Department of Defense

DoDSTEM

Science · Technology · Engineering · Mathematics

JOIN the BIOTECH REVOLUTION

SAVE THE PLANET.
FEED THE WORLD.
CURE DISEASES.
PROTECT TROOPS.
MAKE A DIFFERENCE.

A career guide to schools, types of jobs, salary info, and more!

welcome

Dear Student,

Biotechnology is technology that applies to and/or is enabled by life sciences innovation or product development. Future advances in biotechnology will provide new capabilities to the nation across multiple domains including materials, medicine, fuels, and food.

An agile and diverse biotechnology and biomanufacturing workforce is required to meet the dynamic advancement required to analyze, develop, and field novel biotechnologies for the Department. This biotechnology workforce, as well as academia and other STEM stakeholders, form the foundation that is needed to support the workforce of the future.

By choosing a career in biotechnology and biomanufacturing, you enter a community of professionals who strive to make a positive impact on the world by creating novel solutions to difficult problems, such as brittle domestic supply chains and novel materials and chemicals. Biotechnology includes a wide variety of disciplines including biology, chemistry, engineering, computer science, and others, and that diversity of background and thought are the biotechnology community's strength.

As biotechnology and biomanufacturing workforce needs increase, I invite you to consider the many possibilities of a career in biotechnology and biomanufacturing.

Katherine Sixt
Principal Director, Biotechnology
Office of the Under Secretary of Defense
for Research and Engineering

Department of Defense
DoDSTEM
Science · Technology · Engineering · Mathematics

https://dodstem.us/

table of contents

BE AMAZED BY THE WONDERS of BIOTECHNOLOGY

Learn how we can put cells — nature's own factories — to work harnessing the incredible power of biology to develop products and technologies that help improve our lives and heal the planet.

ILLUSTRATION BY SHAW NIELSEN

CONSUMER PRODUCTS & SERVICES

From cosmetics and carry-alls to picnic utensils and purses, biotechnology is helping us reinvent objects from the everyday to the exotic. And it all starts with plant-based materials. With unique, designed-in-the-lab qualities, products of all shapes and sizes can be made from renewable, eco-friendly materials to meet almost any human need.

Sequins From the Sea

Did you know that most of the clothes we wear are made of synthetic fibers like polyester, nylon, and acrylic – all petroleum-based and non-biodegradable? And don't forget about plastic sequins! However, the fashion industry is starting to make changes, partnering with biotech companies to go eco-friendly. For example, designer Phillip Lim teamed up with industrial designer Charlotte McCurdy to create this dress made entirely without petroleum-based materials. It features bioplastic sequins made from algae, sewn onto a biodegradable base layer of plant fibers. This makes the dress free of synthetic fibers, plastic sequins, and oil-based dyes. And this is just one example. New fabrics are being made from industrial waste, from microorganisms, and more. Keep reading to find other ways biotechnology is making fashion more sustainable!

Replacing Plastic With Plants

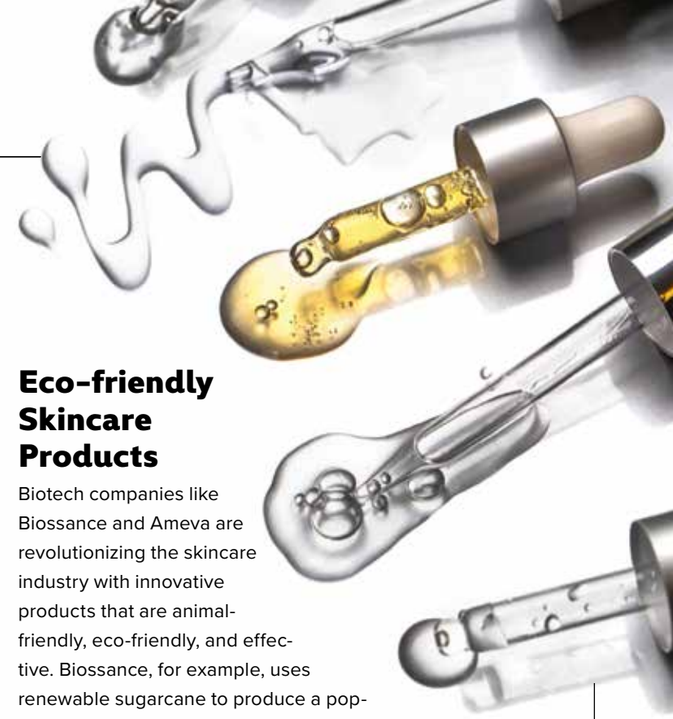
Plastics are handy, no doubt, but their impact on our planet is enormous. They are non-biodegradable, derived from fossil fuels, hard to recycle, and damaging to the environment. As a result, companies such as BASF, Eastman, and Eco-Products have come up with eco-friendly and biodegradable alternatives, known as bioplastics. Bioplastics are made from renewable sources such as corn starch, sugarcane, and vegetable fats and oils, and they are as versatile as plastic. You may already have seen them in items like fast-food utensils, candy wrappers, water bottles, and yogurt cups. Some bioplastics, found in carpeting or cars, are not biodegradable, but still offer a more sustainable alternative to traditional plastics.

Stretchy Fashions From Nature

Synthetic fabrics that stretch as we move — called lycra or spandex — are perfect for workouts or lounging around. Traditionally, these fabrics are made from fossil resources (seeing a trend here?) which are not eco-friendly. Biotech firms like Natural Fiber Welding are responding by creating plant-based materials as sustainable alternatives — and consumer companies like H&M, Patagonia, and New Balance are buying, bringing these new fabrics and materials to the marketplace. Meanwhile, the biotech company called Spiber uses a *fermentation process* to make their stretchy fabrics. You can check them out at Pangaia and The North Face.

Cruelty-Free Leather and Silk

Bolt Threads, a biotech company known for its sustainable textile innovations, has developed a way to create leather from mushrooms and silk from fermented yeast, yielding cruelty-free and eco-friendly alternatives to conventional materials. Their mushroom leather, called Mylo™, is produced by growing mycelium, the root structure of mushrooms, and tanning it into a soft and durable material that can be used to make purses, shoes, and more. Their silk-like fiber offers a sustainable and cruelty-free replacement for traditional silk, which requires boiling silkworms (!) and uses considerable water and chemicals. Designers like Stella McCartney are adding these new materials to their fashion lines.



