noble profession.

An Update on Happenings at Maryland

Last year we reported in this newsletter the recommendation that a new Bioengineering Department be established at Maryland, and that such a department would supercede the Biological Resources Engineering (BRE) Department. In May of 2005 the Provost announced that a Bioengineering Department would be formed in the College of Engineering and that there would no longer be any engineering the College of Agriculture and Natural Resources. The new department would begin on 1 July 2006.

Faculty in BRE were given the choice to affiliate with the new department in the College of Engineering or to remain with the College of Agriculture and Natural Resources in other assignments. Four faculty members chose to change departments and colleges. No partial appointments were allowed.

Other faculty in the Clark School of Engineering were also asked if they wished to join the new department. About six of these indicated that they also wanted to join.

In December it was announced that Robert Fischell and his family would donate $31 million to the new Fischell Bioengineering Department and, within the department, a Robert E. Fischell Institute of Biomedical Instrumentation. Dr. Fischell heads a company that is a leading supplier of vascular stents, and his sons also head companies that manufacture neural stimulators and other devices.

Discussions were held to establish the undergraduate educational program in bioengineering. The curriculum is based on the previous BRE curriculum with several modifications: several additional courses, such as biomechanics and physiological systems, were added, and a Biology for Engineers course was moved to the freshman year. This curriculum and the new department have received campus approval.

Discussions have not yet taken place regarding merging the BRE graduate program and the existing Bioengineering graduate program in the College of Engineering. The latter was intentionally structured with minimal overlap with the BRE graduate program. Likewise, details concerning departmental procedures have not been finalized either. Many of these may not be considered before fall 2006 because faculty in the College of Engineering generally have nine month appointments.

There will be one last BRE freshman class. It is also anticipated that the bioengineering program will begin this fall. Judging by conversations thus far, most, if not all, BRE freshmen will probably switch to bioengineering. BRE courses will continue to be provided until the current BRE students graduate.

Poster Winners IBE 2006 ANNUAL MEETING

Congratulations to all!

1st Place:
Andrea Ludwig, Marty Matlock, Brian Haggard, University of Arkansas, Biological and Agricultural Engineering, Fayetteville
Titled: *Identification and Evaluation of Limiting Factors on Algal Growth in Headwater Ozark Streams*

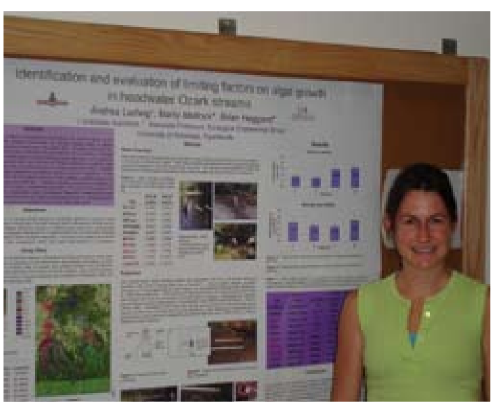
2nd Place:
Ashwath Jayagopal, Raghav Venkataraman, Greg P. Stone, Frederick R.Haselton, Dept. of Biomedical Engineering, Vanderbilt University
Titled: *Light-Guided Surface Engineering for Biological Screening Applications*

3rd Place:
Diana DeRosa, Dr. Mark Riley, The University of Arizona, Department of Biosystems Engineering
Titled: *Evaluating Titania as a Model Biomaterial Using Murine Alveolar Cells as Probes*

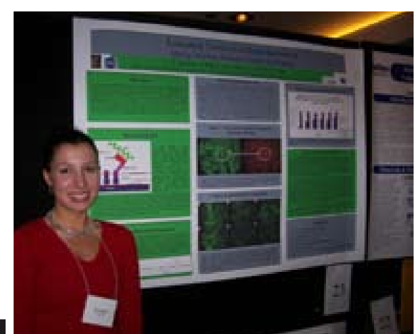
Honorable Mentions:
E.A. Hawes, J.T. Hastings, C. Crofchek, M.P. Menguc, University of Kentucky
Titled: *Surface Plasmon Assisted Melting and Fusion of Nanosized Particles: The Underpinnings of Directed Self Assembly*

Christina Matson, Jianxu Zhao, John Koehler, Arun Bhunia, Jenna Rickus, Department of Agricultural and Biological Engineering, Mississippi State University
Titled: *Development of a Liposome-Based Biosensor for Listeria Monocytogenes: Determination of Phospholipid Concentration in Liposome Solution*s

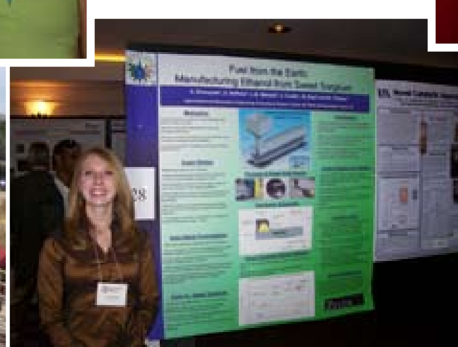
Nalinikanth Kotagiri, Jeong-Hwan Kim and Jin-Woo Kim, Biological and Agricultural Engineering, University of Arkansas
Titled: *DNA Hybridization Kinetics Based on Reaction and Diffusion in DNA-Carbon Nanotube Nanoarray System*



Andrea Ludwig with the 1st place poster.



