The Institute of Biological Engineering

www.ibeweb.org

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Spring and Summer 2001 Highlights

Jason Kreiselman, IBE Member, and team mates took first place in the NABEC Design Competition for the design project, "Non-Fossil Fuel Based New Age Home." Co-authors on the project are Kristen Graf, Jon Adler, Ryan Fitchett and Adam Marshall. Jason and Kristen presented their project in an oral presentation at the University of Guelph, Ontario, on July 9, 2001. Way to go, Jason!

Jason Kreiselman (Cornell), F. Spencer Givens III (AgCore, Inc.), P.K. Krishnan (Univ. of Delaware)

Jason was also responsible for creating the IBE on-line membership and registration forms that compliment our IBE web site. He graciously donated his time and talent for what he feels is a very worthwhile cause. We applaud Jason, for his skills and commitment to IBE, and wish him and all IBE students much success in their hunt for employment.

New Student Branch

IBE welcomes the University of Missouri as the newest student chapter. Officers are:

President: Matthew Bange

Vice President: Malinda Boyd

Secretary: Ali Thompson; Treasurer: Michael Maloney

Faculty Advisor: Dr. Steven Borgelt

Norm Scott
IBE 2001 President

As a substitution for a July letter from the IBE President I am pleased to introduce this newsletter, our first which will be only electronic. The last one at the end of 2000 is on the web site but it was also mailed in hard copy to all members and interested persons. There is something to say for having a piece of paper which you can show people as a tangible document. On the other hand one can look at this issue from the perspective that all we have done is shift the point of printing if a hard copy is desired. In the "old" style an organizational unit has done the printing and provides hard copy incurring both costs for printing and mailing to its desired readership. The effect with this electronic newsletter can be the same if one, upon accessing the electronic form, prints one or more copies for use. The information is unchanged but elimination of printing and mailing costs are advantages for IBE as an organization,

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while the direct user incurs some inconvenience and cost for local printing. I suggest that IBE do one hard copy newsletter per year and utilize the electronic form to distribute as many as desirable throughout the year. What do you think?

This newsletter comes to you about a week before the annual meeting in Sacramento, CA, July 27 – 29, 2001 at the Sacramento Convention Center. An excellent program has been arranged by program chair, Sue Nokes. Details of the programming are found herein and on the IBE web site www.ibeweb.org. In addition, my June letter emphasized the Sacramento meeting program.

IBE is at a critical juncture at this time! This can be seen as an overused cliché and I might agree, but I suggest as we near the end our second year of independence we face many challenges. It would be easy to cast these challenges in terms of standard problems of: need to increase and expand the base of membership, costs of supporting a headquarters operation, need to get a creditable publication process established and need to differentiate IBE from other organizations in the arena of biological engineering. Rather, however, I want to focus on an opportunity to attack the intellectual issue of biological engineering as a discipline and what is the body of knowledge for the discipline or for those who like a little play on words, the "DNA" of biological engineering!

On Sunday morning, July 29, from 8 AM – noon there will be an opportunity to engage in a workshop, "DNA of Biological Engineering: Defining the Body of Knowledge for the Discipline," which be in the Sacramento Convention Center in Room 204. As an excellent introduction you can and should read Art Johnson's piece in this newsletter, " Bioengineering in the US: The Rush is on". In addition, Andrew Baldwin addresses ecological engineering and introduces it as a relatively new field within the broad confines of biological/biosystems engineering. I do encourage that you read both of these articles and come prepared with your thoughts for a highly interactive and stimulating workshop.

My reason for saying IBE is at a critical juncture is that the organization and the departments, formerly named agricultural and or biological engineering or some form of both, are seeking to create a definition of biological engineering as a term with "stickiness" per Malcolm Gladwell author of the Tipping Point. We have to create a uniqueness, which differentiates biological engineering on some basis. Both IBE and the departments need to be clearly perceived in terms of mission and context. The Sunday morning Workshop will be an important step in this process and I am sure it will also be fun and useful. The Workshop agenda is attached and has been designed to look at some key aspects of biological engineering in terms of fundamental concepts, curriculum development in terms of the body of knowledge and with an inclusion of perspectives from industry. Don't miss this opportunity to participate in the Workshop!