Eco-friendly Skincare Products

Biotech companies like Biossance and Ameva are revolutionizing the skincare industry with innovative products that are animal-friendly, eco-friendly, and effective. Biossance, for example, uses renewable sugarcane to produce a popular skincare ingredient that was previously sourced from sharks. Ameva has developed plant-derived enzymes that nourish the skin and provide a protective barrier. By eliminating harmful chemicals and animal-derived ingredients, the skincare industry is taking a more responsible and conscious approach to skincare.

A Good Use for Greenhouse Gas

Mango Materials, meanwhile, is pioneering eco-friendly materials by using bacteria. They have developed a technology that allows bacteria to eat methane, a potent greenhouse gas that causes global warming. When the bacteria eat the methane, they make a special kind of material called polyhydroxyalkanoate, or PHA for short. This material can be used to make lots of different things, like fibers for clothes and materials for packaging, replacing traditional petroleum-based plastics. Even better — their PHA biopolymers are fully biodegradable in any environment where biology is present. A definite win-win.

COURTESY ECO-PLASTICS, PHILLIP LIM AND CHARLOTTE McCURDY, STELLA McCARTNEY

FOOD & AGRICULTURE

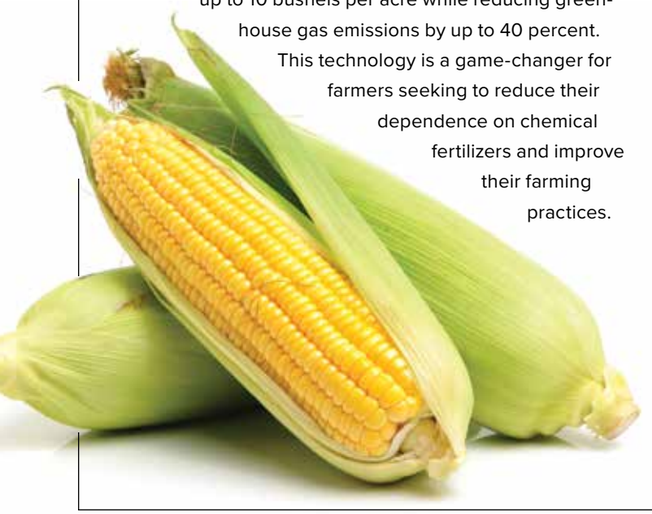
More food, made more nutritious with safer and cleaner methods of production — that's what innovations and transformations from biotechnology promise to deliver to the ways we grow, raise, process, and distribute food in the agriculture industry.

Bee Vaccine

Bees play a crucial role play in pollinating crops. But honeybee populations have taken a big hit due in part to an aggressive and deadly bacterial infection called American foulbrood, which can wipe out entire hives. Fortunately, Dalan Animal Health, a biotech company in Georgia has just developed a vaccine for honeybees — the first for any insect — to combat the infection. The vaccine is added to a sugar feed given to queen bees and is then passed along to their offspring. Scientists hope to stop all kinds of other nasty viruses and pests with this technology. Good riddance!

Microbes for Better Crops

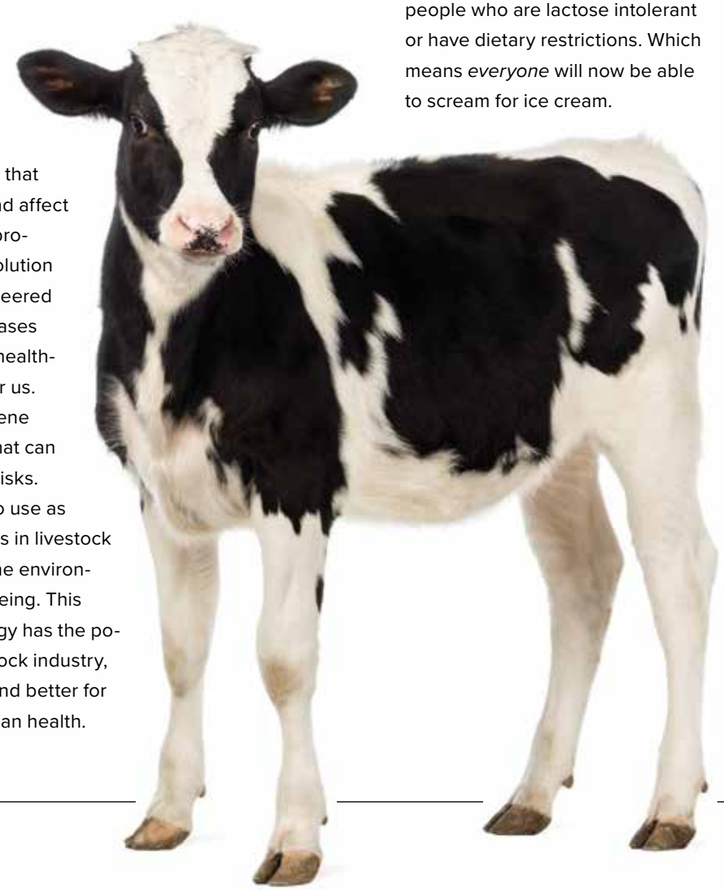
Many farmers use synthetic fertilizers and manure, which can harm the environment with excessive use. To address this, Pivot Bio developed Pivot Bio PROVEN, a fertilization technology that uses **microbes** to enhance crop yields. The technology delivers nitrogen directly to plants, reducing the need for chemical fertilizers. Pivot Bio PROVEN increases corn yields by up to 10 bushels per acre while reducing greenhouse gas emissions by up to 40 percent. This technology is a game-changer for farmers seeking to reduce their dependence on chemical fertilizers and improve their farming practices.



Healthier Livestock

Livestock farming has always faced problems with diseases and nasty parasites that can make the animals sick and affect the quality of the meat they produce. Biotechnology has a solution in the form of **vaccines** engineered to protect against these diseases and parasites, which means healthier animals and safer meat for us.

