Biomedical Engineering

Starting salary: $68,000
Median Income: $86,960

Biomedical engineering is, in a very real sense, people engineering. The objective of biomedical engineering is to enhance health care by solving complex medical problems using engineering principles. Those who specialize in this field want to serve the public, work with health care professionals, and interact with living systems. This broad field allows a large choice of sub-specialties. Many students say they choose biomedical engineering because it is people-oriented.

Imagine designing a medical device that appears to breath life into someone. The pacemaker was invented by biomedical engineers who literally gave recipients the ability to perform physical activities such as climbing a flight of stairs or walking around the block.

The biomedical engineering field changes rapidly. New technology is designed and fabricated every day. Biomedical engineers can expect a satisfying career with tremendous diversity and growth potential. The field includes many branches: biomechanical, bioelectrical, biochemical, rehabilitation, clinical, and genetic engineering. There are also many sub-specialties within biomedical engineering such as surgical lasers, telemedicine, nuclear medicine, and clinical computer systems.
Examples of specializations within biomedical engineering include:

- Artificial organs such as hearing aids, kidneys, hearts, blood oxygenators, synthetic blood vessels, pacemakers and joints.
- Prosthetic devices such as arms, legs, hands, feet, fingers, toes, and facial organs.
- Automated patient monitoring devices for surgery or intensive care. Automated monitoring devices also include monitoring healthy persons in unusual environments such as astronauts in space or deep sea divers.
- Blood chemistry sensors for detecting higher or lower levels of potassium, sodium, O2, CO2, and pH balance.
- Advanced therapeutic and surgical devices such as laser systems for eye surgery, endoscopic surgery, and automated delivery of insulin.

Job Outlook

Employment of biomedical engineers is projected to grow 27 percent from 2012 to 2022, much faster than the average for all occupations. Demand will be strong because an aging population is likely to need more medical care and because of increased public awareness of biomedical engineering advances and their benefits.

Industries with the highest levels of employment in this occupation:

1. Medical Equipment and Supplies Manufacturing
2. Scientific Research and Development Services
3. Pharmaceutical and Medicine Manufacturing
4. Colleges, Universities, and Professional Schools
5. General Medical and Surgical Hospitals

Top paying industries for this occupation:

1. Scientific Research and Development Services
2. Offices of Physicians
3. Architectural, Engineering, and Related Services
4. Computer Systems Design and Related Services
5. Wholesale Electronic Markets and Agents and Brokers

Source: US Bureau of Labor Statistics

- Computer-based systems for diagnosing diseases and hospital management.
- Clinical laboratory design such as computer analyzers for blood or urine samples and cardiac catheterization laboratories.
- Medical imaging such as ultrasound, computer assisted tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET) systems.
- Physiologic system computer modeling for blood pressure control, renal function, seeing and hearing nervous circuits, and more.
- Biomaterials design such as the mechanical, transport, and biocompatibility properties of implantable artificial organs, limbs, and materials.
- Biomechanical applications using gait analysis and growth factor applications.
- Sports medicine in rehabilitation and physical therapy as well as external support devices.

A fascinating application of biomechanical engineering, according to Ellen Morrissey and Donald Lehr of the Nolan/ Lehr Group, is the helmets for hockey players. Though they appear to be made of a single piece of material, they are actually three different parts fitted together in an intricate geometric configuration refined over the years for maximum energy absorption. (To test the helmet's ability to attenuate impacts, manufacturers fit helmets with instrumental test heads and then drop them several meters. At the end of the drop, known as a "sudden deceleration," the testers examine the helmet's level of protection and whether it has withstood impacts from 275 to 300 G-forces.) Besides providing protection, the helmet must also be light enough to keep the head cool, since hockey players are in constant motion and release a great deal of heat through their head. Lightness also allows players to accelerate at high speeds and then, since sudden stops square the effect of inertia, stop without tumbling off balance.