Diana DeRosa with the 3rd place poster.



Erin Blomquist with her senior design project poster.

Insects Used as Environmental Biosensors

by Glen Rains

Many animals are known to have a remarkable ability to detect, recognize and locate target materials based on olfactory, visual and other cues. However, the capacity hidden within these natural sensing systems has remained poorly understood and largely unused, other than a long and rich history whereby dogs' keen sense of smell has been used for detecting and monitoring for drugs, cadavers, bombs, contraband, etc. Emerging information regarding the chemical detection capabilities of insects has revealed the potential for developing detection strategies utilizing whole invertebrate organisms that are highly sensitive, flexible, portable, cheap to reproduce, and easy to use.

Dog training relies on the associative learning process discovered and made famous by Ivan Petrovich Pavlov in 1927. Since that time, associative learning has been proven to occur in invertebrate organisms as well. While insect learning has not been a widely studied phenomenon, a substantial study of learning and conditioning in invertebrate organisms was funded by the Department of Defenses DARPA program in the late 1990's. Parasitic wasps, moths, honey bees and other insects were studied to determine their abilities to learn specific odors and provide a method of alert when these odors were encountered. Our studies have focused on a parasitic wasp, Microplitis croceipis, a beneficial insect species that helps control populations of crop pests. These wasps find hosts for their eggs by following chemical signals produced by the plants their hosts are feeding on. Microplitis croceipis' hosts are two moth larvae that feed on cotton and corn. When these larvae feed on the plants, their "spit" initiates the biosynthesis of volatile chemicals that attract the wasps. The volatile compounds are produced systemically within 24 to 48 hours after the larvae begin feeding on the plants.

Parasitic wasps are extremely easy to handle (they do not sting), cheap to produce (pennies per wasp), are extremely sensitive to chemical odors, and can be quickly conditioned (trained). Wasps can be conditioned to an odor within minutes and on the spot if necessary. An unconditioned stimulus (sugar water) is associated with a conditioned stimulus (odor) by feeding sugar water to starved wasps for 10 seconds. This association is made stronger by repeating two more times with about one minute between feedings. Wasps will then respond to the odor with a food-searching behavior. The strength of the association does not increase with further conditioning and the memory of the association can be retained for at least 48 hours.

In addition, wasps conditioned to associate one odor (odor 1) to food can also be conditioned to associate another odor (odor 2) to its host (moth larvae). Subsequently, when the wasp is exposed to one of the odors, it will exhibit a resource-dependent behavior that can indicate which odor it is detecting. In other words, if the wasp exhibits food-searching behavior it has detected odor one. If it exhibits host-searching behavior, it has detected odor 2. A number of odors could also be examined using several wasps, each conditioned to a different odor.

Because many potential applications occur in environments that are completely unnatural, wasps need to be "contained and observed" as opposed to "released and followed". In open flight, there are too many distractions; especially in artificial environments (They would just as likely fly to a light as toward an odor in a room).Consequently, testing consists of introducing the odor to the wasp and observing its behavior to the odor. A positive response to an odor can be determined by subjectively watching the wasp for its specific behavior. Using this method, several studies were conducted to test for potential applications of wasp sensors, and to compare their sensitivity to an electronic device. One such study was conducted to determine if wasps could detect aflatoxin in corn and peanuts. We discovered that the wasps could detect aflatoxin-producing fungi and discriminate that fungus from non-toxin producing strains of the same species. Another study indicated that the wasps were able to detect dinitrotoluene (DNT), a volatile released from the explosive TNT. Finally, we compared the sensitivity of the wasp to an electronic nose (e-nose). The wasp and e-nose were tested to determine their threshold of sensitivity to a fungal odor and a plant. The wasps were almost 100 times more sensitive than the e-nose.

Even though it was shown that these parasitic wasps were easily conditioned, extremely flexible in their ability to sense different compounds, and also highly sensitive, it was little more than a novelty unless a method could be developed to utilize this technology in a usable device. Therefore, the next step was to develop a portable device that measured the wasp's behavior objectively, without human interpretation, while sampling for odors of interest. Based on the work of my graduate student Sam Utley, we developed a device to visually interpret the food-searching behavior and a software program to analyze the movements of five wasps within a device that controls the wasp's environment. Outside air is pulled into the device and a camera records the behavior of the wasps to the sampled air. A positive response can be determined within 20-30 seconds.. We dubbed this device the "Wasp Hound" to illustrate its connection to sensing chemicals using conditioned animals.

