Our Fundamental Commonality

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Appeared in the volume 30, number 4 (2006) issue of the BMES Bulletin

I last wrote about disunity for expectations of bio-based engineers, and decried the fact that many of us seem to assess expectations of these engineers based upon the application areas with which we are familiar. However, application areas can only define applications based engineering disciplines, not science-based engineering disciplines. If we are an engineering discipline based upon the science of biology, and I think most of us would prefer to think of ourselves that way, then we must stop thinking primarily of applications when we describe who we are.

That is not easy to do. Bio-based engineers work on problems confined to some small locus within the biological realm. They are thus experts in some particular applications areas. They think first and foremost about their areas of specialization and are not always comfortable thinking outside the confines of these little boxes. So, sticking with the familiar, they have little to say about what they may share in common with those inhabiting other little boxes.

Duane Bruley used to talk of the four basic pillars of bioengineering: physics, chemistry, mathematics, and biology. We can start there when listing those features that define bioengineering or biological engineering. Biomedical engineering tends to be focused primarily on applications in medicine and may or may not fit the construct we are about to offer.

Physics was the first pillar on the list, and we have all studied physics. Bioengineers need to know a lot about physics. They need to know about optics, mechanics, fluids, electricity, and thermodynamics. They need to know about the difference between potentials and things that flow in response to a potential. They need to know about forces, velocities, and accelerations. They need to know about mechanical strengths of different materials, stresses created in these materials, and deformations that result. They need to know about fluid pressures exerted equally in all directions, about vessel resistances, and about input/output relationships. They need to know about material diffusion, convection (advection), and osmosis. They need to know about interactions among like and unlike charges, ionic currents, and electrical hazards. They need to know about the equivalence between work and energy, the second law of thermodynamics, and energy conversions. They should know about the states of matter and how each serves a different purpose in living things. They should appreciate that the order inherent in living things requires energy to maintain that order. Further, bioengineers should know about the methods physicists used to arrive at scientific truths, their quantitative methods, and their ingenious experimentation.

Bioengineers need to know about chemistry, how chemical compounds are formed, and energy transfer among different chemicals. They should know something about chemical equilibrium and disequilibrium, and how chemicals can be used as energy-storage repositories. They should know about normal metabolic pathways and metabolic and chemical efficiencies. They should know about classes of biochemicals, general characteristics of each, and where they are normally found in living things. They should know about physical chemistry, the differences in physical attributes that accompany different chemical compositions. They should know about surface energies and bioactivity. They need to know about molecular shape effects, geometrical conformation, and the physical basis for enzyme reactions and complementary DNA formation. They should know about pH effects, and appreciate the uniqueness of carbon chemistry and water as a solvent. They should also appreciate the meaning of free energy and what it means for living things. In addition, some appreciation of the methods of chemical detection and quantification should be retained.

Bioengineers should know mathematical concepts. They should know about the basis for differential and integral calculus, and when to switch from continuum to discreteness. They should be familiar with first-and second-order responses. They should know about randomness, probability, and statistics. They should be familiar with the concept of chaos, and path-based outcomes. And, certainly, they should be aware of the differences between different modeling approaches, especially between theoretical and empirical models, and the limitations of each. Methods of mathematical manipulation should also be committed to memory.

Bioengineers should also draw knowledge from the engineering sciences. Many of these are based on physics, and won't be repeated. Others are more mathematical in nature. Information theory is one of those, and the equality between information and biological order should be appreciated. Control systems are extremely important for living things, and bioengineers should have a thorough understanding of the elements of a control system (including means of communication among elements). They should also know about redundancy, optimization, amplification techniques, sensory discrimination, and reliability. Pattern recognition is important, as is just noticeable difference.

From the science of biology, came important concepts for bioengineers to know. First and foremost is the first law of biology: survival and reproduction. What should bio-based engineers know about biology? They should certainly know that form and function are related. They should be familiar with genes as information storage units, but also aware of intergenerational information transfer by cultural means (learning). They need to know about competition and selection pressures, and about necessary conditions for evolution. They should appreciate the different contributions of information legacies and environmental effects on biological outcomes, including genetic expression. Lastly, biological engineers or bioengineers should be aware of the difficulty defining what life is or isn't

I know that this list is a long one. There are many facts and concepts that I have enumerated that many would consider unnecessary. Likewise, there are others that might be added to the list. In particular, I can imagine some readers who would add a number of physiological facts to this list. But, remember, I am writing here of foundational knowledge for a science-based discipline instead of information necessary for particular applications. There are additional facts and concepts necessary for specific sub-fields, and these must be learned later, in addition to foundational knowledge.