Scientists are now using gene therapies to breed animals that can naturally resist these health risks. That means we won't need to use as many vaccines and antibiotics in livestock farming, which is better for the environment and the animals' well-being. This advancement in biotechnology has the potential to transform the livestock industry, making it more sustainable and better for both animal welfare and human health.



Plant-based Cheese, Milk, and Ice Cream

You've likely heard of oatmilk and almond milk. Superbrewed Food is a company that produces plant-based milk, cheese, and ice cream using **proteins** brewed from natural ingredients. Unlike traditional animal-based products, or other plant-based milks, Superbrewed Food's products have a significantly lower environmental impact, requiring less land, water, and energy to produce. Moreover, the brewing process results in products that are rich in nutrients and free from cholesterol and lactose, which means they are healthier alternatives for people who are lactose intolerant or have dietary restrictions. Which means *everyone* will now be able to scream for ice cream.

Eco-Friendly Water Solutions

To make our drinking water safe and delicious, water treatment plants rely on chemicals like chlorine, alum, and fluoride, which can end up as harmful waste downstream in the environment. Plus, those treatment plants can be big energy hogs. Fortunately, biotech companies like Solugen and Microvi have developed more eco-friendly solutions for water treatment. Solugen's approach involves using enzymes produced from plant-based sources to break down all the yucky stuff in wastewater, while Microvi uses high-performance microorganisms to zap pollutants from water. These new systems effectively remove harmful pollutants and contaminants from wastewater, so it's safe to reuse or release into the environment. A definite win-win, keeping our water clean without causing harm to our planet.

New Sources of Meats

As people are becoming more conscious about sustainable food, biotech companies like Mission Barnes and Upside Foods are stepping up their game to create delicious non-meat options. Plant-based food has been a hit for some time now, but these companies are taking it to the next level by using fat cells from meat to make meat alternatives that taste even better. And guess what? This approach makes the texture and flavor so realistic, you won't even miss traditional meat! But it's not just about making tasty food. It's also about saving the planet and being ethical. Meat production has been linked to environmental problems and concerns about cruelty to animals, but with this new approach, we're looking at a more sustainable solution. Plus, it could even help address world hunger by providing a more efficient way to produce protein-rich food. The future of food production looks brighter (and more delicious) than ever!

COURTESY UPSIDE FOODS

HEALTH & MEDICINE

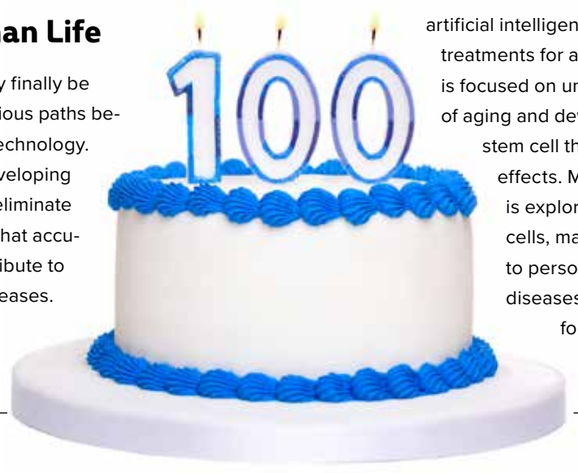
Biotechnology is transforming the tools and treatments that keep us healthy and happy. Among the benefits: longer lives, quicker recovery from wounds with less pain, cures that move from the lab to the doctor's office at race-car speed, and miniature devices under the skin to detect the earliest signs of sickness. And with therapies tailored to each person's unique DNA, biotechnology can make the dream of individualized medical care a reality for all.

Better Vaccines, Manufactured Faster

COVID-19 has made it clear how crucial vaccines are in keeping us healthy, and biotech companies have been champions in getting those vaccines created. Moderna and Pfizer used biotechnology to quickly whip up COVID-19 vaccines that prevented people from getting really sick or even dying. Traditionally, vaccines are produced by growing large amounts of the virus or bacteria that the vaccine is meant to protect against, a time-consuming process that poses a risk of contamination. With biotechnology, vaccine development is faster, and the vaccines can be more effective. Plus, it's even allowing us to develop vaccines for diseases we couldn't treat before, like cancer! BioNTech's cancer vaccine helps the immune system attack cancer cells and is currently being tested in clinical trials for melanoma, prostate cancer, and breast cancer.

Extending Human Life

The Fountain of Youth may finally be within reach, thanks to various paths being explored through biotechnology. Unity Biotechnology is developing therapies that target and eliminate senescent cells, the cells that accumulate with age and contribute to a range of age-related diseases. Insilico Medicine is using artificial intelligence to develop personalized treatments for age-related diseases. Calico is focused on understanding the biology of aging and developing interventions, like stem cell therapy, to slow or reverse its effects. Meanwhile, Cellino Biotech is exploring the intersection of stem cells, machine learning, and physics to personalize the cure for tough diseases and make them available for many more people.



New Ways to Fight Diseases

Mosquitoes are not only annoying, but they also spread deadly diseases like malaria, dengue, and Zika, killing up to 1,000,000 people per year. But it's the females who bite, hungry for blood to produce their offspring. Now, Oxitec has genetically modified the male mosquitoes to produce only other male offspring. They are being released into the wild to mate with females, generating offspring that cannot survive. The process offers a promising solution to combat the devastating impact of mosquito-borne illnesses on human health. Could cockroaches be next?

Gene Therapies

Gene technologies hold enormous potential for humans, too. Biotechnologists at companies like CRISPR Therapeutics and Intellia Therapeutics are now able to make precise changes to DNA sequences, allowing them to correct genetic mutations. Since more than 6,000 human diseases are caused by genetic mutations, this technology has huge potential for major medical breakthroughs — and enormous economic growth.

