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Independent Study Mentorship 3A

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Aldridge, Susan. "Biochemical Engineering." Biotechnology: In Context, edited by Brenda Wilmoth Lerner and K. Lee Lerner, Gale, 2012. In Context Series. Student Resources in Context,

Accessed 13 Oct. 2017.

**Assessment:**

 Normally, I am very indecisive when it comes to my research assessments and do not know what topic I should research, but this week, I was confident in my decision to research biochemical engineering. Usually, I research a subject that regards to chemical engineering, however, I wanted to learn more about a specific branch of chemical engineering that is more specialized. Before my research, I had an overall idea what biochemical engineering was about but my research was what truly opened the field to me.

 The first article, "Biochemical Engineers” elaborates on what biochemical engineers do. The duties, work schedule, and education required were clearly explained. Normally, a biochemical engineer works 40 hours a week and sometimes is required to work extra hours and on weekends to meet their deadlines or be flexible to their research they are conducting. Many people would not be willing to do that unless they truly enjoy what they are doing. Pursuing this career will end up compromising many things. It appears to me that biochemical engineers are willing to give up their time for their work in order to help out the world. It makes me sad that this career is not is not greatly appreciated for all their hard work and effort. The information present shows the persistent effort required. I never really understood the main difference between just chemical engineering and biochemical engineering. With the research conducted with this article and the next article, the topics a biochemical engineer can pursue were expressed in an easily interpretable way and I became interested in pharmaceuticals. The innovative ability is a great skill to have because it will help an individual be successful in this field. The article highlighted the importance of innovation because that is a key required skill to work in this field. This skill fits well into my personality because I am a person who enjoys challenges and likes to improve while helping others.

While reading the second article I selected for this research, I strongly realized the numerous procedure biochemical engineers should know. Their experiments are highly in depth. The experiments they conduct are usually on living microbes which requires a specific environment for the experiment to obtain the best results. The sterilized workspace required shows how one small contamination can completely skew up the results and draw the wrong conclusions. Science is a subject that is constantly changing through new research and discoveries. This always affects the future experiments because as an engineer, it is crucial to keep up with the current discoveries to progress as a career, team, and individual, and to obtain the best result with the most accuracy. The challenge it poses shows the continuous passion that radiates from the engineers which inspire me.

 The research I have conducted gave me a vivid insight on biochemical engineering. I noticed how my personal goals connected with this topic. I have gained valuable information and am excited for this career in the future for what it has to bring to help our healthcare. My confusion on the differences between chemical engineering and biochemical engineering have been cleared with this research. The research has made me realized that it might be a more beneficial to narrow my ISM journey towards this path. The determination required for this career and the passion that should always be apparent is highly required to be successful and help out the world with the new technology that has been created by biochemical engineers. The overview I have received through this research has given me a great advantage because I know now what to aim for and how to position my path on this journey through ISM.

**Article 1:**

## Biochemical Engineers

*Career Information Center*, 2014

What Biochemical Engineers Do

Biochemical engineers develop usable, tangible products, using knowledge of biology, chemistry, and engineering. They solve problems related to materials, systems, or processes that interact with humans, plants, animals, microorganisms, or biological materials. Biochemical engineers spend a great deal of time analyzing and processing the scientific data that they record during their experiments.

**Duties**

Biochemical engineers typically do the following:

* Devise scalable recovery, purification, or fermentation processes for producing proteins or other biological substances for human or animal therapeutic use, food production or processing, biofuels, or effluent treatment
* Read current scientific or trade literature to stay abreast of scientific, industrial, or technological advances
* Design or conduct studies to determine optimal conditions for cell growth, protein production, or protein or virus expression or recovery, using chromatography, separation, or filtration equipment, such as centrifuges or bioreactors
* Develop biocatalytic processes to convert biomass to fuels or fine chemicals, using enzymes of bacteria, yeast, or other microorganisms
* Prepare technical reports, data summary documents, or research articles for scientific publication, regulatory submissions, or patent applications
* Confer with research and biomanufacturing personnel to ensure the compatibility of design and production
* Design or direct bench or pilot production experiments to determine the scale of production methods that optimize product yield and minimize production costs
* Develop methodologies for transferring procedures or biological processes from laboratories to commercial-scale manufacturing production
* Design or conduct follow-up experimentation, based on generated data, to meet established process objectives
* Maintain databases of experiment characteristics or results

Work Environment

Biochemical engineers typically work in laboratories, office buildings, or industrial manufacturing plants. These engineers commonly work with hazardous chemicals and machinery, so they must wear proper safety equipment and follow safety procedures.

