BIOENGINEERING

7.1 What is Bioengineering: Bioengineering is the "biological or medical application of engineering principles or engineering equipment – also called biomedical engineering."

We like to think of it as the application of engineering principles to biological systems.

Bioengineering as a defined field is relatively new, although attempts to solve biological problems have persisted throughout history. Recently, the practice of bioengineering has expanded beyond large-scale efforts like prosthetics and hospital equipment to include engineering at the molecular and cellular level – with applications in energy and the environment as well as healthcare.

A very broad area of study, bioengineering can include elements of electrical and mechanical engineering, computer science, materials, chemistry and biology. This breadth allows students and faculty to specialize in their areas of interest and collaborate widely with researchers in allied fields.

Biological Engineering or **bioengineering** (including biological systems engineering) is the application of concepts and methods of biology (and secondarily of physics, chemistry, mathematics, and computer science) to solve real-world problems related to the life sciences or the application thereof, using engineering's own analytical and synthetic methodologies and also its traditional sensitivity to the cost and practicality of the solution(s) arrived at. In this context, while traditional engineering applies physical and mathematical sciences to analyze, design and manufacture inanimate tools, structures and processes, biological engineering uses primarily the rapidly developing body of knowledge known as molecular biology to study and advance applications of living organisms.

An especially important application is the analysis and cost-effective solution of problems related to human health, but the field is much more general than that. For example, biomimetics is a branch of biological engineering which strives to find ways in which the structures and functions of living organisms can be used as models for the design and engineering of materials and machines. Systems biology, on the other hand, seeks to utilize the engineer's familiarity with complex artificial systems, and perhaps the concepts used in "reverse engineering", to facilitate the difficult process of recognition of the structure, function, and precise method of operation of complex biological systems.

The differentiation between biological engineering and biomedical engineering can be unclear, as many universities loosely use the terms "bioengineering" and "biomedical engineering" interchangeably.[1] Biomedical engineers are specifically focused on applying biological and other sciences toward medical innovations, whereas biological engineers are focused principally on applying engineering principles to biology - but not necessarily for medical uses. Hence neither "biological" engineering nor "biomedical" engineering is wholly contained within the other, as there can be "non-biological" products for *medical* needs as well as "biological" products for *non-medical* needs (the latter including notably biosystems engineering).

Biological engineering is a science-based discipline founded upon the biological sciences in the same way that chemical engineering, electrical engineering, and mechanical engineering can be based upon chemistry, electricity and magnetism, and classical mechanics, respectively.

Biological engineering can be differentiated from its roots of pure biology or other engineering fields. Biological studies often follow a reductionist approach in viewing a system on its smallest possible scale which naturally leads toward tools such as functional genomics. Engineering approaches, using classical design perspectives, are constructionist, building new devices, approaches, and technologies from component concepts. Biological engineering utilizes both kinds of methods in concert, relying on reductionist approaches to identify, understand, and organize the fundamental units which are then integrated to generate something new. In addition, because it is an engineering discipline, biological engineering is fundamentally concerned with not just the basic science, but its practical application of the scientific knowledge is to solve real-world problems in a cost-effective way.

Although engineered biological systems have been used to manipulate information, construct materials, process chemicals, produce energy, provide food, and help maintain or enhance human health and our environment, our ability to quickly and reliably engineer biological systems that behave as expected is at present less well developed than our mastery over mechanical and electrical systems.

ABET, the U.S.-based accreditation board for engineering B.S. programs, makes a distinction between biomedical engineering and biological engineering, though there is much overlap (see above). Foundational courses are often the same and include thermodynamics, fluid and mechanical dynamics, kinetics, electronics, and materials properties. According to Professor Doug Lauffenberger of MIT, biological engineering (like biotechnology) has a broader base which applies engineering principles to an enormous range of size and complexities of systems ranging from the molecular level - molecular biology, biochemistry, microbiology, pharmacology, protein chemistry, cytology, immunology, neurobiology and neuroscience (often but not always using biological substances) - to cellular and tissue-based methods (including devices and sensors), whole macroscopic organisms (plants, animals), and up increasing length scales to whole ecosystems.

The word bioengineering was coined by British scientist and broadcaster Heinz Wolff in 1954. The term bioengineering is also used to describe the use of vegetation in civil engineering construction. The term bioengineering may also be applied to environmental modifications such as surface soil protection, slope stabilisation, watercourse and shoreline protection, windbreaks, vegetation barriers including noise barriers and visual screens, and the ecological enhancement of an area. The first biological engineering program was created at Mississippi State University in 1967, making it the first biological engineering curriculum in the United States. More recent programs have been launched at MIT and Utah State University.

Description: *Biological engineers* or *bioengineers* are engineers who use the principles of biology and the tools of engineering to create usable, tangible, economically viable products. Biological engineering employs knowledge and expertise from a number of pure and applied sciences, such as mass and heat transfer, kinetics, biocatalysts, biomechanics, bioinformatics, separation and purification processes, bioreactor design, surface science, fluid mechanics, thermodynamics, and polymer science. It is used in the design of medical devices, diagnostic equipment, biocompatible materials, renewable bioenergy, ecological engineering, agricultural engineering, and other areas that improve the living standards of societies.

In general, biological engineers attempt to either mimic biological systems to create products or modify and control biological systems so that they can replace, augment, or sustain chemical and mechanical processes. Bioengineers can apply their expertise to other applications of engineering and biotechnology, including genetic modification of plants and microorganisms, bioprocess engineering, and biocatalysis.