Biochemical Engineering—Biochemical engineers concern themselves with body responses on a microscopic level. These engineers study the interactions between artificial materials that may cause negative reactions in the human body. They apply anatomy, biochemistry, and cellular mechanics to understand diseases and modes of intervention. They developed woven acrylic artificial arteries to prevent blood clotting in artificial blood vessels. And they designed and constructed the artificial kidney for patients with incurable kidney disease.

Bioelectrical Engineering—Biomedical engineering with an electrical emphasis is a popular choice among students. Bioelectrical inventions are everywhere, from digital ear thermometers to sophisticated MRI machines. Another bioelectrical development is the pacemaker, a device that senses irregular or arrested heart rhythms and restores the rhythms by giving electrical stimulation to the heart muscle. Bioelectrical engineers have also developed the electrocardiogram machine, which records, through electrodes placed on the skin, the beating of a heart. Bioelectrical engineers may design software or devices to aid doctors and hospitals such as electrophysiology cardiac monitors or telemedicine equipment. They may design devices to allow patients to self-monitor their conditions, or they may help a paraplegic become self-sufficient by designing an electrical system to regulate all switches and/or appliances in the patient's house.

Biomechanical Engineering—Biomechanical engineering or biomechanics is the specialty that sees the human body as a mechanical structure. These specialists investigate the motion of the human body, the stresses on bones and muscles, and the deformation of artificial materials, such as bones and joints. They might work for a company such as Nike to design a new running shoe after studying the impact caused by running. Biomechanical engineers may also design artificial limbs, joint replacements, or new materials to replace ligaments, tendons, or bones. An early development from a biomechanical engineer was the invention of the iron lung, which was an airtight respirator consisting of a metal tank that enclosed the entire body except for the head. It provided artificial respiration by contracting and expanding the walls of the chest.

Clinical Engineering—Clinical engineering is the branch of biomedical engineering that applies technology to health care in organizations such as hospitals and long-term care facilities, and for

medical equipment vendors. Clinical engineers must understand the relationship of the equipment to the diagnosis, care, and treatment of the patient. High-risk assessments and the development of maintenance schedules and protocols are some of the other tasks they perform. They may also provide training for doctors, nurses, and other health professionals on the effective use of all medical equipment, and they may maintain the equipment. Clinical engineers may also evaluate equipment prior to purchase, test the equipment for safety, or modify existing hospital equipment. In addition, they may participate in accident or incident investigations.

Genetic, Cellular and Tissue Engineering—Genetic, Cellular, and Tissue engineering is a new branch of biomedical engineering that researches ways to harness biomedical problems on a microscopic level. Researchers manipulate DNA, stimulate or retard cellular growth, and study the structure and mechanics of cells to better understand disease and detect methods of intervention. Genetic and agricultural engineers also design products to break down oil slicks efficiently.

Rehabilitation Engineering—Rehabilitation engineering is another popular specialty within biomedical engineering. Rehabilitation engineers participate in the research and development of technology to assist people with disabilities. According to the Biomedical Engineering Society, "Rehabilitation engineers enhance the capabilities and improve the quality of life for individuals with physical and cognitive impairments."

Assistive technology includes devices such as powered wheelchairs, talking computers, hearing aids, electronic talking devices, and any facilities that are modified, including grab bars for showers and restrooms. Recreational assistive technology such as specially adapted skis and fishing poles are also available. If rehabilitation engineering interests you, watch the Special Olympics to see the assortment of assistive technology devices available. Imagine the feeling of power and accomplishment associated with giving a disabled person a new lease on life, providing a way to meet everyday life challenges successfully, and eliminating some of the challenges associated with having a disability in today's society.

A rehabilitation engineer may work on site with a person recently confined to a wheelchair to redesign the person's work space; changes might include a desk that can be raised and lowered at the push of a button, wider doorways, and indoor ramps. A rehabilitation engineer may also redesign computer systems to assist people with cognitive or physical disabilities. One rehabilitation engineer designed a Braille keyboard so blind people can type; another developed a system that enables people that are paralyzed below the waist to drive an automobile.