**Work Schedules**

Biochemical engineers typically work a standard 40-hour workweek. However, a new project or a tight deadline may result in additional hours during nights and weekends. Those biochemical engineers employed at industrial manufacturing plants that run 24 hours a day often work in shifts, some during the day and others at night, in order to maintain the production process around the clock.

## Job Facts

**MEDIAN PAY** $90,580 per year

**GROWTH** 3% to 9% (More slowly than average)

**EDUCATION** Bachelor’s Degree

## Licensure/Certification Organization

**National Society of Professional Engineers (NSPE)**

1420 King St.

Alexandria, VA 22314

(703) 684-2800

<http://www.nspe.org/index.html>

How to Become a Biochemical Engineer

Biochemical engineers hold at least a bachelor’s degree, usually in biochemical or chemical engineering. Recent graduates can apply for entry-level positions, which involve working under the supervision of an experienced biochemical engineer. As the worker gains experience, they will be assigned projects that are more complex, while enjoying an increase in working independence.

**Education**

Individuals interested in becoming biochemical engineers must complete a bachelor’s degree in biochemical or chemical engineering. Admission into these degree programs is largely based on individuals having a strong background in chemistry, as well as biology, physics, and mathematics. Once finishing their undergraduate studies, individuals who are interested in research or academic positions will need to complete a master’s degree or doctorate in engineering.

In order to prepare for the workforce, individuals enrolled in degree programs should seek internship opportunities in order to gain some relevant work experience. This not only exposes the individual to the type of work they will be doing as a biochemical engineer, but the work experience gained is very attractive to employers. Applicants become highly competitive when they can show relevant work experience on their resumes.

Biochemical engineers, similar to most engineering specialties, should actively keep their education current through enrolling in continuing education classes. Biotechnology is one particular field where technological advancements are rapidly produced; therefore, those working professionals who need to understand and be familiar with those technological advances can immensely benefit through continuing education programs. This provides more value to their employers and keeps them competitive in the job market.

**Licenses**

Biochemical engineers that work for the government will need to become licensed. In fact, any engineer that offers their services directly to the public is required to become licensed. Each state has its own licensing requirements although nearly all states require the applicant to hold a four-year bachelor’s degree from an accredited engineering program. Licenses may be obtained from the National Society of Professional Engineers (NSPE).

## Tools and Technology

**CALORIMETERS** This is an instrument for measuring the quantity of heat exchanged in a chemical reaction. Biochemical engineers frequently use these instruments to determine the energy content of certain biological materials, such as food or fuel.

**CHROMATOGRAPHS** This is an instrument used for separating a mixture by passing it in solution or suspension as a vapor. This tool is used frequently when biochemical engineers are isolating biological compounds as part of an experiment.

**MASS SPECTROMETERS** This is an instrument for separating isotopes, molecules, and molecular fragments according to mass. When conducting experiments, biochemical engineers frequently must isolate these biological materials. Engineers can use this tool in a variety of ways, including investigating the presence of harmful materials in common consumer products.

**SCIENTIFIC SOFTWARE** This software is a specialized computer program that can be used for chemical experimentation and design. Biochemical engineers frequently must use this software to simulate design models as a means of reducing the cost of necessary experimentation.

**SPREADSHEET SOFTWARE** This software is designed specifically for the user to organize and analyze numerical data by using an efficient tabular method. Biochemical engineers often use spreadsheet software programs to input large data sets, organize the information effectively, analyze it, and generate visual representations of the data in order to clearly display the findings.

Job Outlook

Employment of biochemical engineers is expected to increase 3 to 9 percent from 2010 to 2020, more slowly than average for all occupations. Based on this expected growth rate, 44,800 new job openings are projected to become available during the same period. As the global population continues to increase, demand for the goods biochemical engineers help to manufacture will increase as well. Manufacturing firms are also seeking to improve the production process, focusing on increased efficiency while reducing internal costs. These trends are expected to fuel the occupation’s growth from 2010 to 2020.

**Job Prospects**

Job prospects for biochemical engineers should be good. Many of the job openings projected in the upcoming years will be the result of current biochemical engineers retiring, transitioning to a different occupation, or leaving the occupation for other reasons. Biochemical engineers can work on a variety of projects and are employable by private firms in the pharmaceuticals, food production, energy, and research industries. The government is also a significant employer of biochemical engineers. Those applicants with relevant work experience along with a comfortable understanding of the most current technological developments in the biotechnology field should enjoy the best job opportunities.