Future research is focused on unraveling the behavioral responses to changing odor characteristics, examining other insect species for associative learning and sensing capabilities and studying the integration of olfactory coding and insect behavior to develop better sensing devices (biomimicry). Preliminary results indicate that there is a correlation between wasp body movement and odor concentration and quality. By analyzing this behavior "on-the-go", we should be able to modify the current "wasp hound" to track an odor to its source, either manually while moving the wasp hound around, or automatically using a robotic vehicle. Secondly, other insect species are being examined that may be better suited for specific applications. For example, a fungi-eating beetle may be more easily conditioned and sensitive to pathogenic fungi that grow on plants. Finally, the study of the insect sensing system and behavioral response could also help develop better electronic sensors from biomimicry of the insect sensing system. Little is known about the signal integration from the antennae, where the olfactory sensors are, and the antennal movement during initial detection and subsequent tracking of an odor. Understanding the fundamental mechanisms behind the antennal system could lead to the development of chemical tracking systems utilizing electronic sensors.

CALL FOR CONTRIBUTIONS

Encyclopedia of Earth (http://www.earthportal.net/eoe)

The world's experts on the environment of Earth, and the interaction between society and the natural spheres of the Earth, are forming to produce a single comprehensive and definitive electronic encyclopedia about the Earth. The *Encyclopedia of Earth* (EoE) will be free to the public and free of advertising.

We seek all qualified editors and authors to collaboratively develop:

- A free, fully searchable, trusted source of articles about the Earth
- A to Z coverage of topics describing the environment of Earth that span the natural, physical, and social sciences, the arts and humanities, and the professional disciplines
- An information resource that will be useful to students, educators, scholars, professionals, decision-makers, as well as to the general public
- An authoring site that combines the authority of peer review with the power of Web-based collaboration
- A public reference site that is updated every 15 minutes

Editors: Professor Cutler J. Cleveland of Boston University, Editor-in-Chief of the award-winning *Encyclopedia of Energy* (Elsevier Science), is the Editor-in-Chief of the *Encyclopedia of Earth.* A distinguished International Advisory Board provides editorial oversight (see below).

Publisher: The *Encyclopedia* is one component of the *Earth Portal (http://earthportal.net/)*, the world's first comprehensive resource for timely, objective, science-based information about the Earth and environmental change. It is published by the Environmental Information Coalition, National Council for Science and the Environment (http://www.ncseonline.org).

Scope: The scope of the *Encyclopedia* is the environment of the Earth broadly defined, with particular emphasis on the interaction between society and the natural spheres of the Earth. See the taxonomy and topic areas at http://earthportal.net/EP/eoe/eoetopics/.

Join the Effort: If you are interested and want more information, please send an email to <eoe@earthportal.net>, or visit (http://earthportal.net/EP/steward/).

Biological Engineer at Work

Wendy Devaney graduated from the Biological Resources Engineering program at the University of Maryland in 2000.

How did you choose Biological Resources Engineering as your major?

I had always known I wanted to do something related to the environment. I started out as chemistry major. After three years, I switched to Biological Resources Engineering because I had heard it had an environmental engineering focus. Although it took me five years to graduate, I found the environmental and water resources program within Biological Resources was exactly what I wanted to do.

What does your current job entail?

I am currently employed with a company called Environ, an environmental consulting company. I am based out of California, and I work on water-remediation treatment systems, sub-surface water investigation, and ground water clean up plans.

Do you use what you learned in your biological resources education in your current job?

I did learn many of the basics as an undergrad. Hydrology and groundwater modeling was covered slightly in my biological resources courses as well as civil engineering electives. However, I learned most of what I needed to know after the company hired me. My undergraduate program did teach me the fundamental background I needed to succeed in an environmental engineering career.

What was the most beneficial part of your undergraduate studies?

I think the most critical thing I gained as an undergraduate was good technical writing skills. The required technical writing class, as well as the many technical reports we were required to write for design projects, prepared me well for my career. I often have to write reports on my work, and the experiences I had in my undergraduate classes makes it much easier for me than some of my coworkers.

How did you go about the job searching process after graduation?

After graduation I moved back home to the Northeast. I had applied for jobs and interview through the Maryland Career Center for jobs in that area, but I wanted to go home for a while. My mother actually had a connection with

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someone working in the environmental field, which is how I obtained my first job. I remained in touch with a coworker from that company, and after she left the company, she was able to get me a job at her new company, which is where I currently work.

Does it limit your career to have a B.S. degree? Do you have or want to get an advanced degree?

I do not think not having an advanced degree has limited me. I think it depends on whom you talk to and their jobs right out of school. I was very lucky to get a job I enjoy, and do not currently feel that I should have gotten an advance degree right away. I did take the GRE's while an undergrad, but I really wanted to go in the work force after graduation. I do believe for most areas of bioengineering it might be easier to get a job with a higher degree, but I do not feel it is absolutely necessary for the environmental aspect of engineering.

Did you take the Fundamentals of Engineering exam your last semester? Are you pursing a PE certification?

I took the fundamentals of engineering exam a year after I graduated. It was definitely hard for me to remember all of the information. I recommend not waiting and doing it as soon as possible when you are still in school. I am not sure if I want to pursue a PE. I might consider working towards a PE if my company is willing to pay me to go through the process. If I ever want an environmental consulting job, I will need PE certification.