In addition you are all invited to the meeting of the IBE Council on Saturday evening, 8 – 10 PM, July 28, in Room 204 of the Sacramento Convention Center. You'll have an opportunity to learn more about IBE and we look forward to your input.

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Bioengineering in the U.S.: The Rush is On

Arthur T. Johnson
University of Maryland

The plethora of new biology-based technologies has sparked a frantic rush to establish and enhance academic bioengineering programs in the U.S. The economic boom of the 1990's and the Whitaker Foundation, with its goals to contribute its entire sizeable endowment to bioengineering projects and programs by the year 2006, enabled bioengineering research and academic activity to reach an unparalleled frenzy in recent years. However much good these pressures have been for the field, they may also have kept bioengineering from emerging in an orderly and thoughtful way necessary for the establishment of a truly independent engineering discipline.

What characterizes a discipline? There are two generally-accepted characteristics: 1) a distinct body of knowledge, and 2) distinct methods. Of the two, the body of knowledge is generally easier to define; methods require that the discipline emerges from its nascent period. Without both of these, a new discipline is just an extension of prior disciplines, and the new discipline may never achieve recognition as being separate.

There are two basic categories of engineering discipline: 1) applications-based, and 2) science-based. The first category defines the discipline by those served. For example, mining engineering, agricultural engineering, and petroleum engineering are all applications disciplines. The second category defines the discipline by its scientific foundation. For example, mechanical engineering and chemical engineering are science-based disciplines based upon mechanics (physics) and chemistry, respectively. Education in an applications discipline is usually more specific and applied than that for the fundamental science-based discipline.

It is not particularly clear whether bioengineering will become an applications discipline or a science–based discipline. Much of biomedical engineering, constituting the core of bioengineering, is applications-based. Biomedical engineering utilizes knowledge and techniques from electrical, mechanical, or chemical engineering, and applies them to the field of medicine.

Biological engineering, a term sometimes used synonymously with the term bioengineering, is science-based, and requires a strong background in biology as well as in engineering. It is recognized within biological engineering that unique solutions to technical problems may as well come from the biological side of the discipline as from the engineering side.

One big difference between these two is the loyalties, or identifications, of their practitioners. Those who practice an applications discipline are likely to have studied a more fundamental discipline and to retain their identification as part of the fundamental discipline. Thus, many biomedical engineers who work with signal processing identify themselves as electrical engineers. Many rehabilitation engineers still think of themselves as mechanical engineers. When these practitioners work with a particular application, they often do so with minimal knowledge of the system of application, and they use the methods they were taught in their fundamental discipline.

Biological engineers, on the other hand, have a thorough and intrinsic knowledge of biological systems. They are aware of nuances and expectations typical of biological systems, and identify with no other discipline.

The trouble is that the formation of biological engineering (or bioengineering) has not been completed. A body of knowledge has not been completely defined and unique methods have not been identified. There are few true science-based bioengineers because there is no pattern for automatically forming engineers with this type of education. The students of today are being taught by the students of yesteryear, and those students were taught in fields different from biology-based biological engineering. Thus, progress toward a truly separate discipline with distinct bodies of knowledge and methods can only be incremental.

There are many distractions hindering this process of development. To use a biologically-based analogy, a new species can only emerge from isolation. Continued interbreeding with established species only adds to the richness of the gene pool, but does not lead to a new species (one trait of which is the inability to breed with other species). Likewise, the establishment of a new discipline requires a certain isolation and reflection on the vision of that discipline. In these days of unparalleled opportunity and multidisciplinary research, that isolation is not occurring. Consequently, visions for the bioengineering discipline are numerous, and often reflect the habits derived from the many source disciplines that are now feeding into what we presently call bioengineering.

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Thus, we see bioengineering described in terms of biomedical engineering, which is engineering applied to medicine and health care. The biology in this vision is at the organismal level, and specifically the human organism. We also see bioengineering described in terms of cellular and tissue engineering, which is engineering applied to living cells and tissues, including genetic engineering. This vision encompasses the biotechnological and nonmedical applications, and is science-based up to the level of tissues. We also see bioengineering described in terms of biological systems engineering, which features biology and engineering as coequal foundations. This vision includes all levels of biology, including the population interactions of ecology. Because the potential applications are so numerous, this is a science-based vision.

