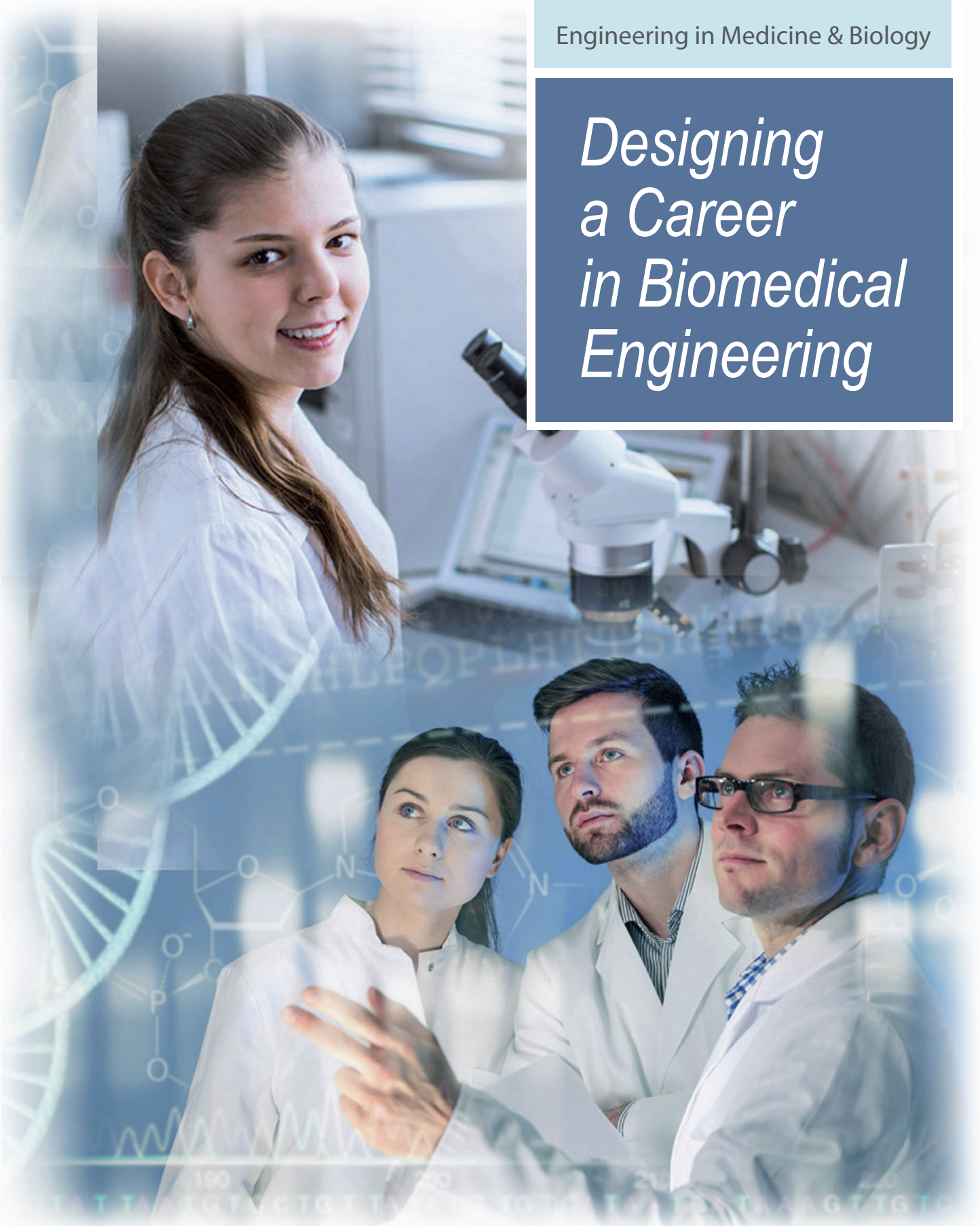


Engineering in Medicine & Biology

# *Designing a Career in Biomedical Engineering*





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# Designing A Career In Biomedical Engineering

## Is biomedical engineering right for you?

*What kind of career do you imagine for yourself? Doctor? Lawyer? Scientist? Engineer? Teacher? CEO? Manager? Salesperson?*

There is no “one” path to a career in Biomedical Engineering—just as this important technical area is interdisciplinary, there are many ways to chart your academic career in this exciting field. Biomedical engineers use their expertise in biology, medicine, physics, mathematics, engineering science, and communication to make the world a healthier place. The challenges created by the diversity and complexity of living systems require creative, knowledgeable, and imaginative people working in teams of physicians, scientists, engineers, and even business professionals to monitor, restore, and enhance normal body function. The biomedical engineer is ideally trained to work at the intersection of science, medicine, and mathematics to solve biological and medical problems.