As you can see, the diverse field of biomedical engineering offers a real way to make a large impact on society. Biomedical engineers work in hospitals, government regulatory agencies, corporations, medical device companies, research labs, and universities. Many go to medical school; biomedical engineers have a higher acceptance rate into medical school than people with any other degree. Many go to law school and become regulatory requirement attorneys for the Federal Drug Administration (FDA). Some go into teaching, and many become consultants or advisers to medical companies.

The Biomedical Engineering Society (BMES) has an excellent website at www.bmes.org that details the numerous specialties available within the field and provides links for additional information resources such as job opportunities, individual state BMES chapters, and prominent companies in the medical industry.

Glossary of Terms

Automated - to run or operate (something, such as a factory or system) by using machines, computers, etc., instead of people to do the work (merriam-webster.com)

Blood Oxygenators - a medical device that is capable of exchanging oxygen and carbon dioxide in the blood of human patient during surgical procedures that may necessitate the interruption or cessation of blood flow in the body, a critical organ or great blood vessel (Wikipedia, 19 November 2013 at 11:54)

Cardiac - of or relating to the heart (merriam-webster.com)

Catheter - a thin tube that is put into the body to remove or inject a liquid or to keep a passage open (merriam-webster.com)

Catheterization - the use of or introduction of a catheter (as in or into the bladder, trachea, or heart) (merriam-webster.com)

Clinical - relating to or based on work done with real patients : of or relating to the medical treatment that is given to patients in hospitals, clinics, etc. (merriam-webster.com)

Computer Assisted Tomography (CAT) - Tomography in which computer analysis of a series of cross-sectional scans made along a single axis of a bodily structure or tissue is used to construct a three-dimensional image of that structure (thefreedictionary.com)

Design - to plan and make (something) for a specific use or purpose (merriam-webster.com)

Diagnose - to recognize (as a disease) by signs and symptoms (merriam-webster.com)

Diversity - an instance of being composed of differing elements or qualities (merriam-webster.com)

Endoscope - an illuminated usually fiber-optic flexible or rigid tubular instrument for visualizing the interior of a hollow organ or part (as the bladder or esophagus) for diagnostic or therapeutic purposes that typically has one or more channels to enable passage of instruments (as forceps or scissors) (merriam-webster.com)

Endoscopic - of, relating to, or performed by means of an endoscope or endoscopy (merriam-webster.com)

Fabricate - to make or build (something) (merriam-webster.com)

Gait Analysis - is the systematic study of animal locomotion, more specifically the study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles (Wikipedia, 23 January 2014 at 17:59)

Genetic Engineering - the science of making changes to the genes of a plant or animal to produce a desired result (merriam-webster.com)

Implant - to place (something) in a person's body by means of surgery (merriam-webster.com)

Insulin - a substance that your body makes and uses to turn sugar into energy (merriam-webster.com)

Living Systems - are open self-organizing living things that interact with their environment. These systems are maintained by flows of i
information, energy and matter (Wikipedia, 13 December 2013 at 19:30)

Magnetic Resonance Imaging (MRI) - a method used to produce images of the inside of a person's body by means of a strong magnetic field (merriam-webster.com)

Monitor - a device for observing a biological condition or function (merriam-webster.com)

Nuclear Medicine - a branch of medicine dealing with the use of radioactive materials in the diagnosis and treatment of disease (merriam-webster.com)

Pacemaker - an electrical device for stimulating or steadying the heartbeat or reestablishing the rhythm of an arrested heart (merriam-webster.com)

Physiologic - characteristic of or appropriate to an organism's healthy or normal functioning (merriam-webster.com)

Positron Emission Tomography (PET) - tomography in which a cross-sectional image of regional metabolism is obtained by a usually color-coded representation of the distribution of gamma radiation given off in the collision of electrons in cells with positrons emitted by radionuclides incorporated into metabolic substances that have been administered (as by injection) (merriam-webster.com)

Prosthetic Device - an artificial device that replaces a missing body part lost through trauma, disease, or congenital conditions (Wikipedia, 14 January 2014 at 03:04)