**Advancement Possibilities**

Biochemical engineers have a few career paths available in order to advance their careers. As they become more skilled and independent, biochemical engineers can advance to become technical specialists. They may be promoted to supervisory roles, responsible for overseeing a team of engineers and technicians working on a complex production project.

Biochemical engineers may also have the opportunity to transition into chemical engineering as many of the same skills and technological knowledge are required for that occupation.

Similar Occupations

Occupations with job duties that are similar to those of biochemical engineers include:

* Biochemists and Biophysicists
* Biomedical Engineers
* Chemical Engineers
* Chemists
* Energy Engineers
* Food Scientists and Technologists
* Materials Engineers
* Nuclear Engineers
* Photonics Engineers
* Validation Engineers

Sources of Additional Information

**Books**

“Biochemical Engineer.” *Career Opportunities in Engineering.* McDavid, Richard A., and Susan McDavid. New York: Ferguson Publishing, 2007. 48–50.

**Organizations**

**American Society for Healthcare Engineering of the American Hospital Association (ASHE)**

155 N Wacker Dr., Ste. 400

Chicago, IL 60606

(312) 422-3800

<http://www.ashe.org>

**Association for the Advancement of Medical Instrumentation (AAMI)**

4301 N Fairfax Dr., Ste. 301

Arlington, VA 22203

(703) 525-4890

<http://www.aami.org>

**Biomedical Engineering Society (BMES)**

8201 Corporate Dr., Ste. 1125

Landover, MD 20785

(301) 459-1999

<http://www.bmes.org>

**BioProcess International**

One Research Dr., Ste. 400A

Westborough, MA 01581

(508) 616-5550

<http://www.bioprocessintl.com>

**Engineering Education Service Center (EESC)**

1004 5th St.

Springfield, OR 97477

(541) 988-1005

<http://www.engineeringedu.com>

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**Article 2:**

## Biochemical Engineering

*Biotechnology: In Context*, 2012

Introduction

[Biochemical engineering](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs) is concerned with the design, construction, and operation of processes that make [biotechnology](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs) products, including vaccines, enzymes, and [antibodies](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs). It is an important component of food, detergent, beverage, pharmaceutical, and other [biotechnology industries](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs).

## Words to Know

**Biosimilar**

Sometimes also known as a follow-on biologic, a biosimilar is a new version of a biopharmaceutical drug whose patent has expired. The word similar is used because the version is unlikely to be an exact copy of the original biological molecule, because biotechnology production processes are more variable than chemical production processes. An exact copy can be made of a small molecule drug, such as aspirin, and is known as a generic version.

#### Downstream processing

All the process steps involving isolation and purification of a biotechnology product.

#### Medium

A liquid or gel containing all the components, such as glucose and vitamins, needed to support the growth of cells.

#### Upstream processing

All the process steps from selection of the cell strain that will be used for production to harvest of the product from the bioreactor.

## Historical Background and Scientific Foundations

The first known application of biochemical engineering was in the brewing of beer in Mesopotamia around 4,000 years ago. Written instructions for the process were discovered on a cuneiform tablet found in Northern Syria in 2001. Chemical engineering became a discipline in its own right in the early twentieth century. Around the same time, before petroleum became the main feedstock of the chemical industry, fermentation was used to produce not just ethanol but other important industrial chemicals such as acetone. Through the study of such processes, the principles of biochemical engineering were developed. In 1964 Shuichi Aiba (1923–) of Tokyo University and colleagues published the first major textbook on biochemical engineering. This multidisciplinary topic can now be studied at many leading universities.

Many of the principles of biochemical engineering are based on chemical engineering. A process is typically first developed on a laboratory scale. Conditions such as temperature, pressure, rate of stirring, and nature of solvent for making a product from raw materials are optimized at this stage. The process is then transferred to a larger scale reaction vessel so that commercial quantities of high purity can be manufactured. Biochemical engineering differs from chemical engineering as it involves growing cells in a reaction vessel called a bioreactor and harvesting the products they make. Often the cell will have been genetically modified in order to ensure it makes the desired product.



In some cases, the cells themselves are the product; for example, they may be applied in medicine as tissue replacement therapies. Bacterial, fungal, insect, and mammalian cells can all be used as production units in [bioreactors](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs). Biochemical engineering involves more challenges than chemical engineering because living cells are more delicate and difficult to work with than chemicals. Issues such as cleanliness, sterility, and safety are therefore very important in designing and operating a biotechnology process.