The field of biomedical engineering encompasses those people with formal degrees in biomedical engineering as well as those with degrees in other engineering disciplines who, through coursework (for example, a minor in biology) or through experience, have gained mastery over one or more areas of biomedical inquiry and application. Very occasionally, biologists or biomedical scientists who have gained skills in engineering also are considered members of this field.

One definition of biomedical engineering would be anything that combines—in any proportion—biology or medicine on the one hand and one of the engineering disciplines on the other. Biomedical engineering is therefore a very large field—it would take a gifted person several lifetimes to master just a few of the many disciplines. This means it is important to understand the field’s breadth, but to focus on what really interests you. This brochure describes many of the issues and topics that interest today’s biomedical engineers.



*Biomedical engineers use their expertise in biology, medicine, physics, mathematics, engineering science, and communication to make the world a healthier place.*

# Designing A Career In Biomedical Engineering

## What do biomedical engineers do?

Perhaps a simpler question to answer is: “What don’t biomedical engineers do?” Biomedical engineers work in industry, academic institutions, hospitals, and government agencies. Some may spend their days designing, manufacturing, or testing mechanical devices such as prosthetics and orthotics, while others design electrical circuits and computer software for medical instrumentation. These instruments may range from large imaging systems such as conventional x-ray, computerized tomography (a sort of computer-enhanced three-dimensional x-ray), and magnetic resonance imaging, to small implantable devices, such as pacemakers, cochlear implants, and drug infusion pumps.

Biomedical engineers may use chemistry, physics, mathematical models, and computer simulation to develop new drug therapy. Indeed, a considerable number of the advances in understanding how the body functions and how biological systems work have been made by biomedical engineers. They may use mathematical models and statistics to study many of the signals generated by organs such as the brain, heart, and skeletal muscle. Some biomedical engineers build artificial organs, limbs, knees, hips, heart valves, and dental implants to replace lost function; others are growing living tissues to replace failing organs. The development of artificial body parts requires that biomedical engineers use chemistry and physics to develop durable materials that are compatible with a biological environment.

Biomedical engineers help translate complex human organs such as the heart or brain into thousands of mathematical equations and millions of data points, which then run as computer simulations. The result is a visual simulation that looks and behaves much like the real organ it mimics.

Biomedical engineers are also working to develop wireless technology that will allow patients and doctors to communicate over long distances. Many biomedical engineers are involved in rehabilitation—designing better walkers, exercise equipment, robots, and therapeutic devices to improve human performance. They are also solving problems at the cellular and molecular level, developing nanotechnology and micro-machines to repair damage inside the cell and alter gene function. Biomedical engineers are also working to develop three-dimensional simulations that apply physical laws to the movements of tissues and fluids. The resulting models can be invaluable in understanding how tissue works, and how a prosthetic replacement, for example, might work under the same conditions.



*Some biomedical engineers spend their days designing, manufacturing, or testing mechanical devices such as prosthetics and orthotics, while others design electrical circuits and computer software for medical instrumentation.*

# Designing A Career In Biomedical Engineering

Some biomedical engineers solve biomedical problems as physicians, business managers, patent attorneys, physical therapists, professors, research scientists, teachers, and technical writers. Another area where biomedical engineers excel is sales and field engineering. While these careers often require additional training beyond the bachelor's degree in biomedical engineering, they are all appropriate careers for the person trained in biomedical engineering. Sometimes electrical, mechanical, computer, or other types of engineers may find themselves working on bioengineering-related problems. After a few years, they may have so much biomedical-related expertise that they can be considered biomedical engineers.

## How do biomedical engineers differ from other engineers?

Biomedical engineers must integrate biology and medicine with engineering to solve problems related to living systems. Thus, biomedical engineers are required to have a solid foundation in a more traditional engineering discipline, such as electrical, mechanical, or chemical engineering, and increasingly, materials science. Most undergraduate biomedical engineering programs require students to take a core curriculum of traditional engineering courses. However, biomedical engineers are expected to integrate their engineering skills with their understanding of the complexity of biological systems in order to improve medical practice. Thus, biomedical engineers—whether in formal BME (biomedical engineering) or in traditional engineering degree programs—must all be trained in the life sciences as well.