Rehabilitation - to restore or bring to a condition of health or useful and constructive activity (merriam-webster.com)

Renal - relating to or involving the kidneys (merriam-webster.com)

Synthetic - of, relating to, or produced by chemical or biochemical synthesis; especially : produced artificially (merriam-webster.com)

Telemedicine - the practice of medicine when the doctor and patient are widely separated using two-way voice and visual communication (as by satellite or computer) (merriam-webster.com)

Therapeutic - of or relating to the treatment of illness (merriam-webster.com)

Tomography - a method of producing a three-dimensional image of the internal structures of a solid object (as the human body or the earth) by the observation and recording of the differences in the effects on the passage of waves of energy impinging on those structures (merriam-webster.com)
Ultrasound - a method of producing images of the inside of the body by using a machine that produces sound waves which are too high to be heard (merriam-webster.com)

ABET Accredited Programs in Biomedical Engineering

School Name	Location	Website	Program and Degree Name
Arizona State University	Tempe, AZ, US	www.asu.edu	Biomedical Engineering, BSE
Boston University	Boston, MA, US	www.bu.edu	Biomedical Engineering, BS
Brown University	Providence, RI, US	www.brown.edu	Biomedical Engineering, BS
Bucknell University	Lewisburg, PA, US	www.bucknell.edu	Biomedical Engineering, BS
Case Western Reserve University	Cleveland, OH, US	www.case.edu	Biomedical Engineering, BS
City University of New York, City College	New York, NY, US	www.ccny.cuny.edu	Biomedical Engineering, BE
Columbia University	New York, NY, US	www.columbia.edu	Biomedical Engineering, BS
Drexel University	Philadelphia, PA, US	www.drexel.edu	Biomedical Engineering, BS
Duke University	Durham, NC, US	www.duke.edu	Biomedical Engineering, BSE
Florida International University (Modesto Maidique Campus)	Miami, FL, US	www.fiu.edu	Biomedical Engineering, BS
Georgia Institute of Technology	Atlanta, GA, US	www.gatech.edu	Biomedical Engineering, BS
Illinois Institute of Technology	Chicago, IL, US	www.iit.edu	Biomedical Engineering, BS
Indiana Institute of Technology	Fort Wayne, IN, US	www.indianatech.edu	Biomedical Engineering, BSBME
Indiana University - Purdue University Indianapolis	Indianapolis, IN, US	www.iupui.edu	Biomedical Engineering, BS
Lawrence Technological University	Southfield, MI, US	www.ltu.edu	Biomedical Engineering, BS
Louisiana Tech University	Ruston, LA, US	www.latech.edu	Biomedical Engineering, BS
Marquette University	Milwaukee, WI, US	www.mu.edu	Biomedical Engineering, BSBE
Michigan Technological University	Houghton, MI, US	www.mtu.edu	Biomedical Engineering, BS
Milwaukee School of Engineering	Milwaukee, WI, US	www.msoe.edu	Biomedical Engineering, BS
New Jersey Institute of Technology	Newark, NJ, US	www.njit.edu	Biomedical Engineering, BSBE
North Carolina State University at Raleigh	Raleigh, NC, US	www.ncsu.edu	Biomedical Engineering, BS
Northwestern University	Evanston, IL, US	www.northwestern.edu	Biomedical Engineering, BS
Purdue University at West Lafayette	West Lafayette, IN, US	www.purdue.edu	Biomedical Engineering, BS
Rensselaer Polytechnic Institute	Troy, NY, US	www.rpi.edu	Biomedical Engineering, BS
Rose-Hulman Institute of Technology	Terre Haute, IN, US	www.rose-hulman.edu	Biomedical Engineering, BS
Rutgers, The State University of New Jersey	New Brunswick, NJ, US	www.rutgers.edu	Biomedical Engineering, BS
Saint Louis University	St. Louis, MO, US	parks.slu.edu	Biomedical Engineering, BS
Stevens Institute of Technology	Hoboken, NJ, US	www.stevens.edu	Biomedical Engineering, BE
Stony Brook University	New York, NY, US	www.sunysb.edu	Biomedical Engineering, BE
Texas A&M University	College Station, TX, US	www.tamu.edu	Biomedical Engineering, BS
The Catholic University of America	Washington, DC, US	www.cua.edu	Biomedical Engineering, BS
The College of New Jersey	Ewing, NJ, US	www.tcnj.edu	Biomedical Engineering, BSBME
The George Washington University	Washington, DC, US	www.gwu.edu	Biomedical Engineering, BS
The Johns Hopkins University	Baltimore, MD, US	www.jhu.edu	Biomedical Engineering, BS
The Ohio State University	Columbus, OH, US	www.osu.edu	Biomedical Engineering, BSBME

