BE.010 Spring 2005
Session # 1 notes

Engineering Science and Technology

Outline of this session:
- discussion of the components of engineering science and technology
- career paths and industries for biomedical engineers
- comparison of the overlap between engineering and biology in the past and in the present

Introduction

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Engineering Science and Technology

The process of engineering any product is usually composed of three parts: analysis, synthesis, and design. Analysis is the study of systems in order to understand their function. Synthesis is the practical building of the systems under analysis. Both steps contribute to the end goal of engineering, which usually lies in the final design of the product.

Many of the different engineering disciplines at MIT are founded on a particular pure science. Different branches of physics serve as bases for Civil Engineering, Mechanical Engineering, and Electrical Engineering. Similarly, different branches of chemistry serve as bases for Chemical Engineering, Nuclear Engineering, and Materials Science and Engineering. The engineering disciplines take off from a traditional science and use it to explore, innovate, and finally design.

The quantitative engineering paradigm outlines the typical steps involved in the engineering of a product. It establishes a direction to pursue and a set of boundaries within which to explore. Ideas are first experimented with computational models and then tested in real life. The performance of individual components is evaluated and improvements are made as necessary.

The Biology/Medicine-Engineering Landscape

The current disciplines at MIT of Chemical Engineering, Electrical Engineering, Mechanical Engineering, Materials Science and Engineering, and the soon to be Biological Engineering are founded on the MIT general institute science requirements of biology, chemistry, physics, and mathematics. Students in any of these fields are provided with the necessary background to go into biology related disciplines. At one end of the spectrum is biotechnology, which is generally applied to diverse industries and to the development of health-related devices and pharmaceuticals. At the other end of the spectrum is biomedical engineering, which is generally used in the hospital setting. The uses of bioengineering lie somewhere in-between the two.

Traditional Career Areas for Biomedical Engineers

The work of traditional biomedical engineers actually did not require much knowledge of biology. Due to many of the reasons listed and others, for a long time, biology was not amenable to engineering analysis and synthesis design approach.

This slide show some examples of areas where engineers rely on the design and implementation skills learned in their own disciplines to solve problems in biology. Until recently, the development of imaging techniques to diagnose a particular medical condition relied mostly on physics. The design of replacement body structures, the fabrication and fitting of artificial limbs, and the creation of devices used for repairing and/or replacing these body parts were founded on knowledge of mechanics and material sciences. The processing and delivery of pharmaceuticals into biological systems were based on chemistry.

The New Interface of Engineering and Biology

The genomic and molecular revolutions in biology, commonly identified by the Human Genome Project, has allowed us to identify all 26,000 genes in the human body and to determine many of their individual sequences. Our sequencing of amino acids in proteins and of bases in nucleic acids spurred the development of bioinformatics, which relies on the use of computers to analyze the sequences for patterns and similarities. The subsequent understanding of the information underlying the sequences resulted in the creation of a comprehensive “Parts List.” Cellular molecular components can now be easily identified and manipulated.

These advances in the understanding of biology added much knowledge to our toolkit and spurred the growing interface between biology and engineering. For the first time, we can look at biology from a different perspective and with a much greater attention to detail. The operation of biological functions can now be understood as complex “biomolecular machines.” The regulation of biological functions can be seen as complex “biomolecular circuits.”

The following slides show a few of the many areas today that solicit the knowledge and practical skills of bio-engineers:

1. In the past, only mechanical aspects such as flexibility, durability, and endurance to changes in outside conditions were considered in the design of spacesuits. Now, bio-engineers incorporate knowledge of the physiology of the human body into the finalization of their designs.

2. Like the design of space suits, the design and implantation of hip implants was previously solely a branch of mechanical engineering. The mechanics and movements of the hip were studied to produce the best metal substitute. Today, greater emphasis is placed on the understanding of bone composition and tissue-implant suitability.

3. MRI produces images of the body regardless of intervening bone by means of a strong magnetic field and low-energy radio waves.

4. Controlled-release drug delivery as explored in the Langer lab at MIT relies on knowledge of the body's enzymes and whether certain polymers/drugs would be degraded by them.

5. Image-guided surgery records surgical processes with greater detail and allows doctors to consult past steps for comparison and completeness.

6. The quest for an ideal replacement artificial heart continues to baffle the scientific community. In the past, engineers devoted their efforts to designs based on non-biological materials. They were met with repeated failure as the complex biological systems of the body formed blood clots to signal rejection of foreign substances such as metal, plastic, and polyester. Today, biological engineers are exploring ways to design hearts out of biomaterials and possibly other tissues.

7. Bioprocessing is the method/procedure of preparing a biological material, especially a product of genetic engineering, for commercial use.

8. An increasing emphasis is placed on environmental bioremediation to insure that all chemical processes must be environment friendly.