## What kind of education does a biomedical engineering degree require?

As you read through the following sections, keep in mind that science or technology education has both tangible and intangible components. The tangible components include the science as well as engineering design. The intangible components, often more important, include so-called “soft skills,” such as teamwork, practical experience, leadership, entrepreneurship, speaking, and writing—essentially a well-rounded education preparing the student for a wide variety of opportunities and challenges in life and career.



*Some biomedical engineers solve biomedical problems as physicians, business managers, patent attorneys, physical therapists, professors, research scientists, teachers, and technical writers.*

# Designing A Career In Biomedical Engineering

## How much education does a biomedical engineer require?

A biomedical engineering degree typically requires a minimum of four years of university education. Following this, the biomedical engineer may assume an entry level engineering position in a medical device or pharmaceutical company, a clinical engineering position in a hospital, or even a sales position for a biomaterials or biotechnology company. Many biomedical engineers will seek graduate level training in biomedical engineering or a related engineering field. A master's or doctoral degree offers the biomedical engineer greater opportunities in research and development, whether such work resides in an industrial, academic, or government setting. Some biomedical engineers choose to enhance their education by pursuing a graduate degree in business, eventually to help run a business or manage health care technology for a hospital.

Many biomedical engineers go on to medical school and dental school following completion of their bachelor's degree. A fraction of biomedical engineers even choose to enter law school, planning to work with patent law and intellectual property related to biomedical inventions. What better training than biomedical engineering for our future physicians, dentists, and patent lawyers?

## How can a high school education prepare me for studies in biomedical engineering?

Biomedical engineers require education and training in several sciences, as well as in mathematics, engineering design, communication, teamwork, and problem-solving. To best prepare for a college program in biomedical engineering, one should take a well-rounded course of study in high school. The minimum such study should include a year each of biology, chemistry, and physics. Advanced courses in any of these sciences are a plus. High school algebra, geometry, advanced algebra, trigonometry, and pre-calculus are a must. A course in calculus is also typical of students entering biomedical engineering programs. A computer programming course gives students a definite advantage in their college program. One might also consider a drafting or mechanical drawing course, or better, a computer-aided design (CAD) course as an elective.

The humanities and social sciences are also important to the biomedical engineer. High school preparation should include four years of English and composition, a speech course, several years of history and social studies, and even study of a foreign language. As biomedical engineers work to improve healthcare worldwide, the ability to communicate in another language is a valuable skill.



*Biomedical engineers require education and training in several sciences, as well as in mathematics, engineering design, communication, teamwork, and problem-solving.*

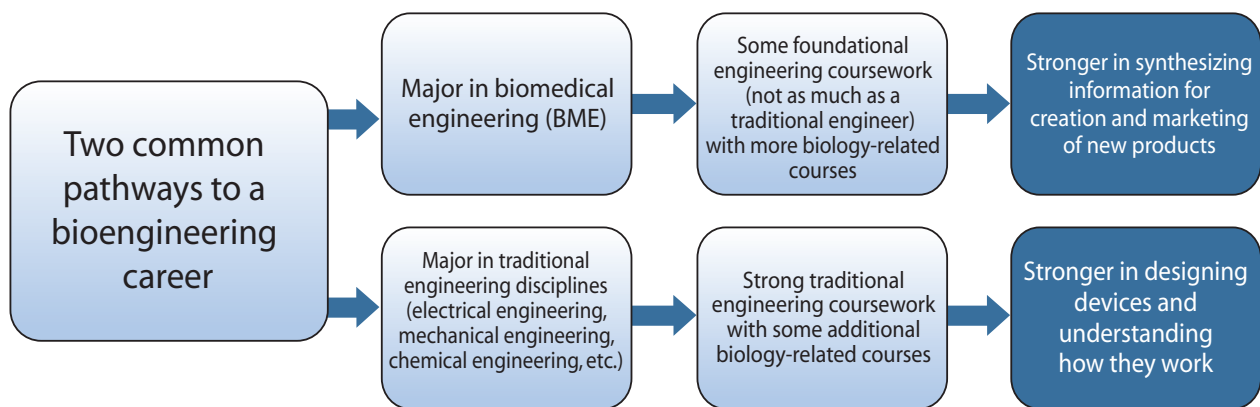
# Designing A Career In Biomedical Engineering