PROTECTING OUR TROOPS

SYNTHETIC SKIN AND REPLACEMENT TISSUES

Soldiers in the field can suffer some of the worst wounds imaginable. The good news is that scientists have made enormous advances in what's called regenerative medicine. They've created synthetic tissues that work just like real skin and organs. This means that we can use these tissues to help treat burns and wounds, and even replace organs that are damaged. So even if soldiers are in really far away or dangerous places, they can still get the medical care they need to recover. Regenerative medicine is an enormous area of biotechnology, with many companies around the globe developing these technologies. And it's not just soldiers who will benefit. These same regenerative technologies will also improve the lives of injured firefighters, who sustain serious burns on a regular basis — and anyone else with similar injuries.

REAL-TIME MEDICAL SENSING

Companies like Profusa Biosciences are developing implantable biosensors: super-tiny devices that are implanted in the skin and allow for real-time, remote monitoring of a person's health, stress levels, oxygen levels, and blood chemistry. As you can imagine, this kind of information would be extremely useful in the battlefield, making it easier for medical personnel to monitor soldiers' vital signs remotely. These biosensors could also be used to help doctors and patients manage chronic conditions, such as diabetes or kidney disease — like having a medical team 24/7.

SHUTTERSTOCK; COURTESY PROFUSA BIOSCIENCES

THE ENVIRONMENT, ENERGY & MATERIALS

Burning fossil fuels accounts for over half of the carbon dioxide pumped into the atmosphere and driving global climate change. Using some other source for producing energy is vital for preserving the earth. The tools of biotechnology can unlock incredible potential for generating energy from an enormous range of biological sources, including plants, microbes, algae, and even waste.

Replacing Fossils Fuels With Biofuels From ....

➔ **ALGAE** Synthetic Genomics is growing algae in ponds or bioreactors and converting it into biofuels such as biodiesel and jet fuel. Algae is highly efficient at converting CO_2 into biomass, making it a promising solution for capturing carbon emissions.

➔ **CARBON EMISSIONS** A partnership between Honeywell and HIF Global is launching operations to convert industrial waste gases, such as carbon monoxide and carbon dioxide, into biofuels. C3Biotech, meanwhile, feeds carbon emissions to trillions of carbon-hungry microbes that turn pollution into fuels.

➔ **PLANTS** Biotech companies such as LanzaTech are using special enzymes to break down plant materials like corn, sugarcane, and switchgrass to produce liquid fuel.

➔ **MICROBES AND SUNLIGHT** Certain strains of bacteria and yeast can be engineered to produce ethanol and other fuels directly from sunlight, without the need for plants or algae. LanzaTech is also developing this technology.

➔ **WASTE** Companies like Enerkem specialize in converting non-recyclable and non-compostable waste materials, such as wood chips and municipal solid waste, into biofuels. Other companies like Renewable Energy Group are converting used cooking oil, food scraps, animal fats, and plant oils into biofuels.

DEFENDING OUR COUNTRY, PROTECTING OUR TROOPS

Biotechnology can endow our military with decisive advantages in all areas of engagement.

➔ **Using biomass to produce fuels and materials** in the battlespace can shorten and strengthen supply lines.

➔ **Monitoring troops and activities with robust, nature-based sensors** can deliver real-time, mission-critical information to protect human assets and improve decision-making in the heat of battle.

➔ **Advanced materials** – lighter, stronger, cheaper to make – can make weapons systems more durable and efficient as well as easier to repair in the field.

➔ **Tools for adapting to changing circumstances** — think paint that changes color with the environment for better camouflage — can be customized quickly to a nearly infinite degree, making surprises in conflict less of an obstacle.

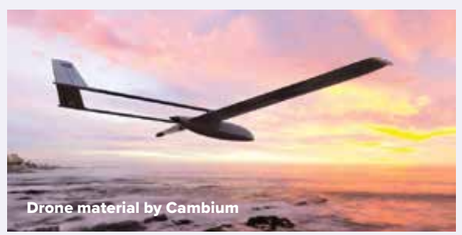
CHECK OUT THESE BIOTECHNOLOGY INNOVATIONS NOW BEING TESTED:

Biocement by Biomason

BIOCEMENT Stronger, more durable, and holding up better in extreme circumstances, biocement can also be “grown” in the field from biological feedstock often found right underfoot.

Vest by Qore

THERMO-REGULATION TECHNOLOGIES Portable, self-regulating hydration and body temperature technologies keep the bodies of fighting men and women working at optimum levels.



Drone material by Cambium

FIRE-RESISTANT MATERIALS In partnership with the US Navy, Cambium developed composite, lightweight bio-based building materials that will not burn.

Synthetic silk by Kraig Biocraft Laboratories

PROTECTIVE MATERIALS Stronger than Kevlar, synthetic spider silk provides super-light, super-strong protection for warfighters from both enemy fire and harsh environments.

COURTESY BIOMASON, QORE, CAMBIUM, KRAIG BIOCRAFT LABORATORIES

Join the Revolution

Explore biotechnology education and career opportunities.

The world is moving towards a new way of building, maintaining, and renewing the physical environment in which we live. Biotechnology is shaping a world in which cells and proteins from plants, animals, microbes, and other biological sources drive manufacturing systems, replacing petroleum-based and industrial chemicals that have been doing so for the last 150-plus years. The bioeconomy is currently valued at an impressive $2.6 trillion, and continues to experience rapid growth every year.

If you are a student thinking about your future, the question is not if you will participate in the bioeconomy, but how. We use goods and services provided by the bioeconomy already. Studying biotechnology can lead to more, though. It can be a gateway to a career for you to help create a cleaner, healthier, more sustainable way of life for the whole world, working in technical as well as non-technical roles. And along the way, you will be rewarded with meaning, purpose, and a fine salary.

FIRST, A LITTLE HISTORY

The late 1800s launched the rapid growth of fossil fuels — first coal, then oil — into the dominant sources of energy and industrial chemicals for the entire world. Though widely available and efficient, these resources come with the enormous drawback of being largely terrible for the environment.