What do you see as the most prominent up coming fields in bioengineering?

Since I work in environmental engineering, I do not feel I know much about the bioengineering field. As an undergrad, biotech and everything "dot com" was very popular. Now that bioengineering is becoming so popular, there seems to be less interest in the environmental side. However, there are still countless opportunities in either field.

Do you have any advice for up coming Biological Resources graduates?

Definitely build up your resume while still in school. Make sure you have internship and other related experience in your field. It will make it much easier to get a job. Interview through the career center, and attend information sessions to meet people, even if not exactly in your field of study. Just keep in contact with the people you meet, and do not be afraid to ask for advice or help.

IJEE Special Issue

The Volume 22 (1) 2006 issue of the *International Journal of Engineering Education* is devoted to Agricultural/Biosystems/Biological Engineering Education and contains papers of interest to IBE members. The issue, co-edited by Guest Editor and IBE member Joel Cuello, includes papers authored by several IBE leaders. The following are abstracts from the issue. Issues of IJEE may be obtained from TEMPUS Publications, Dublin Institute of Technology, Bolton St., Dublin, Ireland.

The Making of a New Discipline, Arthur T. Johnson

The transformation of agricultural engineering into biological engineering is a larger change than meets the eye. First of all, agricultural engineering is an applications discipline, and biological engineering is a science-based discipline. Thus, the emphasis of the education must change from its specific uses to a more general utilization of biological systems. Second, any discipline must have a core set of technical materials and methods. In agricultural engineering, these were largely supplied by the Ferguson Foundation series of textbooks that were used very widely. A new agreement must be reached about how to supply these for biological engineering. Third, biological engineering is not likely to evolve only from agricultural engineering. Chemical engineering, and to some extent biomedical engineering, also has designs on the discipline. Fourth, although the goal of biological engineering has been fairly clear since the 1970's, the steps to reach the goal are not obvious to those who are trying to form the new discipline. The prospects for the new discipline of biological engineering are great, but much work needs to be done.

DNA of Biological Engineering: An Engineering Discipline, Norman R. Scott

A fundamental question is whether biological engineering will become a science-based engineering discipline (like mechanical engineering, electrical engineering, chemical engineering, civil engineering, etc.) or be a subject area where engineering is applied to biological systems. My conclusion, which is presented in this paper, is that biological engineering has the 'DNA' and rational structure to be a well grounded engineering discipline with a mature industry to support its graduates. Also, it is essential that biological engineers adopt a definition of biological engineering and use it consistently in all communications. To do otherwise will add to the confusion about biological engineering and continue to contribute to fragmentation.

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Comparisons of 'Bio'-type Engineering Undergraduate Curricula from Agricultural, Medical and Chemical Origins, Roy E. Young

Since 1965, undergraduate 'bio'-type engineering curricula have evolved from two primary application origins: agricultural and medical. A third origin emerged around 1999 from the chemical engineering community. Comparisons were made among these three curricula by using 20 selected topics representing life sciences, core and advanced engineering, and mathematics and statistics. Of the life science topics, agricultural and chemical curricula have comparable requirements for organic chemistry and biochemistry that are greater than those for the medical curricula, while agricultural and medical curricula place greater emphasis than chemical on introductory biology. Medical curricula dominated requirements for physiology (mammalian), agricultural curricula dominated requirements for microbiology, and chemical curricula dominated requirements for advanced biology topics. Agricultural curricula place a more encompassing emphasis on core engineering topics (engineering graphics, statics, dynamics, fluids, and thermodynamics) than either medical or chemical curricula. With advanced engineering topics, all three curricula have placed greater emphasis on evolving transport phenomena to overcome limitations for biological systems inherent in classical heat and mass transfer. Instrumentation is emphasized strongly in agricultural and medical curricula but not in chemical curricula. Agricultural and medical curricula place comparable and much stronger emphasis on statistics than chemical curricula. Opportunity exists for all three 'bio'-type curricula to work together to develop a biological engineering experience that appropriately balances broad-based core competencies with specializations for the undergraduate level.

The 'Bio'-Type Engineering Name Game, Roy E. Young

Three traditional engineering communities—agricultural, medical, and chemical—have shown interest in forming undergraduate 'bio'-type curricula. Nomenclatures for their efforts, however, have been quite variable both in curricula and department names. The agricultural community has the longest track record and also has the greatest variability of names. The medical community has essentially made the name bioengineering synonymous with biomedical engineering. The chemical community is the most recent to enter this endeavor, and has to date shown more efforts with respect to department name changes than with curricula name changes. Analyses of recent data collected by the ASABE (American Society of Agricultural Engineers) indicate that 'Bio'-only names are statistically correlated with increases in undergraduate enrollments. Combination 'Agr' and 'Bio' names have not yielded significant increases in enrollment, regardless of the ordering of the respective terms.