## What major should I choose as an undergraduate?

For high school and beginning college students this is a difficult question as well as a very personal decision. Let's say you want to be a biomedical engineer—how would you figure out what path to follow? One way is to step back and pretend that biomedical engineering doesn't exist. Ask yourself which path is more attractive: biology (or medicine) or engineering? If engineering sounds more attractive, which engineering path might suit you best: electrical, mechanical, chemical, or something else? If biology sounds more attractive, which path looks better to you: genomics, physiology, environmental, etc.? These questions are not always simple to answer—it is best to look through the course requirements for the different majors and to study the descriptions of the courses in each of the majors. You'll find that online course catalogs can really help you with this. (Don't be intimidated by the titles and descriptions!) Your reaction will tell you a lot about your motivations for becoming a biomedical engineer.

If, after this careful study, your answer is engineering, then the next question is whether to major in biomedical engineering or in one of the traditional engineering disciplines. BME graduates have much better biomedical understanding but reduced knowledge of a particular engineering discipline. If you choose biomedical engineering, you should consider how to create a curriculum with elective and focused engineering courses. If you instead choose a traditional major, you should consider how best to add the right courses—molecular biology to physiology—so that you can work on BME projects both in school and in your career. Both kinds of biomedical engineers have roles to play. Those with BME degrees are especially valuable for their ability to synthesize information from multiple disciplines in the creation and marketing of new products. Those with traditional degrees are stronger in the design and understanding of the devices themselves.

If, however, your answer is biology, then you should next investigate whether your goal is a career in one of the medical professions or as a research scientist or technician. Note that it is almost always harder for biology majors to gain the basic engineering background to switch to a BME graduate program, mostly because biology majors do not get the in-depth education in mathematics and physics that are essential to engineering. By comparison, a traditional engineering major can rapidly acquire enough biology to be competitive.



*Two common pathways to a bioengineering career*

# Designing A Career In Biomedical Engineering

## What types of university courses will prepare me to become a biomedical engineer?

Design is crucial to most biomedical and engineering activities. To design, biomedical engineers must have a solid foundation in biology, chemistry, physics, mathematics, and engineering. Although the biomedical engineering curriculum varies from university to university, most programs require courses in biology and physiology, biochemistry, inorganic and organic chemistry, general physics, electronic circuits and instrumentation design, statics and dynamics, signals and systems, biomaterials, thermodynamics and transport phenomenon, and engineering design. Students also take a number of advanced science and engineering courses related to their specialty in biomedical engineering. Typical specialties include bioelectronics, biomechanics, biomaterials, physiologic systems, biological signal processing, rehabilitation engineering, telemedicine, virtual reality, robotic aided surgery, and clinical engineering. Newer specialties include cellular and tissue engineering, neural engineering, biocomputing, and bioinformatics. Many engineering and science courses incorporate laboratory experience to provide students with hands-on, real-world applications.

In addition to science and engineering courses, the biomedical engineering student must take courses in English, technical writing, ethics, and humanities (such as history, political science, philosophy, sociology, anthropology, psychology, and literature). Some students continue studies of a foreign language in hopes of securing internships or permanent engineering positions in a foreign country. Business courses are also popular for students interested in engineering management.

Many universities actively encourage six-month overseas exchange programs where a component of the biomedical engineering curriculum is taught by a university in another country.



*Biomedical engineering students also take a number of advanced science and engineering courses related to their specialty in biomedical engineering.*



# Designing A Career In Biomedical Engineering

## What kind of practical experience can I expect to gain while training to be a biomedical engineer?

Many undergraduate training programs in biomedical engineering offer students an opportunity to gain real-world experience prior to graduation. Summer internships with medical device and pharmaceutical companies are popular, as are summer research experiences at academic institutions and government agencies, including the National Institutes of Health (NIH) and regulatory approval bodies such as the FDA (Food and Drug Administration) in the United States. Some universities offer formal cooperative training programs in biomedical engineering whereby the student spends several semesters working at a biomedical company or hospital, earning academic credit as well as a salary. Such real-world experiences allow a student to explore career options and better define his or her role in the biomedical engineering community. All biomedical engineering programs emphasize the Senior Design course in which students learn to first identify and then use their engineering skills to solve real biomedical problems.

A significant number of biomedical engineering students engage in research in a faculty laboratory, beginning at a low level and working toward more intensive involvement in the laboratory's activities. Such experiences are excellent preparation for future graduate study and are especially valuable for students planning to go on to the MD or PhD degrees. However, usually students must proactively approach faculty in order to obtain these positions, as there are many more students desiring research than there are openings for undergraduates in research labs.