Biotechnology offers us the hope of moving away from dependence on the fossil fuels that drive our manufacturing and energy sectors. As a driving force behind a “fourth industrial revolution,” biotechnology promises change that will equal — even exceed — the changes brought on by steam, coal and oil, and the microprocessor. Instead of depleting natural resources in a wasteful cycle of making, using, and throwing away, biotechnology enables us to build and maintain the products and structures that shape our world without destroying the planet in the process. Nature-based technologies in combination with supercharged computational and machine learning capabilities — all originating with renewable, earth-friendly raw materials — can yield advances that will astonish and amaze us and change our lives in ways we can hardly imagine.

In the last section, you read about just some of the amazing innovations flowing from applications of biotechnology. What we eat, wear, build with, inject into our bodies, use to power our machines — nearly every product we imagine making can be reshaped and renewed by biotechnology. In just about any career you could choose, a grasp of biotechnology can give you a unique entry point — and unique advantage — as you gather learning and experience and find your way in the workplace.

START WITH BIOLOGY

Learning about the field starts with the “bio” in biotechnology, or biology. In both life and biotechnology,

career basics

biology comes down to cells, nature's own almost infinitely variable factories of growth and energy. Cells produce more different things with greater efficiency and speed than any manufacturing process humans have ever invented. In plants, animals, microbes — wherever they are at work — cells function as an all-purpose, widely adaptable building tool, unparalleled in their potential to make things of use, interest, beauty, value, or need. A career in biotechnology, therefore, starts with a solid grounding in cell biology — what cells are, how they work, how they enable life, and how we can manipulate their productive energies towards our own ends.

ADD IN TECHNOLOGY

The "tech" in biotechnology is just as important as the "bio." Technology encompasses all the tools, systems, and procedures that enable us to apply basic knowledge of the physical and natural world towards practical products and services that meet our needs. Important areas of knowledge can include subjects closely related to biology, like chemistry and physics. Engineering, computer science, and mathematics are also relevant fields of study. Learning across all these areas plus a foundation in biology enables us to deploy the building blocks of nature — molecules, proteins, and cells — in applications of biotechnology that result in finished products.

DIFFERENT EDUCATIONAL PATHS

You can enter the field of biotechnology with different levels of education. From two- and four-year degree-holders to PhD's, graduates from all levels of higher education can find a place in the field. Advanced study of some form is necessary to gain at least a basic understanding of the science and technology that go into biotechnology. And continued learning in the workplace will help you extend your skills.

WORKING IN TEAMS

Teamwork is vital in biotechnology projects because they require a combination of practical and academic knowledge from various fields. Team members need to work together and effectively collaborate to maximize the benefits of their complementary skills. Developing the ability to coordinate and collaborate with others is a valuable skill that you can focus on improving.

A VERY BROAD FIELD

In fields ranging from textiles to pharmaceuticals to construction to energy to agriculture to manufacturing to the military, biotechnology professionals can fill diverse roles. Advanced technical education can lead to positions as scientists or engineers, conducting research, designing and developing projects, or heading up teams. Alternatively, these professionals can move into senior leadership or management roles, guiding organizations towards longer-term goals.

The industry also needs economists and businesspeople to manage finances, marketers and communicators to help us understand how to make the best use of products and services, legal and government experts to make sure rules and regulations are safe, logical, and equitable, and educators and researchers to excite and inform the next generation of biotechnology professionals. In the military, expertise in the field helps professionals integrate knowledge and tools from biotechnology advances into security strategies and systems to keep us all safer.

A RANGE OF WORKPLACES

These many different roles can take biotechnology professionals into many kinds of workplaces. They work in the field, often traveling to gather and study samples of biological organisms. In a lab or workshop, they conduct experiments, run tests, or manage instruments, engaged in the important work of translating basic knowledge into practical applications. In offices, classrooms, government organizations, media settings, and more, they draw on knowledge of the field in combination with other professional skills to advance and support biotechnology-related projects and products.

The Department of Defense puts people to work in nearly all these roles. Biotechnology specialists do everything from cutting-edge science done in military labs to deployment of new technologies in the field to collaborations with industry and the public sector to promote understanding and adoption of biotechnology for national security purposes.

A BETTER, SAFER WORLD

In both civilian and military realms, biotechnology serves vital national needs. It will keep the United States safer in an uncertain world, fortify our position in the global economy, and enable wider distribution of material benefits and opportunities among our fellow citizens. For the world, biotechnology will yield advances to help repair the environment, feed the hungry, heal the sick, and fuel engines of progress that can bring opportunity and comfort to more people than ever before.

Next, you will read about various educational pathways into biotechnology, how to start preparing yourself for work in the field, and what kinds of careers might await you.

What To Do Now

The world-changing potential of biotechnology makes it an exciting career option for students with all kinds of interests. Maybe the opportunities for scientific discovery grab your attention. You might want to be part of things on the cutting edge of new technologies. Or perhaps it is the chance to help solve global challenges like clean energy, food insecurity, emerging diseases, or sustainable manufacturing.

Whatever your reasons, you can do things now to put yourself on the path to a career in biotechnology. Start with education of some kind in both biology and technology. Look into summer camps and other hands-on opportunities — as the next article describes in more detail. But the field draws on learning in a wide range of subjects. You can pursue other areas of interest with confidence that a diverse set of skills and experiences will lead you to the place in the field that is right for you.

1. Take a full load of courses across all subjects.

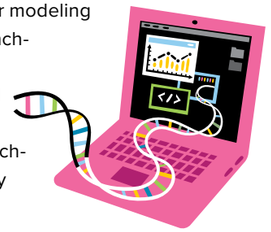
Science and math are primary – challenge yourself with higher-level courses in these areas. But biotechnology professionals need to communicate, reason, work together, and understand larger social issues. Keep up with your English, history, and social studies, and consider electives like economics or business, if offered.

2. Dig into "dual-credit" options.

Some community colleges offer courses in biotech to students as young as 9th grade. And they count as both high school and college credits! If local schools don't offer dual-credit, look into online options, too.

3. Get comfortable with computers.

True of any profession, but especially in biotechnology, the ability to put computers to work is fundamental. Whether modeling changes to DNA, crunching large sets of data, or using software and programming tools, command of digital technologies makes nearly everything happen.