'Engineering to Biology' and 'Biology to Engineering': The Bi-directional Connection Between Engineering and Biology in Biological Engineering Design, Joel E. Cuello

Biological engineering, the engineering discipline that connects engineering and biology, encompasses both 'connecting engineering to biology' and 'connecting biology to engineering' in its engineering design process. The first directional case of 'connecting engineering to biology' pertains to the application of the engineering design process to regulate and manipulate a given biological system for the purpose of achieving a desired end. The second directional case of 'connecting biology to engineering' pertains to employing the knowledge of the attributes of biological systems to inform or guide the engineering design of a physical system for the purpose of achieving a desired end. The second directional case of 'connecting biology to engineering' pertains to employing the knowledge of the attributes of biological systems to inform or guide the engineering design of a physical system for the purpose of achieving a desired end. For 'connecting engineering to biology' the object of the design process is a biological system and its design factors are limited to physiochemical principles. Contrastively, for 'connecting biology to engineering' the object of the design process is a physical system and its design factors are limited by biological attributes. The first case of 'connecting engineering to biology' addresses the design of: (1) protocol for biological system; (2) structure for biological system; and (3) model for biological system. The second case of 'connecting biology to engineering' addresses the design of: (4) material based on biological system (5) machine/device based on biological system; and (6) instrument based on biological system.

The Descent of Biological Engineering, Joel E. Cuello

The genealogy of Biological Engineering, spanning a period of at least four millennia, shows that Biological Engineering is descended from the intersections of various disciplines that originate from three ancient pillars of knowledge, including the practices of engineering and medicine and the discipline of philosophy. The descent of Biological Engineering through the ages flowed from the demise of Teleology and from the triumph of Mechanism, making Biological Engineering a throughgoing mechanistic discipline, no different from all the other modern engineering disciplines. It is the mechanistic nature of Biological Engineering that enables the basic technical activity of Biological Engineering, engineering design, to be successfully accomplished. The genealogy of Biological Engineering also underscores that, based on historical evolution, Biomedical Engineering precedes Biological Engineering. Based on the disciplinary hierarchy, however, Biomedical Engineering falls under the rubric of the broader, more inclusive, Biological Engineering.

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The Evolution of Biological Engineering, Bernard Y. Tao, Douglas K. Allen and Martin R. Okos

The discipline of Biological Engineering is an academic structure evolving to address educational needs based on technologies arising from the new advances in the life sciences. This paper focuses on presenting concepts that distinguish Biological Engineering as a discipline, distinct from existing engineering disciplines, based on unique principles that define biology/living systems. It presents a perspective of Biological Engineering that focuses on the engineering of the inherent, central principles of living systems versus the application of externally engineered systems to existing living systems to alter their behavior or structure. Important concepts in educational curricular topics and concepts are also discussed, along with the historical background to the development of Agricultural Engineering into Biological Engineering.

Building an Integrated Undergraduate Biological Engineering Program in an Agricultural and Biological Engineering Department: Incorporating the Student Perspective, Jenna L. Rickus

Agricultural engineering is the only traditional engineering discipline in which biology and living systems have always played a major role. The emerging field of biological engineering, therefore, finds a natural home in agricultural engineering departments, many of which have recently changed their names to reflect their inherent and growing emphasis on biology. These departments are restructuring, or expanding to integrate focused biological engineering programs into their educational infrastructure. The goal is to create a new community of engineers who are savvy in the biological sciences and can engineer living systems. This paper discusses the challenges specific to building biological engineering programs in a historically agricultural engineering department at the undergraduate level and suggests a framework for meeting these challenges. The student perspective is emphasized and the author draws on personal experience as both a former student and a current faculty member in biological engineering. The recent efforts within Purdue University's department of Agricultural and Biological Engineering are used as an example and a backdrop for discussion.

Student Perceptions of the Public Image of Agricultural Engineering and Their Preferred Name for the Discipline and Title Degree, Linus U. Opara, Seif S. Al-Adawi and Talal S. Al-Shukeili

During the past decade, there has been a worldwide debate on the future of Agricultural Engineering education. In a previous paper, we discussed the historical evolution of and curriculum reforms in agricultural engineering (AE) education at Sultan Qaboos University. Some of the significant changes implemented during the last decade have included renaming the department and degree major, and restructuring the curriculum to meet ABET's minimum requirements for professional accreditation. Our objective in the present article is to assess students' perceptions on several issues affecting the future of agricultural engineering education, especially the factors which influence its attractiveness to students. Our results show that the majority of students perceived the public profile of AE and public understanding of the role of AE in society to be very low. The poor image of agricultural engineering was mostly attributed to its association with agriculture (74%) rather than engineering (26%). The majority of students expressed a preference for a degree name that includes 'Engineering' or 'Technology' rather than 'Agriculture' or 'Science'. The low appeal of names connected with biology among the students was attributed to the high esteem accorded to the engineering profession in society and also a strong connection made by students between engineering and 'machines' and between engineering and math/physics instead of engineering and biology. Students also suggested practical steps to enhance the image, visibility and appeal of AE among students through targeted promotional campaigns and community outreach programs.