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# Designing A Career In Biomedical Engineering

## The BME job market

The BME job market is still small, but fast growing percentage-wise. The number of BME majors is growing even faster. Reliable and informative data is very hard to find. You may wish to take a look at online information from the Bureau of Labor Statistics, which details the United States national labor force by category, including biomedical engineering, and the American Society for Engineering Education, which tracks the number of graduates at the BS, MS, and PhD levels in various engineering fields.

The BME job market is open not only to BME graduates but also to many students whose degrees are in the traditional engineering disciplines (often with minors in biology) and, to a much lesser extent, biology majors (with some engineering or computational training). BME majors compete with engineering graduates for some jobs and graduate programs. Obviously, the winner of a particular competition will have a background that is more closely oriented towards the needs of the job or program in question. BMEs will win if the biomedical component is high, and engineers from other engineering disciplines, such as electrical or mechanical, will win if a specific type of engineering content is high. Bioengineers and more traditional engineers have advantages over biology majors as long as there is engineering or design content. Traditional engineers have more technically advanced opportunities and salaries than biology majors, with BME majors in the middle.

For perspective, one should understand that engineers with a bachelor's degree—including BME graduates—go on to a wide variety of careers. These include those requiring advanced education such as research (PhD), law (JD), medicine (MD, RN), and business (MBA). Many bachelor degree engineers obtain design engineering positions, often after completing a master's degree. Bachelor degree engineers also find positions in manufacturing, field engineering, sales, and marketing. Somewhat unique to BME is that there is a big job market in the field of regulation, such as in working with the Food and Drug Administration on new products, as well as in the creation and supervision of protocols for human and animal trials. A significant number of bachelor degree BME graduates find themselves in non-design positions where technical knowledge is of great advantage. But BME design positions often require at least a master's and often a PhD.

Opportunities are greatest for students with industry or clinical design experience. You can begin to gain this kind of experience through an internship, summer job, industry or clinical-focused senior design project, or with solid laboratory or computer experiences and skills.



*Opportunities are greatest for BME students with industry or clinical design experience.*

# Designing A Career In Biomedical Engineering

## What are some of the key areas of biomedical engineering?

As you read through the descriptions you will notice substantial overlaps among areas of biomedical engineering. Cross-cutting technologies include diagnostic devices, imaging and computation. Biomolecular technologies are proliferating from area to area. This is a sign that bioengineering is a rapidly evolving and vibrant field.

### *Practical Applications*

**Clinical Engineering** supports and advances patient care by applying engineering and managerial skills to healthcare technology. Clinical engineers can be based in hospitals, where responsibilities may include managing the hospital's medical equipment systems, ensuring that all medical equipment is safe and effective, and working with physicians to adapt instrumentation to meet the specific needs of the physician and the hospital. In industry, clinical engineers can work in medical product development, from product design to sales and support, to ensure that new products meet the demands of medical practice.

**Rehabilitation Engineering** is the application of science and technology to improve the quality of life for people with disabilities. This can include designing augmentative and alternative communication systems for people who cannot communicate in traditional ways, making computers more accessible for people with disabilities, developing new materials and designs for wheelchairs, and making prosthetic legs for runners in the Paralympics.

### *Starting from Physiology*

**Neural Systems Engineering:** This emerging interdisciplinary field involves study of the brain and nervous system and encompasses areas such as the replacement or restoration of lost sensory and motor abilities (for example, retinal implants to partially restore sight or electrical stimulation of paralyzed muscles to assist a person in standing), the study of the complexities of neural systems in nature, the development of neuro-robots (robot arms that are controlled by signals from the motor cortex in the brain) and neuro-electronics (e.g., developing brain-implantable micro-electronics with high computing power). Also included are diagnostic devices.

**Cardiac Bioengineering:** Cardiovascular diseases represent the foremost healthcare problem in the industrialized world. Cardiac bioengineering uses imaging, quantitative systems analysis, and molecular and nanotechnologies to advance our understanding of cardiovascular systems and diagnose problems. How do proteins work to control endothelial mechanotransduction? How do microvessels adapt to environmental stresses? How can new drug delivery and vascular imaging techniques be used to understand what happens on a molecular scale after a heart attack? These questions, and many more, are explored in this promising area of preventive and therapeutic medicine, which encompasses sub-cellular to organ levels, and involves many different disciplines.