4. Experiment with extracurriculars.

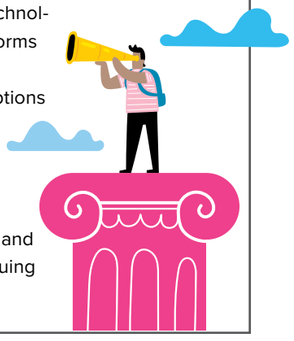
Your school probably has science clubs, and perhaps chances to participate in interscholastic science events. Check with teachers around the building. Local health- or environment-related organizations often have volunteer opportunities for students. Real-world experience and evidence of your commitment to the field will make you stand out to colleges and future employers.

5. Do some research.

From biotech basics to breakthroughs that might change the world, information about biotechnology is available all over the internet. Good online starting points: BIO, a big biotech industry group; BioBuilders.org, great for students AND teachers; and InnovATEBIO, a rich resource of learning materials for educators. Then, find people in the field to learn from. Start with teachers or career counselors, reach out to people from biology or engineering in higher education, look for career fairs that include companies in the field. With prepared questions and a story of your own interests, you will almost certainly find people willing to share their experiences and offer guidance to you.

6. Look at what colleges offer.

Degree programs in biotechnology can take a variety of forms and names. Review online course listings and descriptions of schools you like to see what studying biotechnology is really about. What you find will broaden your understanding of the field and might also show you intriguing new directions to pursue.



ILLUSTRATIONS BY SHAW NIELSEN

Use Summer to Explore Biotech

Camps, internships, and apprenticeships can help define your interests and develop lab skills.

Once you understand the transformative, nearly-magical potential of biotechnology, picking the field as your future career seems almost irresistible. How could a smart, science-oriented student committed to making the world a better place NOT want to work in biotechnology?

The challenge lies in translating excitement about biotechnology into plans for a career in the field. Biotechnology spans so many different industries, subjects, and professional roles that finding the right mix of all these variables can be bewildering.

The good news, though, is that colleges and universities, companies, and the government all work to help motivated students define their interests and develop skills in biotechnology by offering summer camps, internships, and even apprenticeships. Such programs can help students understand and then start becoming the kind of biotechnology professional they want to be.

SUMMER CAMPS

Summer camps can give students a real flavor for biotechnology as well as connect them with teachers and professionals to guide them on next steps. Start by studying examples of programs to see if they sound appealing. A first stop is BioBuilder .org, a program founded at MIT that provides mostly in-person but some online courses for high school students. It also provides support for school clubs, self-guided learning materials, and career guidance information.

Other general biotechnology summer camp programs include American University's Biotechnology option in the High School Summer Scholars Program; the HudsonAlpha Institute for Biotechnology programs for 6th- through 12th-graders; and the Biotechnology track in the Engineering & Science programs offered at multiple campuses across the country through Summer Springboard. If these programs sound exciting but are not accessible to your location, check in with a community college or four-year institution nearby. Search the school's website for potential camp options as well as people in the Biology Department or Engineering School who work in the field. Reach out to anyone you can find with questions and you might be surprised by how many warm, informative responses you get.

National Student Leadership Conference Biotech Program
WASHINGTON, DC , AND CALIFORNIA

Summer Springboard
WASHINGTON, DC, AND CALIFORNIA

HudsonAlpha Biotech Camp
ALABAMA

ENGAGES Summer program
GEORGIA

INTERNSHIPS

An internship will place you in an actual biotechnology workplace. It might be a lab, an office, even out in the field. One good source of information is the website for InnovateBIO, a biotechnology education effort supported by the National Science Foundation. The National Institutes of Health run several high school internships through the Office of Intramural Training & Education. A program like ENGAGES at Georgia Tech brings area high school students onto campus to work on biotechnology projects, and BioBuilder offers internships in their Boston lab. Remember, the connections you make at summer camp can help you find opportunities closer to home. And note that community colleges often establish internship programs with local employers, so be sure to explore possibilities in this area.

APPRENTICESHIPS

The most structured, job-like experience available, an apprenticeship offers pay and real learning in exchange for a defined commitment of time and effort. While mostly available to college grads, apprenticeships for high school students do exist, like the Biotech Research Apprentice Program at the University of Kansas-Edwards. Juniors, seniors, and community college students can work with and learn from advanced undergraduates running experiments in university labs. And BioBuilder runs an apprenticeship program for Boston-area students.

No matter what form your biotechnology learning might take, you truly cannot go wrong with whatever you choose to do. Explore, ask questions, stay open to what becomes available, and use the knowledge you gain to keep moving towards the future that seems most appealing to you.

PHOTOS COURTESY THE CAMPS OR SCHOOLS

PICK YOUR PATH

By now, you know that you need both "bio" and "tech" under your belt to build a future in biotechnology. But how do you choose the right path for a career in this field? Should you pursue a two-year degree or go for a science or engineering four-year deal?

If you like getting your hands on the actual gear and can stay on top of complex details and procedures, consider a **two-year degree**. These degrees lead to "technician" jobs of great variety, all with a hands-on role in biotechnology production processes.

A **science degree** will prepare you to design and conduct technical experiments and projects. In both lab and office environments, you will be pushing for advances and breakthroughs, always learning, and maybe hitting on the next big thing for your company.

Engineers are the designers and builders of solutions, driving innovations in both tools and procedures that help biotech teams get their work done successfully. They work with and between teams, bringing technical expertise plus a broad view of how whole systems are supposed to work.

Review the charts for more details about opportunities in all three areas.

HIGH SCHOOL

See page 18 for tips.

GET A 2-YEAR ASSOCIATE DEGREE

Majors include:
Automation Engineering Technology
Biotechnology
Electrical Engineering Technology
Electronics Technology
Facility Maintenance Technology
Instrumentation
Industrial Engineering Technology
Industrial Management Technology
Manufacturing Engineering Technology
Materials Science Technology
Mechanical Engineering Technology

See page 20 for more info.