Institute of Biological Engineering
2005-2006 Bioethics Essay Contest
First Place

It's Your Choice

by Casey Lee Berson
Cornell University

The entertainment industry has always questioned boundaries between humanity and science. Recent movies such as *Gattaca, The Matrix*, *AI: Artificial Intelligence*, *Minority Report* and *I Robot* have all explored the boundaries between technology and humanity. At the core of these commentaries lies the basic difference between man and machine—that man can choose the direction of his life and machine cannot. Our physicality, does not define our essence. Free will is the essential aspect of human experience that differentiates humans from machines. Advancements in technology and science benefit human evolution up until the point that we lose control over decisions. Once we have crossed that line, we have overstepped the boundaries of humanity.

At the core of every decision lies free will. Free will means that our choices are ultimately our own; it is the essential aspect of being human. In moments of persuasion we find our greatest inner strength and more broadly, our humanity. Individual thought shapes and moves our society, not individual physicality. Differences in opinion are essential to progression and changing one's physicality does not undermine this aspect of humanity.

Humanity may be defined spiritually, socially, and biologically. While there is some overlap within these three classes, they each have their own foundation. The question then becomes, how do foreseeable technological advances affect each of these subcategories, and therefore humanity as a whole?

Socially, humans are a complex species. We form groups that work to both compete and help one another. Peer pressure and choice are at the core of our social network. While others force us to push the limits of society, they also force us to make decisions on a daily basis. It is this ability to deduce and choose that provides us our greatest strength. From these decisions stem pride, dignity and honor. How we exercise free will in a social setting has a profound effect on how we feel about ourselves and our overall quality of life. This is because when we exercise free will, we are consciously forming our own moral character.

An equally important piece of humanity is spirituality. Humans have distinguished themselves from other species on this planet spiritually. While other animals have a specific biological make-up and may have a social structure, it is the core beliefs that humans hold which set them apart. While it would be erroneous to claim that all humans hold the same beliefs, it is fair to say that almost all humans have some sense of what is right and wrong in their own culture. At the basis of spirituality lies the choice to decide what to believe and how to act on it. Free will is once again a building block.

Biologically we think of humans as a bipedal primate. In more general terms; when we picture a human we see two legs, two arms, a body and a head. Physical attributes such as hair color, body type, facial structure, vision, and gender are unique to individual persons based on genetic makeup. It is these characteristics that advancements in technology hope to improve. These advancements are not meant to deplete any genetic variability, but rather to better the standard of living. Engineering advancements that could produce a perfect metabolism, perfect sight, vision or internal organs could also allow humans with an opportunity to further the influence of free will by allowing for a choice in our physicality. We are at a stage in our development where biotechnological advances capable of producing the ideal body are within reach. However, much like trading in a used Chevy for a new Acura does not change the fact that you are driving a car; these alterations will not change the core of what defines humans.

Humanity is a combination of the above categories. While we have a basic sense of beliefs, we also have a choice of whether or not to uphold those beliefs. Socially we are constantly testing the bounds of acceptance. Creativity, power, and intelligence are relentlessly forcing society in different directions. In all fields of study and life, free will is necessarily exercised daily. Technologically, when replacing body tissue and parts, we do not lose the essence of being human because our physicality does not define our humanity.

Some argue that improving upon our physicality unifies us and therefore, forces our society into conformity. This claim is untrue. The argument implies that at the basis of individuality lies appearance. While I do concede that we have formed a society segmented by looks, in the future we will be forced to differentiate ourselves by other standards. Intelligence, wealth, and character will be the basis for individuality. Advancements in Engineering do not, at this point, seek to diminish individuality, choice or free will. The aim is to make humans, as a species, more adaptable to their environment. And who's to say that this isn't just the next step in evolution?

If we accept Darwin's theory of evolution, then these technological steps may just be the next species advancement. It may be that the way to move forward is for humans to push their own species further by using their intelligence to perfect their physical attributes. What essentially defines the species as human will always be a central aspect of that enhanced species because what fundamentally characterizes humans is not simply the superficial. As long as humans have the choice to differentiate themselves from others, there will always be a struggle within society that forces us into the future. We will remain human as long as we remain unique in character because it is by character that we are defined.

Our desire to exceed the normal functioning level of our body through engineering advancements will only be inappropriate when we allow technology to eliminate the ability to choose. If, for example, in the future we engineered a computer chip that allowed the government to see our thoughts. Even in the name of safety, this would be an improper pursuit because it would undermine free will and choice. It is wise to be wary of where technology is taking us, but it would be unwise to shy away from progression that is still permitting and encouraging the essence of being human.

Institute of Biological Engineering
2005-2006 Bioethics Essay Contest
Second Place

Biotechnology and Genetic Engineering: Food with a Cause

by Mikhal Gold
University of Arizona

This year, 18 million people will die from starvation. Most of those live in the poorest of countries; Niger, Cambodia, and Tanzania, where on average over 30% of the population is severely malnourished[1]. With this sad reality, a new technology has arisen with a bold goal in mind – to not only end world hunger, but also improve the quality of crops. This is the era of genetically engineered foods. As with any new technology, this one comes with its fair share of risks, which critics say far outweigh the benefits. But many proponents, including the scientists behind the technology, state that those who are not in the field have no right to criticize. However, not understanding the technology does not preclude people from having a valid opinion, and so many people have taken up the fight against GM (genetically modified) foods. The question is, does the advancement of a technology that can dramatically improve the world justify the risks that may be associated with it?