**Physiological System Modeling:** Many recently improved medical diagnostic techniques and therapeutic innovations have been a result of physiological systems modeling. In this field, models of physiological processes (e.g., the control of limb movements, the biochemistry of metabolism) are developed to gain a better understanding of the function of living organisms. Modeling is also incorporated into diagnostic equipment and into patient simulators for training.

# Designing A Career In Biomedical Engineering

## What are some of the key areas of biomedical engineering?

### *Electronics Technology and Instrumentation*

**Instrumentation, Sensors, and Measurement** involves the hardware and software design of devices and systems used to measure biological signals. This ranges from developing sensors that can capture a biological signal of interest, to applying methods of amplifying and filtering the signal so that it can be further studied, to dealing with sources of interference that can corrupt a signal, to building a complete instrumentation system such as an x-ray machine or a heart monitoring system.

**Bio-signal Processing** involves extracting useful information from biological signals for diagnostics and therapeutics purposes. This could mean studying cardiac signals to determine whether or not a patient will be susceptible to sudden cardiac death, developing speech recognition systems that can cope with background noise, or detecting features of brain signals that can be used to control a computer.

### *Biomedical Images and Signals*

**Imaging and Image Processing:** X-rays, ultrasound, magnetic resonance imaging (MRI), computerized tomography (CT), nuclear medicine, and microscopy are among the imaging methods that are used to let us “see” inside the human body. Work in this area includes developing low-cost image acquisition systems, image processing algorithms, image/video compression algorithms and standards, and applying advances in multimedia computing systems in a biomedical context.

**Radiology** refers to the use of radioactive substances such as x-ray, magnetic fields as in magnetic resonance imaging, and ultrasound to create images of the body, its organs, and structures. These images can be used in the diagnosis and treatment of disease, as well as to guide doctors when performing minimally invasive image-guided surgeries.

### *Molecular Biology Meets Computers*

**Medical and Health Informatics**, one of the largest and fastest growing of all biomedical engineering areas, involves developing and using computer tools to collect and analyze data related to medicine and biology. Work in bioinformatics could involve using sophisticated techniques to manage and search databases of gene sequences that contain many millions of entries. Other activities are automated analyses of images, mining of patient record data bases to infer disease and treatment relationships, and securely managing data from, for instance, handheld wireless diagnostic devices.

**Bioinformatics (including Genomics)** is the mapping, sequencing, and analyzing of genomes—the set of all the DNA in an organism. A full understanding how genes function in normal and/or diseased states can lead to improved detection, diagnosis, and treatment of disease.

**Proteomics** is the study of proteomes—the set of all proteins produced by a species. Advances in proteomics have included the discovery of a new cellular process that explains how infections occur in humans—an advance that is leading to new treatments for infectious diseases. Additionally, these advances have led to discovery of a method to detect protein patterns in the blood for early diagnosis of ovarian cancer. Work in proteomics can also involve the development of hardware devices that provide accurate and rapid measurements of protein levels.

# Designing A Career In Biomedical Engineering

## What are some of the key areas of biomedical engineering?

### *Medicine Meets Computers*

**Information Technology** in biomedicine covers a diverse range of applications and technologies, including the use of virtual reality in medical applications (e.g., diagnostic procedures), the application of wireless and mobile technologies in health care settings, artificial intelligence to aid diagnostics, and addressing security issues associated with making health care information available on the World Wide Web.

**Telemedicine**, sometimes called “telehealth” or “e-health,” involves the transfer of electronic medical data from one location to another for the evaluation, diagnosis, and treatment of patients in remote locations. This usually involves the use of “connected” medical devices, advanced telecommunications technology, video-conferencing systems, and networked computing. Telemedicine can also refer to the use of these technologies in health-related distance learning.

### *Mechanics Meets Biology and Medicine*

**Biomechanics** is mechanics applied to biology. This includes the study of motion, material deformation, and fluid flow. For example, studies of the fluid dynamics involved in blood circulation have contributed to the development of artificial hearts, while an understanding of joint mechanics has contributed to the design of prosthetic limbs. Orthopedic biomechanics and materials is a major industry, one of the most successful areas of biomedical engineering.

**Robotics in Surgery** includes the use of robotic and image processing systems to interactively assist a medical team both in planning and executing a surgery. These new techniques can minimize the side effects of surgery by providing smaller incisions, less trauma, and more precision, while also decreasing costs.