Biochemical engineering can be divided into two main areas, upstream processing and downstream processing, each of which has a different disciplinary focus.

Upstream processing, which involves the investigation of potential host cells for production, is a microbiology related process. The cell may naturally manufacture the product of interest: For example, yeast turns sugar into ethanol. Increasingly, however, genes that code for a product are inserted into the host cell to create a genetically-modified bacterium, yeast, insect, or mammalian cell. Another important aspect of upstream processing is to find the best medium to grow the host cell so it manufactures the maximum amount of product. Upstream processing includes the production process itself, in which the optimized host cell strain is allowed to multiply in a bioreactor under the conditions most conducive to the manufacture of the product, such as temperature, rate of stirring, and other factors. This stage is known as fermentation or cell culture. The design of the bioreactor and monitoring of conditions during production have a strong engineering focus.

Downstream processing covers all those operations from recovering the product from the host cell to its final purification ready for use. How product is recovered from the cell depends on whether the product is retained inside the host cell or secreted into the growth medium. Following harvest, there are several purification stages in the downstream processing to make the product ready for formulation, packaging, and distribution. These steps usually involve filtration and chromatographic purification, important processes in analytical chemistry.

## Impacts and Issues

Biochemical engineering plays a part in several industries. It has a profound impact on health care. Several of the top 100 best-selling pharmaceutical drugs are monoclonal antibodies, vaccines, or [recombinant proteins](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs). Examples include the antibody infliximab, used in the treatment of rheumatoid arthritis, and erythropoietin, for anemia. These products required many years in development because processes involving cells are particularly challenging to engineer successfully. For example, production must always be carried out under strictly sterile conditions. Failures, through leaks in the bioreactor or technicians not wearing correct protective clothing, usually lead to the introduction of unwanted microbes into the process. Making changes to the process can also have very serious consequences. For instance, in 1990 people being treated with tryptophan, a drug produced by microbial fermentation, began to fall ill. They had disabling fatigue, muscle weakness, and inflammation of major organs. Some victims died. The problem was traced back to a biotechnology firm in Japan that had switched production strains to one that, unknown to them, was producing a contaminant that was responsible for the adverse symptoms.

For these reasons, the regulations for production of a biotechnology drug are very strict. Biochemical engineers must be prepared to justify any changes they introduce into a process. This is also why biopharmaceutical drugs tend to be very expensive. However, many of the earlier biopharmaceutical drugs, such as insulin and erythropoietin, have reached the end of their patent life. As patents expire, opportunities open for companies to make cheaper biosimilar versions of these drugs. The debate at present centers around how far a company wanting to make a biosimilar version can benefit from the biochemical engineering knowledge of those scientists who first developed the process.

There have been some technical developments in biochemical engineering that may make biotechnology products more readily available. First, miniaturization technology means that upstream processing is faster and easier. For example, microtiter plates, which contain many tiny wells, each of which resembles a miniature test tube, enable many different experiments to be carried out in parallel over a short time frame. This approach allows rapid identification of the best conditions for growing the cells. As production time decreases, patients may ultimately benefit from the less expensive drugs. In addition, single-use or disposable technology is becoming more popular. This means that instead of using an expensive stainless steel bioreactor, the biochemical engineer can use a giant plastic bag to grow the cells, harvest the product, and then throw it away. There are also disposable filters, tubes, and other components. Some companies are packing single-use components into mobile production units, which are cheaper and more flexible than the traditional production plant. This opens up the possibility of less developed countries being able to locally produce [biopharmaceuticals](https://docs.google.com/document/d/1Q3Q3BwHEYgNKoDMoHw1sc2l5Z4UKlJZkjjrZjOppcUs/edit#bookmark=id.gjdgxs), including vaccines, thus reducing dependency on upon relatively more expensive imports.

## Further Readings

### Books

Annadurai, B. *A Handbook of Biochemical Engineering and Fermentation*. Cambridge: Woodhead Pub Ltd., 2011.

Beard, Daniel A., and Hong Qian. *Chemical Biophysics: Quantitative Analysis of Cellular Systems*. Cambridge: Cambridge University Press, 2008.

Haracoglou, Irina. *Competition Law and Patents: A Follow-on Innovation Perspective in the Biopharmaceutical Industry*. Cheltenham, UK: Edward Elgar, 2008.

Mills, Oliver. *Biotechnological Inventions: Moral Restraints and Patent Law*. Rev. ed. Burlington, VT: Ashgate Publishing, 2010.

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