Defending the position of the scientist:

Human beings have always feared new technology – flying, organ transplants and in-vitro fertilization were all met with reluctance at first. However, human beings have been manipulating foods for thousands of years. When a farmer wanted a better crop, he crossed his best plants with the hope of achieving the desirable characteristics. Biotechnology has merely perfected the technique used by humankind for generations. People no longer have to "fish" for the desirable traits, but can use recombinant DNA technology to get the expected result. This has made farming and food production a faster and more efficient process.

In today's world, with the population expected to reach 9 billion in the next 50 years, conventional crop breeding techniques are simply not fast enough to keep up with food demand.[2] As a result, the world population will be forced to rely on genetically engineered foods if they hope to survive. This is especially true for developing nations, as Henry Miller, author of *The Frankenfood Myth* notes: "If today's rich nations decide to stop the clock [with regard to GM crops] they will still be rich. But if we stop the clock for developing countries, they will still be poor and hungry. And many of their inhabitants will be dead."[3] Genetic engineering will soon become essential, as it promises to yield crops that are more nutritious, resistant to pathogens and last longer after harvesting. Moreover, some genetically modified foods, such as golden rice, contain essential vitamins that are often lacking in the diet of those from the poorest nations. Even though opponents contend that the safety of GM foods has not yet been thoroughly tested, it is a risk worth the potential benefit of feeding the world's most needy nations.

While critics' main concern is over the safety of GM foods, so far they seem to be quite safe. The Food and Drug Administration (FDA) declared in 1992 that GM foods are completely safe and do not need to be labeled or separated from traditional food.[4] As Roy Fuchs of the industry giant Monsanto notes "We've done [thousands of] tests . . . the food is as safe to eat as corresponding products." [5] Many scientists contend that genetic engineering of food is even safer than older breeding techniques. "When breeders [in the 1930s] moved the nematode resistance trait into the cultivated tomato, it brought with it 50 or 100 other genes. Now you can buy this product at organic farms. No one is worried about it," says Charles Gasser, professor for molecular biology at the University of California-Davis. Today, scientists could do the same genetic swapping but limit the amount of information to only the applicable gene.[6] Thus, GM foods are not only safe to eat, the greatest benefit of GM foods remains their ability to reduce world hunger and supply food for an ever-growing population. With space for farmland becoming a pressing concern in the near future, the benefits of genetic modification will become undeniable.

Refuting the position of the scientist:

While many might say the whole of modern society owes its livelihood to the advent of biotechnology, from domestication of cows to blood transfusions, there are some boundaries which have been unnecessarily overstepped. This is especially true in the case of genetically modified food. Over two thirds of the products on grocery store shelves contain some sort of genetic modification.[7] Many are concerned that GM foods may affect humans in ways that have not yet become apparent. Greenpeace, an environmental group, says that biotechnology "should not be used as a justification to turn the environment into a giant genetic experiment by commercial interests."[8] Genetic engineering bypasses natural order by speeding up expression of traits that may otherwise take centuries to evolve. The greatest fear is that it may destroy essential genetic diversity by creating monocultures that can be wiped out by a single virus. Ultimately, without genetic diversity the future of the environment is in grave danger.

One of the main benefits pointed out by proponents of GM foods is their ability to end world hunger. However, world hunger is not simply caused from lack of food. "Hunger and famine around the world have more to do with the absence of land reform, social inequality, [and scarcity of] basic agricultural tools than with lack of agribusiness super-seeds," claims Sean McDonagh, author of many books on ecology and religion.[9] Moreover, while the chairman of Monsanto claims their main goal is to "help people around the world"[10] over 70% if the crops that are modified, are done so not to make them more nutritious, but to garner herbicide resistance.[11] To end world hunger, what is in fact needed is social equality and an end to political corruption.

There is no one federal body that regulates genetic engineering nor do companies need FDA approval before putting food on the market.[12] Many protestors demand that consumers have a right to know whether they are eating modified foods. Additionally, many people refuse to support an industry that has substantial environmental impact. For instance, golden rice requires the use of herbicides that have poisoned rice paddy waters in Bangladesh, causing steep declines in fish and shrimp populations, where integrated rice-fish farming is practiced. [13] The fear of the environmental impact of GM foods is substantial in the population, but companies such as Monsanto have not provided adequate answers for how those issues will be addressed.

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Conclusion

The era of genetically modified foods has yet to be judged in the test of time. However, with the world population expanding at an unprecedented rate and decreased available farmland becoming a growing concern, the need for genetically modified foods is more of a necessity than a choice. Nonetheless, the risks pointed out by critics, such as loss of genetic diversity, safety of modified food, and harsh environmental impacts, are hard to ignore. The question remains, does the advancement of a technology that can dramatically improve the world justify the risks that may be associated with? The answer, I believe, is yes. We are a society driven by change, and genetic engineering, with its ability to increase the quality and quantity of food, is the future of that change.