### *Materials Go Very Small*

**BioMEMS** is the area of MEMS (microelectromechanical systems) which integrates mechanical elements, sensors, actuators, and electronics on a silicon chip. BioMEMS is MEMS applied to medicine and biology. Examples of BioMEMS work include wireless sensors worn on the body, inexpensive and disposable diagnostic chips, and sophisticated devices miniaturizing racks of equipment needed for molecular biology. While micro-robots doing surgery is a bit far off, tiny implantable devices releasing drugs are beginning to be used as well as swallowable miniature cameras for detecting cancer in the gastrointestinal tract.

**Micro and Nanotechnology:** Microtechnology involves development and use of devices on the scale of a micrometer (one thousandth of a millimeter, or about 1/50 of the diameter of a human hair), while nanotechnology involves devices on the order of a nanometer (about 1/50,000 of the diameter of a human hair, or ten times the diameter of a hydrogen atom). These fields include the development of microscopic force sensors that can identify changing tissue properties as a way to help surgeons remove only unhealthy tissue, and nanometer length cantilever beams that bend with cardiac protein levels in ways that can help doctors in the early and rapid diagnosis of heart attacks. This field is closely related to and often overlapping with MEMS and BioMEMS.

**Biomaterials** are substances that are engineered for use in devices or implants that must interact with living tissue. Examples of advances in this field include the development of coatings that fight infection common in artificial joint implants, materials that can aid in controlled drug delivery, and “scaffolds” that support tissue and organ reconstruction.

# Designing A Career In Biomedical Engineering

## What are some of the key areas of biomedical engineering?

### Chemical Engineering Approaches

**Biotechnology** is a set of powerful tools that employ living organisms (or parts of organisms) to make or modify products, improve plants or animals, or develop microorganisms for specific uses. Some of the earliest efforts in biotechnology involved traditional animal and plant breeding techniques, and the use of yeast in making bread, beer, wine, and cheese. Modern biotechnology involves the industrial use of recombinant DNA, cell fusion, and novel bioprocessing techniques, which can all be used to help correct genetic defects in humans. It also involves bioremediation—degradation of hazardous contaminants with the help of living organisms.

**Drug Delivery** involves the delivery of a chemical compound to the point where treatment is being applied. This can relate to various genetic and nucleic acid therapeutic techniques, including the selective targeting of imaging contrast agents. Work in this area can be very helpful in predicting the effects of drugs on patients.

**Biofuels** research pertains to the search for renewable alternatives to gasoline. Some chemical engineers and biologists, for example, have found ways to dramatically boost the production of isobutanol in yeast. Such approaches might also potentially produce other useful chemicals that would be of great use to society. Other bioengineers work toward bioengineering algae and bacteria for biofuel production.

### Biology Goes Engineering

*Although these fields are still in their infancy, the future potential for growth is high.*

**Tissue Engineering** is the study of—and the coaxing of—new growth of connective tissues and even entire organs that can be useful in the human body. These new tissues and organs are produced from tiny samples of a person's original tissue, often placed on a scaffold that can later dissolve. Once the tissue or organ might be grown and then implanted back into the original donor, the new materials have no need for anti-rejection drugs. Such techniques are particularly useful for cartilage and bone repair, as well as dermal wound healing.

**Cellular and Molecular Biomechanics** involves studying and working with the mechanical characteristics of biomolecules such as genes and proteins that underpin cells—all towards building a better understanding of tissues and organs. How do cells sense mechanical forces? How do such forces affect various important outcomes, including cell growth, movement, and gene expression? Mechanical stimulation can cause surprising signal cascades, and even change a cell's phenotype. Understanding such factors could underpin many important new breakthroughs.

**Genetic Engineering and Synthetic Biology:** Genetic engineering pertains to the modification of an organism's genes. Such approaches can, for example, allow for slight changes in the American Chestnut's genetic makeup—changes that could allow the tree to survive and thrive despite the chestnut blight that decimated whole forests during the early 1900s. Synthetic biology goes a step beyond genetic engineering. Rather than tiny snippets of DNA, entire plasmids and chromosomes, for example, would be synthesized as standard modules that could be pulled from a library, rather like standard engineered parts can be pulled from parts bins.