And then there are hybrids of these approaches that combine them in different ways. The U.S. National Institutes of Health promotes one of these: by its definition bioengineering is an integration of "physical, chemical, or mathematical sciences and engineering principles for the study of biology, medicine, behavior, or health. It advances fundamental concepts, creates knowledge from the molecular to the organ systems level, and develops innovative biologies, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health."

There are opposing research directions that also influence this field. Reductionism is the tendency to view a system on its smallest possible scale. In biology this means that to understand organisms or populations of organisms one needs to understand completely their functional genomics. Many of the present bioengineering opportunities owe their importance to the reductionist approach.

On the other hand, other researchers are struggling to understand relations among groups of organisms and to model ecological outcomes. This holistic systems view does not presently view the system from its genetic base.

How do these two approaches affect bioengineering? They tend to pull it in two different directions. There hasn't been time nor the isolated reflection necessary to show how these approaches fit together, and, as a consequence, bioengineering is still largely undefined. At best we can say that the field is still being formed, or in a transitional state.

The present distraction posed by cellular and tissue bioengineering is particularly strong. The opportunities are so vast that many educators have been lured into defining bioengineering in terms of their research interests. The curricula that have resulted often ignore the science of biology at levels higher than tissue. The term "bioengineering" is often applied to this portion only of the field, and this largely applications-based usage is often not distinguished from the more broadly-based scientific discipline usage of the same word that is promoted by others.

Given some thought, it could be realized that the big distinction in biology occurs at the cellular level. At or above that level, biological responses of cells or groups of cells of any complexity are fundamentally similar. Below the cellular level can be characterized as a chemical system. This discontinuity is closely analogous to that in physics above and below the atomic level. Therefore, any bioengineering that does not recognize the supercellular biological continuum is not the science-based discipline that is separate and distinct.

As far as distinctive methods are concerned, there are few candidates from which to choose. My own bias is to view the field of biology from a systems viewpoint. Whether at a subcellular, cellular, tissue, organ, organism, or population level, biology can be considered to be another system with input/output relationships that can be anticipated as following certain general principles with some important exceptions. Looked at this way, a biological system is a product both of its genetic basis and the environment in which it finds itself. Thus, both reductionism and ecological systems approaches have their contributions to make.

It is hard to say whether bioengineering will someday emerge as a separate and distinct discipline. There are many influences from many sources that are tending to keep the field from coalescing as a cohesive unit. Until that happens, there will not be general agreement about a specific knowledge core, courses to offer, or typical academic programs to design. And, without these, industrial or other employers will not be completely sure about the capabilities of graduates from the 90 or so bioengineering programs in the U.S.

Nonetheless, these are exciting times. The opportunities are great and the contributions that an individual can make are numerous. We have a frenetic pace in the field that is not waiting for a definition or a unique discipline to emerge. That will take some time and a lot of reflective thought.

You've heard about it! But what is it?
Introducing…
ECOLOGICAL ENGINEERING

Andrew H. Baldwin
Department of Biological Resources Engineering
University of Maryland

Ecological engineering. "Hmm," you say to yourself. "Sounds kind of like environmental engineering." Or maybe you have heard that it integrates ecology and engineering, a field where engineers design ecosystems such as constructed wetlands for wastewater treatment. But still, you wonder, is that all that there is to ecological engineering? If you're a little confused, you're not alone. Even ecological engineers can't agree on exactly what the field is or encompasses. That's because the field is a young one, still in a dynamic state, perhaps like a plant community during the early stages of succession.