ENTRY-LEVEL POSITIONS

Biomanufacturing Technician
Cell Culture Technician
Environmental Health & Safety Technician
Greenhouse or Field Technician
Instrumentation / Calibration Technician
Lab Technician

STARTING SALARY RANGE
$40,000-55,000

GET A 4-YEAR SCIENCE DEGREE

Majors/Degrees include:
Biotechnology, Biology, Chemistry, Physical sciences

See page 24 for more info.

ENTRY-LEVEL POSITIONS

Instrumentation / Calibration Technician
Microbiology Quality Control Technician
Process Development Technician
Water Quality Technician

STARTING SALARY RANGE
$50,000-65,000

GET A GRADUATE SCIENCE DEGREE

See page 36 for more info.

STARTING SALARY RANGE
$55,000-85,000

GET A 4-YEAR ENGINEERING DEGREE

Majors/Degrees include:
Biotechnology, Bioengineering, Chemical Engineering

See page 28 for more info.

ENTRY-LEVEL POSITIONS

Bioengineer
Biomedical Engineer
Chemical Engineer
Process Engineer
Project Engineer

STARTING SALARY RANGE
$85,000-100,000

GET A GRADUATE ENGINEERING DEGREE

See page 36 for more info.

STARTING SALARY RANGE
$90,000-115,000

SOURCES: BIOTECH-CAREERS.ORG AND PRODIGYFINANCE.COM

Two-Year Programs

Associate of Science and Associate of Applied Science degrees can save you money and offer a quick entry into the job market.

Choosing biotechnology as a career path is a huge step towards interesting, rewarding work in a field that can change the world in exciting, almost unimaginable ways. But this choice is just the beginning. You also need to pick the path to get there that works for you.

The degree program you choose should fit your individual circumstances and preferences. A two-year program might be right if you want to start working sooner than later, need flexible, cost-effective options, and want to focus on developing job-ready skills. Community colleges are easily accessible almost everywhere, and they can offer high-quality, student-friendly on-ramps to biotechnology careers of many kinds. Keep reading to learn more.

THE PRICE IS RIGHT

Tuition and living expenses are almost always much lower at community colleges than at four-year schools. You can save money by living at home, and class schedules are often designed to accommodate part-time work. Community college leaders assume their students have busy lives with many demands on their attention, and they work hard to make useful learning opportunities available to everyone.

GET REAL-WORLD EXPERIENCE

Homing in on the area of biotechnology that works for you can happen quickly at a community college. You can explore various pathways aligned with real-world job opportunities to figure out where you really want to go. The Bioscience Incubator, for example, at Austin Community College places students with cutting-edge research projects at nearby, central Texas biotech companies. And the summer COOP program at Skyline College in California provides paid, short-term work opportunities that teach fundamental skills and techniques used in industrial lab settings.

DEVELOP JOB-READY SKILLS

Both degrees and certificates can validate your capacity to step in and contribute right away to biotechnology work activities. The BIOTECH Pathways program at Harford Community College in Maryland is a collaboration with both the military and the private sector to launch students towards meaningful work opportunities in wide-ranging environments. Likewise, the BioWork certificate program at Central Carolina Community College schools career-changers and high school grads alike in industry-approved operations to help them quickly land jobs with good pay and future advancement prospects.

SMOOTH YOUR WAY TO A FOUR-YEAR DEGREE

Community colleges support students' pursuit of four-year degrees in increasingly varied ways. They structure courses to make credits and learning transfer as easily as possible for students continuing their studies at four-year schools. And some community colleges are starting to offer four-year programs of their own in select areas. Biomanufacturing, for example, applies academic learning in biotechnology to processes of industrial production using biologically-based systems and materials. Mira Costa Community College and Solano Community College, both in California, have recently launched bachelor's degree programs in biomanufacturing, with graduates stepping into jobs that pay on average $70-80,000 a year.

Austin Community College
TEXAS

Skyline Community College
CALIFORNIA

Harford Community College
MARYLAND

PHOTOS COURTESY THE SCHOOLS

education: ASSOCIATE DEGREES

Central Carolina Community College
NORTH CAROLINA

Solano Community College
CALIFORNIA

Ivy Tech Community College
INDIANA

GOOD PLACES TO LEARN

Not so widely appreciated about community colleges is the supportive learning environment. Classes are often smaller, professors more accessible, and schedules more flexible. The kind of personal touch you can find at a community college promotes both students' learning in school and their future prospects in biotech careers.

START TO MAKE A NAME FOR YOURSELF

You can even start building a professional resume while in community college. At the 2023 Envisioning the Next Bioscience Workforce conference, students from 13 community colleges presented results of their own biotechnology research projects — from advances in colon cancer testing to bioengineering fish to resist wastewater toxins.

DECISION TIME

You have a big choice to make before starting your biotech journey at a two-year school — the type of program to sign up for. Community colleges typically offer two kinds of degrees — an Associate of Science and Associate of Applied Science — in addition to certificates of various kinds. Here's the deal:

▸**Associate of Science (AS)** degrees prepare you to transfer into a four-year program. They offer more academic courses, preparing you with foundational, basic learning that will set you up for higher-level biology, chemistry, and even engineering classes as part of a bachelor's degree program.

▸**Associate of Applied Science (AAS)** degree programs teach you more practical, job-relevant skills to get you ready to step into a lab or other company setting where you can contribute right away to biotech projects, usually as a "technician" specializing in one area or another. Look at the "Common Job Titles" box to find specific examples.

▸**Certificate programs** focus even more narrowly on technical skills and operations, filling out your practical learning and making you immediately useful to an employer.

Talk to your family, teachers, and career counselors to assess which option makes the most sense for you.

COMMON JOB TITLES

- Agricultural and Food Science Technician
- Biofuel Technician
- Biomanufacturing Technician
- Cell Culture Technician
- Clinical Research Associate
- Environmental Health & Safety Technician
- Facilities Technician
- Genomics Technician
- Greenhouse or Field Technician
- Instrumentation Technician
- Laboratory Assistant/Technician
- Molecular Biology Technician
- Plant Tissue Culture Technician
- Product Development Technician
- Quality Control Technician

DOUBLE YOUR CREDITS: Attend Community College While You're in High School

Many community colleges offer classes in biotechnology or related areas to high school students. These classes can count for both high school and college credit and give you a leg up on applying to college or even moving directly into the workplace after graduation. Classes can be offered at the community college itself or, in some cases, at your own school. You can also find online dual-enrollment options. Even just to explore the field, dual enrollment can make sense. No matter what you get out of it, you will learn something valuable about the world beyond high school.