(Endnotes)

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Institute of Biological Engineering
2005-2006 Bioethics Essay Contest
Third Place

It's What's on the Inside that Counts

by Jeffrey A. Dietrich
University of California, SF/Berkeley

The need to define what it means to be human has been a pursuit and desire long before such ideas as tissue engineering, biotechnology, and bioengineering were even imagined. The first definitions of humanity relied upon our basic mode of perception: sight. The central role of human-like stick figures on cave walls are a clear indication that people were beginning to set themselves apart from the world around them. Of course, we could not long rely on an image alone as the definition of humanity; people look different, but everyone is still human. So, as science progressed we adopted new means of defining our humanity, eventually quantifying our very building blocks, the genetic code. For after all, it is what is on the inside that counts. Finally, we can give a definitive answer to what makes us human: the 1.2% difference in genetic code between chimps and humans. But just as humanity was deconstructing itself down to our basic building blocks, biotechnology was finding a way to redefine the problem.

Advances in bioengineering have reached the point where questions about what it means to be human are raised in an entirely different light. Already the technologies are present where we can integrate computers with bodies, xenograft tissues, and integrate biomaterials into our existing architecture. Moreover, work on the human genome is rapidly increasing our understanding between individual genes and the growing network of observed phenotypes. What this means is that bioengineering is allowing for alterations to be made to the human form from the genetic level up to the systems level. When it comes down to it, we may soon be able to exhibit conscious control over the most remote aspects of our bodies.

While most of the progress made to date has been decidedly humanitarian in nature – cochlear implants, pig heart valves, artificial hips, etc. – there will inevitably be a person or corporation that begins to market bioengineering as a luxury good. A world in which designer babies and the culture of cloned organs has already been imagined, and now the world is just waiting for science to catch up and a person commercialize it. And will there be a market for these technologies? Surely. Take, for example, egg and sperm banks; there is a reason why a donor lists there intellectual and physical attributes.

It is only after these technologies have been pursued and integrated into everyday life that we will be able to understand the implications these will have on society. But, by examining the situation now we can be better prepared for the dream (or nightmare) that is the future. How will advances in biotechnology alter what it means to be human? Any answer that we come up with will be decidedly arbitrary in nature, considering that we can not come up with a good definition even before the technologies are developed. But, perhaps there are underlying currents of thought intrinsic to being human that can help guide us in the future.

First, can there be a definitive line drawn based on the number or kinds of alterations that are made before we become less human? Most people would not say that pacemakers or an artificial hip changes anyone's humanity; some would even say that recipients gain a degree of humanity by being more grateful for what they have. In terms of genetic engineering, does selecting for genes that will predispose a child to be seven-foot-one change their humanity? While some might revere Shaq as god-like, the fact that he can sit on the bench for over a month because of a torn ligament affirms that he is truly human. The moral quandary becomes more befuddled when the more extreme cases of altering the human form are considered. There was a trend, albeit quite small, for teenagers to have their tongues surgically cut to appear forked. While this is decidedly odd, what will be truly strange is when the same person goes to a physician and wants to have a tongue, or tail for that matter, from a komodo dragon grafted onto their body. Now, some people might be starting to think that this person is deviating from the definition of human. The problem is that there can be no established bright line that confirms that we have lost the essential components of being human. There are neither a number of alterations nor a particular type of alteration that will make one individual more or less human than another.

The answer to being human is going to be hidden in the morass that is the human consciousness. Being human will not be defined by how many parts we add, replace, or remove, but how these changes will be reflected upon how we view ourselves. Perhaps it is our fragility that incites us to take care of one another and express empathy and compassion. Perhaps it is our everpresent mortality that makes us strive to achieve as much as we can in the little time that we have.

A patient entering the doctor's office for a transplant will not just enter with a fragile, old body and leave with a strong, young body. The patient will be fundamentally changed in how they view their body, now it may be more of a machine than an integral part of the self. And if the body is a machine that can be replaced, than why is there a need to take care of it. Perhaps it will be like owning a car. The first car that a person owns is their pride and joy, but mainly because they have no means of replacing it. If that person learns that they have inherited a million dollars, and now has the means to replace it, will they still value their car in the same way? The consequences of this altered mindset could be dramatic. Just like a person who own a Ferrari is tempted to drive it too fast, the person with an upgraded body will want to stretch it to the limits.

If the ability to rejuvenate our lost youth results in a fundamental change in how we view ourselves than we will be moving away from what we call being human. If losing our fragility leads us to lose our ability to understand pain and why not to inflict it upon others than we have gone too far in our improving ourselves. The problem now is for us to determine when we have lost these elements of our humanity. It can not be quantified in the number of type of change that we undergo because that is just as arbitrary. Instead it is going to rely on our ability to observe the changes in ourselves, recognize what is occurring, and then take a step back. Of course, we must make sure that we do not step over a brink before we realize that it is time to take a step back.