It all started back in the early 1960s when Howard T. Odum coined the term "ecological engineering," which he defined as "environmental manipulation by man using small amounts of supplementary energy to control systems within which the main energy drives are still coming from natural sources." Although it does not specifically mention ecosystems, this definition calls into play human manipulation of the environment for some purpose (i.e. design) with systems that use primarily natural energy sources (e.g., sun, wind, water). The definition evolved over the years, with one of Odum's former students and founder of the journal *Ecological Engineering*, Bill Mitsch, in 1996 calling ecological engineering the "design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both." This definition specifically mentions the design of ecosystems, and establishes the unique concept of designing for the benefit of both humans and ecosystems.

What else is unique about ecological engineering? A fundamental tenet of ecological engineering is the concept of self-organization of systems (sometimes called "self-design"). Deviation from designed system properties is defined as "failure" in many engineering disciplines. Ecological engineers on the other hand not only expect change, they welcome it. That is because even simple ecosystems are so complex in structure and interacting processes, as well as naturally dynamic on a wide range of temporal and spatial scales, that the human hand cannot build one that is initially as complex as natural ecosystems or that is static.

Consider a constructed wetland system for treating dairy parlor effluent. Ecological engineers design it for a specific loading rate, build the treatment cells, plant it with several wetland plant species, and run wastewater through it. However, the plants planted grow, some quicker than others. The differences between growth rates depend on nutrient concentrations, water level, and other environmental factors, however, so competition is difficult to model. These plants flower and set seed at different rates, and germinate and become mature plants at different rates, again depending on environmental conditions. To make things more complex, other species of plants colonize the wetland via wind or animal-dispersed seeds. Animals such as frogs, aquatic invertebrates, insects, birds, mammals, and more colonize the wetlands and eat or otherwise disturb plants and soil. Overlying and affecting this complexity is weather: drought and temperature extremes alter biological functioning to varying degrees depending on the species. And finally, human management is rarely perfect and equipment breaks down or wears out, which can add to the variability. Clearly, this ecosystem cannot be tightly controlled. While many of the biological components probably have little effect on the human-benefit side of the equation, i.e., treating wastewater, some components and processes do affect treatment effectiveness. For example, the diffusion rate of oxygen through plant stems differs between species, which can dramatically affect microbially-mediated treatment processes such as nitrification.

So is ecological engineering just about building wetlands for treating wastewater? Constructed wetlands are one of the most obvious examples of ecological engineering, but there are many others. Bill Mitsch has presented examples of ecological engineering along three scales (or as ecologists would say, "gradients") corresponding to three fundamental principles of ecological engineering:

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Moving from left to right is moving from a low to high degree of ecological engineering. For example, conventional activated sludge wastewater treatment systems would be placed toward the left side of the scale, as they are energy intensive, tightly controlled systems. On the right side of the scale would be restoration of wetlands for wildlife habitat or mitigation. Stormwater management bioretention systems would fall somewhere in the middle. Other examples of ecological engineering include mineland restoration, agroecological systems, algal turf scrubbers, living machines, soil bioremediation, tallgrass prairie restoration, “green” golf courses, wildlife corridor management, hydrologic restoration, toxicity bioassays, mesocosms, and Biosphere 2. The point is, there are many designed biological systems that differ in the degree to which they adhere to the fundamental principles of ecological engineering.

As I said before, the field of ecological engineering is young. So young that the American Ecological Engineering Society (AEES) was not formed until this year. This field, much like ecosystems, will continue to change. I hope I have given you some insight into the exciting and dynamic field of ecological engineering, which falls soundly within the broader field of Biological/Biosystems Engineering. The ideology and structure of this larger field are also changing rapidly, suggesting that the concept of self-design could be applied to human organizations as well as ecosystems!

WORKSHOP

Institute of Biological Engineering (IBE)
Sacramento Convention Center, Room 204
Sunday, July 29, 2001, 8 AM - 12 noon

“DNA of BIOLOGICAL ENGINEERING: DEFINING the BODY of KNOWLEDGE for the DISCIPLINE”

0800 Welcome, Introductions and Workshop Objectives—N. R. Scott, Professor, Cornell University

0815 Biological Engineering Core Concepts—Jim Dooley, President, Silverbrook Limited

0830 Concepts for Biological Engineering Curriculum—Kifle Gebremedhin, Professor, Cornell University

0845 Thermodynamics of Living Systems—John Cundiff, Professor, Virginia Tech and George Meyer, Professor, University of Nebraska