# Designing A Career In Biomedical Engineering

## Where do I get more information about biomedical engineering programs?

You can find more information about biomedical engineering degree programs through your high school guidance counselors, at your local library, and through the Internet. Most universities provide program descriptions, curriculum requirements, and admission requirements on their web pages. In addition, most of these programs provide application forms online. You may also find information on biomedical engineering programs at [www.embs.org](http://www.embs.org) (have fun looking around the website!). There is also worthwhile information available through the National Institute of Biomedical Imaging and Bioengineering and its website ([www.nibib.nih.gov](http://www.nibib.nih.gov)) as well at the American Institute for Medical & Biological Engineers, the Department of Labor and O'Net ([www.onetonline.org](http://www.onetonline.org)). *IEEE PULSE*, which is the flagship magazine of the IEEE Engineering in Medicine and Biology Society, and journals such as the *IEEE Transactions on Biomedical Engineering* can also be very useful, as well as books such as *Introduction to Biomedical Engineering, Career Development in Bioengineering and Biotechnology, Medical Instrumentation: Application and Design*, and the *Biomedical Engineering Handbook Series*.

The field of biomedical engineering now enjoys the services of many organizations collaborating to improve the lives of people around the world. These societies include the IEEE Engineering in Medicine and Biology (IEEE-EMBS), the Biomedical Engineering Society (BMES), the European Alliance for Medical and Biological Engineering and Science (EAMBES), and the world umbrella organization for all biomedical engineering societies—the International Federation for Medical and Biological Engineering (IFMBE). Wherever you live, you should be able to find a biomedical engineering organization to help you reach your goals.

## Join a Society to Advance Your Career

Professional societies are very active in helping people advance their professional careers. Students, especially at the undergraduate level, should seek out and join a professional society, usually at the student branch level. If you are interested in bioengineering, you may wish to consider joining the Engineering in Medicine and Biology Society (EMBS), the Biomedical Engineering Society (BMES), the Institute of Electrical and Electronics Engineers (IEEE), the Materials Research Society (MRS), the Tissue Engineering and Regenerative Medicine International Society (TERMIS), or any of the many other societies that support students, researchers, and professional practitioners affiliated with bioengineering.

The authors of this brochure are affiliated with the EMBS, which does impressive work in a broad variety of areas, including the single most useful publication for the beginning biomedical engineer, *IEEE PULSE*. Pulse's articles are edited so as to be appealing to "students of all ages," while covering state-of-the-art biomedical engineering technology and current medical issues, including a global perspective.

EMBS is the oldest, largest, and most global biomedical engineering professional society in the world. Beyond the publication of *IEEE PULSE*, the society advances the application of engineering sciences and technology to medicine and biology, promotes the profession, and provides global leadership for the benefit of its members and humanity by disseminating knowledge, setting standards, fostering professional development, and recognizing excellence. It is a full service professional organization, providing the world's biomedical engineering community with a magazine, journals, conferences, and summer schools.

***We hope that, if your interests align with ours, you join EMBS. But by all means get involved in at least one professional society.***

# Designing A Career In Biomedical Engineering

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The field of interest of the IEEE Engineering in Medicine and Biology Society is the application of the concepts and methods of the physical and engineering sciences in biology and medicine. This covers a very broad spectrum ranging from formalized mathematical theory through experimental science and technological development to practical clinical applications. It includes support of scientific, technological and educational activities.

## PUBLICATIONS

### *IEEE PULSE*

*Journal of Biomedical Health Informatics*

*Journal of Translational Engineering in Health and Medicine*

*Reviews in Biomedical Engineering*

*Transactions on Biomedical Engineering*

*Transactions on Neural Systems and Rehabilitation Engineering*

*Transactions on Medical Imaging*

*Transactions on NanoBioscience*

*Transactions on Computational Biology and Bioinformatics*

## ELECTRONIC PRODUCTS

Biomedical Essentials

EMBS Electronic Resource

## CONFERENCES

Annual International Conference of the IEEE Engineering in Medicine and Biology Society

IEEE EMBS Special Topic Conference on Information Technology in Biomedicine

IEEE EMBS Special Topic Conference on Microtechnologies in Medicine and Biology

IEEE EMBS Special Topic Conference on Cellular, Molecular and Tissue Engineering

IEEE EMBS Special Topic Conference on Neural Engineering

International Symposium on Biomedical Imaging

International Conference on Biomedical Robotics and Biomechatronics

## SUMMER SCHOOLS

International Summer School on Biomedical Imaging

International Summer School on Biomedical Signal Processing

International Summer School on Biocomplexity

International Summer School on Medical Devices and Biosensors

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for use of the included photography

## Engineering in Medicine & Biology



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***We hope that, if your interests align with ours, you join EMBS. But by all means get involved in at least one professional society.***

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