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School Name	Location	Website	Program and Degree Name
The University of Akron	Akron, OH, US	www.uakron.edu	Biomedical Engineering, BS
The University of Memphis	Memphis, TN, US	www.memphis.edu	Biomedical Engineering, BS
Tufts University	Medford, MA, US	www.tufts.edu	Biomedical Engineering, BS
Tulane University	New Orleans, LA, US	www.tulane.edu	Biomedical Engineering, BSE
University of Alabama at Birmingham	Birmingham, AL, US	www.uab.edu	Biomedical Engineering, BS
University of California, Davis	Davis, CA, US	www.ucdavis.edu	Biomedical Engineering, BS
University of California, Irvine	Irvine, CA, US	hwww.uci.edu	Biomedical Engineering, BS
University of Central Oklahoma	Edmond, OK, US	www.uco.edu	Biomedical Engineering, BS
University of Cincinnati	Cincinnati, OH, US	www.uc.edu	Biomedical Engineering, BS
University of Connecticut	Storrs, CT, US	www.uconn.edu	Biomedical Engineering, BSE
University of Hartford	West Hartford, CT, US	www.hartford.edu	Biomedical Engineering, BSE
University of Iowa	Iowa City, IA, US	www.uiowa.edu	Biomedical Engineering, BSE
University of Miami	Coral Gables, FL, US	www.miami.edu	Biomedical Engineering, BSBE
University of Michigan	Ann Arbor, MI, US	www.umich.edu	Biomedical Engineering, BSE
University of Minnesota - Twin Cities	Minneapolis, MN, US	www.umn.edu	Biomedical Engineering, BBmE
University of Rhode Island	Kingston, RI, US	www.uri.edu	Biomedical Engineering, B.S.
University of Rochester	Rochester, NY, US	www.rochester.edu	Biomedical Engineering, BS
University of South Carolina	Columbia, SC, US	www.sc.edu	Biomedical Engineering, BS
University of Southern California	Los Angeles, CA, US	www.usc.edu	Biomedical Engineering, B.S.
University of Tennessee at Knoxville	Knoxville, TN, US	www.utk.edu	Biomedical Engineering, BSBME
University of Texas at Austin	Austin, TX, US	www.utexas.edu	Biomedical Engineering, BS
University of Utah	Salt Lake City, UT, US	www.utah.edu	Biomedical Engineering, BS
University of Virginia	Charlottesville, VA, US	www.virginia.edu	Biomedical Engineering, BS
University of Wisconsin - Madison	Madison, WI, US	www.wisc.edu	Biomedical Engineering, BS
Vanderbilt University	Nashville, TN, US	www.vanderbilt.edu	Biomedical Engineering, BE
Virginia Commonwealth University	Richmond, VA, US	www.vcu.edu	Biomedical Engineering, BS
Washington University	St. Louis, MO, US	www.wustl.edu	Biomedical Engineering, BS
Western New England College	Springfield, MA, US	www.wnec.edu	Biomedical Engineering, BS
Worcester Polytechnic Institute	Worcester, MA, US	www.wpi.edu	Biomedical Engineering, BS
Wright State University	Dayton, OH, US	www.wright.edu	Biomedical Engineering, BS