Because other engineering disciplines also address living organisms (e.g., prosthetics in bio-mechanical engineering), the term biological engineering can be applied more broadly to include agricultural engineering and biotechnology, which notably can address non-healthcare objectives as well (unlike biomedical engineering). In fact, many old agricultural engineering departments in universities over the world have rebranded themselves as **agricultural and biological engineering** or **agricultural and biosystems engineering**. Biological engineering is also called bioengineering by some colleges and biomedical engineering is called bioengineering by others, and is a rapidly developing field with fluid categorization. Depending on the institution and particular definitional boundaries employed, some major fields of bioengineering may be categorised as (note these may overlap):

- Biological systems engineering
- Biomedical engineering: biomedical technology, biomedical diagnostics, biomedical therapy, biomechanics, biomaterials.
- Genetic engineering (involving both of the above, although in different applications): synthetic biology, horizontal gene transfer.
- Bioprocess engineering: bioprocess design, biocatalysis, bioseparation, bioinformatics, bioenergy
- Cellular engineering: cell engineering, tissue engineering, metabolic engineering.
- Biomimetics: The use of knowledge gained from reverse engineering evolved living systems to solve difficult design problems in artificial systems.

7.2 Biological Systems Engineering or **Biosystems Engineering** is a broad-based engineering discipline with particular emphasis on biology and chemistry. It can be thought of as a subset of the broader notion of Biological Engineering, though not in the respects that pertain to Biomedical Engineering as *biosystems* engineering tends to focus less on medical applications than on *agriculture, ecosystems, and food science*. It involves aspects of genetic engineering, particularly regarding the agricultural applications. The discipline focuses broadly on environmentally sound and sustainable engineering solutions to meet societies' ecologically-related needs. Biosystems engineering integrates the expertise of fundamental engineering fields with expertise from non-engineering disciplines.

Background and Organization

Many college and university biological engineering departments have a history of being grounded in agricultural engineering and have only in the last decade or so changed their names to reflect the movement towards more diverse biological based engineering programs. This major is sometimes called Agricultural and Biological Engineering, Biological and Environmental Engineering, etc., in different universities.

Since biological engineering covers a wide spectrum, many departments now offer specialization options. Depending on the department and the specialization options offered within each program, curricula may overlap with other related fields. There are a number of different titles for BSE-related departments at various universities. The professional societies commonly associated with many Biological Engineering programs include the American Society of Agricultural and Biological Engineers (ASABE) and the Institute of Biological Engineering (IBE), which generally encompasses BSE.

A biological systems engineer has a background in what both environmental engineers and biologists do, thus bridging the gap between engineering and the (non-medical) biological sciences. For this reason, biological systems engineers are becoming integral parts of many environmental engineering firms, federal agencies, and biotechnology industries.

Specializations

- Land and water resources engineering
- Food and bioprocess engineering
- Machinery systems engineering
- Natural resources and environmental engineering

7.3 Biomedical engineering (BME) is the application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g. diagnostic or therapeutic). This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to advance healthcare treatment, including diagnosis, monitoring, and therapy. Biomedical engineering has only recently emerged as its own study, compared to many other engineering fields. Such an evolution is common as a new field transitions from being an interdisciplinary specialization among already-established fields, to being considered a field in itself. Much of the work in biomedical engineering consists of research and development, spanning a broad array of subfields (see below). Prominent biomedical engineering applications include the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, common imaging equipment such as MRIs and EEGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biologicals.

7.4 Genetic engineering, also called **genetic modification**, is the direct manipulation of an organism's genome using biotechnology. New DNA may be inserted in the host genome by first isolating and copying the genetic material of interest using molecular cloning methods to generate a DNA sequence, or by synthesizing the DNA, and then inserting this construct into the host organism. Genes may be removed, or "knocked out", using a nuclease. Gene targeting is a different technique that uses homologous recombination to change an endogenous gene, and can be used to delete a gene, remove exons, add a gene, or introduce point mutations.

An organism that is generated through genetic engineering is considered to be a genetically modified organism (GMO). The first GMOs were bacteria in 1973 and GM mice were generated in 1974. Insulin-producing bacteria were commercialized in 1982 and genetically modified food has been sold since 1994. Glofish, the first GMO designed as a pet, was first sold in the United States December in 2003.

Genetic engineering techniques have been applied in numerous fields including research, agriculture, industrial biotechnology, and medicine. Enzymes used in laundry detergent and medicines such as insulin and human growth hormone are now manufactured in GM cells, experimental GM cell lines and GM animals such as mice or zebrafish are being used for research purposes, and genetically modified crops have been commercialized.

7.5 Bioprocess engineering is a specialization of biotechnology, biological engineering, chemical engineering and of agricultural engineering. It deals with the design and development of equipment and processes for the manufacturing of products such as food, feed, pharmaceuticals, nutraceuticals, chemicals, and polymers and paper from biological materials. Bioprocess engineering is a conglomerate of mathematics, biology and industrial design,and consists of various spectrums like designing of bioreactors, study of fermentors (mode of operations etc.). It also deals with studying various biotechnological processes used in industries for large scale production of biological product for optimization of yield in the end product and the quality of end product. Bioprocess engineering may include the work of mechanical, electrical, and industrial engineers to apply principles of their disciplines to processes based on using living cells or sub component of such cells.

7.6 Biomimetics or **biomimicry** is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems. The terms biomimetics and biomimicry come from Ancient Greek: βίος (*bios*), life, and μίμησις (*mīmēsis*), imitation, from μιμεῖσθαι (*mīmeisthai*), to imitate, from μῖμος (*mimos*), actor. A closely related field is **bionics**.

Living organisms have evolved well-adapted structures and materials over geological time through natural selection. Biomimetics has given rise to new technologies inspired by biological solutions at macro and nanoscales. Humans have looked at nature for answers to problems throughout our existence. Nature has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly, and harnessing solar energy.