0900 An Industry Perspective—Karen Brockwell, Director of Technology, Genentech, Vacaville, CA

0930 An Industry Perspective—Carol Schembri, Senior Project Scientist, Life Sciences Technologies Laboratory, Agilent Laboratories

0945 Discussion Q & A

1030 Refreshment Break

1100 Breakout groups (four or more) for Discussion of Specific Questions:

- Agreement on definition of biological engineering.
- Agreement on the essential subjects which establish biological engineering as a discipline.
- What are the expectations of the knowledge required of a biological engineer entering first employment in industry?

1215 Adjourn

2001 IBE/BE Meeting: Engineering BIOdyssey

Sue Nokes, Program Chair

All sessions located in Sacramento Convention Center (SCC) 204 unless otherwise indicated.

Friday, July 27, 2001

- IBE Meeting Registration: 9 – 12 am SCC Lobby
- Tour: 1 pm – 5 pm

The tour will depart from the Hyatt (across from the Sacramento Convention Center) ASAE staff will be available in the lobby at the Hyatt from 12 Noon until departure time for check in and to distribute badges. The bus will begin loading at 12:45 PM. The tour will depart at 1:00 PM.

Genentech

Genentech is an industry leader in the development, manufacture, and marketing of biotechnology products for nnovative pharmaceutical and medicine.

Calgene

Calgene is an agricultural biotechnology company that is developing improved varieties and plant products.

Saturday July 28, 2001

- IBE Meeting Registration: 9 am to 5 pm *SCC Lobby*
- Tour 1:00-5:00 pm UC Davis Campus: Bioprocessing/Biotechnology focus
- Workshop "Self-design in living systems – what can we learn"? 1 – 5 pm *(Jim Dooley, Tim Foutz, and Joel Cuello)*
- Industry Panel: Biological Engineering Alumni 6:00 – 6:30pm
- Student/Faculty/Industry Reception 6:30 – 8:00 pm
- IBE Council Meeting 8:00 – 10 pm

Sunday July 29, 2001

- CPD 1A 8 – 10 am: Introduction to Molecular Techniques for the Analysis of Environmental Samples – *Jean VanderGheynst* *SCC 205*
- CPD 1B 10 am – 1 pm: Laboratory Experience with Molecular Techniques: *Jean VanderGheynst*
- CPD 2 8 am – 12 pm: DNA of Biological Engineering: Defining the Body of Knowledge for the Discipline. *Norm Scott, Moderator*
- Lunch on your own: 12 – 1 pm
- Student poster competition: 1 – 2 pm
- Keynote Speaker: 2 – 3 pm Jane Turnbull, President, Peninsula Energy Partners. The Role of Renewable Energy Resources in Supplying Energy for the Western US.
- Technical Shorts: 3 – 5 pm *Art Johnson, Moderator*

1. Industry, clients and faculty consultants–working with senior capstone design. *David Jones, Univ. of Nebraska*
2. A wavelet method of observing the efficacy of Lisinopril. *Filip To, Mississippi State University*
3. Harvesting, drying, and extracting of milk thistle. *Sunny Wallace, University of Arkansas*
4. Integrated Pest Management and Biosensors. *Raj Raman, University of Tennessee*
5. Two-stage reactor systems for waste treatment/product formation. *Caye Drapcho, Louisiana State Univ.*
6. Crayfish projects. *Paul Schreuders, University of Maryland*
7. My New Book. *Vangie Alocilja, Michigan State University*
8. Development of a lung biosensor to evaluate the health impact of airborne particulate matter. *Carl Okeson and Mark Riley, University of Arizona*
9. Screening of facultatively anaerobic bacteria utilizing D-xylose for xylitol production. S*endil Rangaswamy and Foster Agblevor, Virginia Polytechnic Institute*
10. Biological engineering consulting. *Dennis Heldman, Heldman Associates*
11. Toward a new paradigm for teaching biology to engineers. *Art Johnson, University of Maryland*

Student Social 5-6 pm *Coordinator: Mari Chinn, Univ. of Kentucky*