PHOTOS COURTESY THE SCHOOLS

Four Years of Science

Some schools offer a degree in biotechnology, but you can also build your own program.

Biotechnology is interesting and exciting because it draws on so many different fields. Study and work in the field will mix biology with chemistry, math, physics, computer science, engineering, materials science, even areas as far afield as economics, public policy, and business.

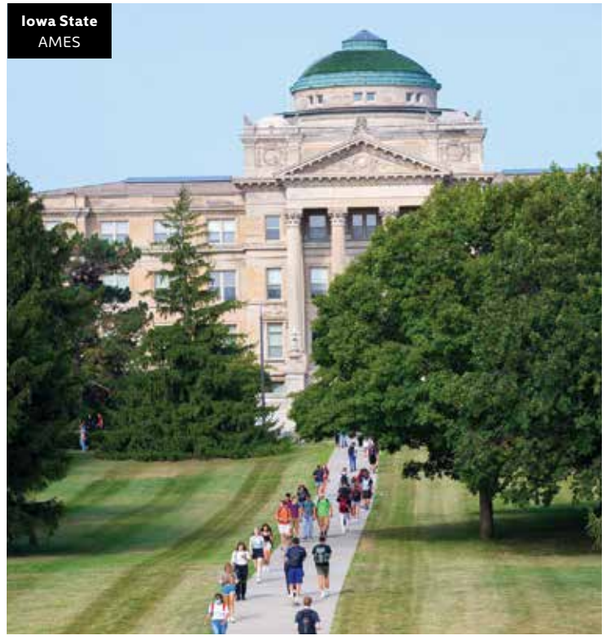
But incorporating such a range of disciplines into your undergraduate studies means you have decisions to make. In a four-year biotech program, you can build a great foundation for the learning you will gain throughout a career in the field. To build the foundation that works for you, though, you will need to choose the right overall framework for your studies and what areas of biotechnology to focus on.

A four-year degree in biotechnology can be a science degree or an engineering degree. In both cases, you will receive an excellent grounding in biotechnology, but the two degrees can differ in areas of emphasis, flexibility, and options available upon graduation. With a science degree, you would typically have more leeway to blend your individual interests with core areas of field knowledge. If you want to maximize flexibility in both your studies and later work options, a science degree might serve you best.

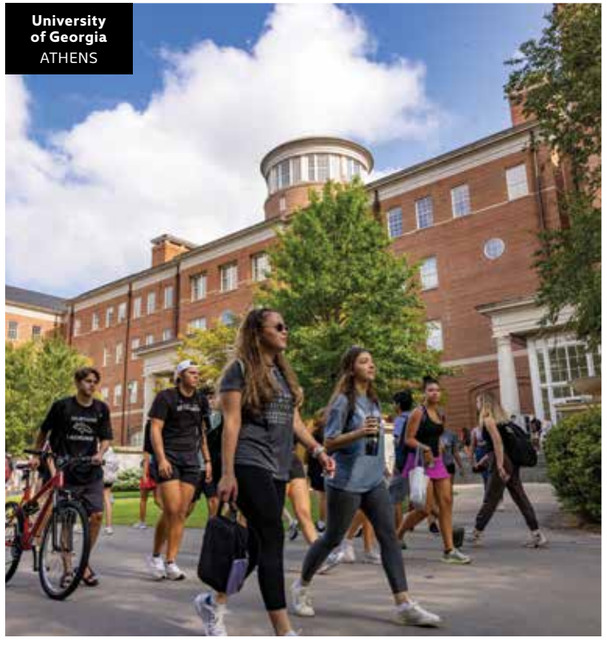
Indeed, biotech grads from science programs do all kinds of things after college — a technical job in the field, graduate study, or adjacent work in sales, policy, or business positions. The very diversity of these paths, though, suggests how much thought students need to put into planning their biotechnology career.

Schools offer programs to suit a wide range of needs and interests. Pay attention to how different schools present themselves to prospective students and look for a program that strikes a chord with you. The examples of schools below can guide your search for colleges you might consider attending yourself. And if the school you really like does not offer an actual biotechnology

University of California, Davis



Iowa State
AMES



University of Georgia
ATHENS

Worcester Polytechnic Institute
MASSACHUSETTS

PHOTOS COURTESY THE SCHOOLS

education: BACHELOR OF SCIENCE DEGREES

degree, don't despair — you'll find tips below on how to build your own "degree" program out of courses available in related departments.

BIOTECHNOLOGY BASICS

A comprehensive, basic program in biotechnology will look like the bachelor's degrees available at North Dakota State University or Utah Valley University. At both schools, biology anchors the biotechnology major, along with a healthy dose of chemistry. You will also find physics, some math and computer science, along with general education requirement in the humanities and social sciences.

In fact, if your school does not offer an actual biotechnology degree, programs like these can guide you in building your own, customized course of study. Look for classes in DNA and cellular biology, statistics or data science, molecular chemistry, and technology or design. And note that these schools emphasize a key element in any biotechnology degree program – instruction in laboratory techniques and procedures. Employers often complain that recent graduates are not job-ready because they lack these basic skills, so be sure to gain command of hands-on lab skills.

COMMON DEGREES

Agricultural Science
Biochemistry
Bioinformatics
Biotechnology
Cell Biology
Chemistry
Epidemiology
Food Science
Genetics
Immunology
Marine Biology
Microbiology
Molecular Biology
Neurobiology
Pharmacology
Plant Science
Virology
Zoology

University of Delaware
NEWARK

A CLEAR CAREER DIRECTION

Some programs address the question of job-ready skills with an explicit emphasis on … job-ready skills. The jobs in question might vary, but the purpose of the program remains preparing graduates to step directly into some form of biotechnology work. A degree in Biological Engineering from North Carolina A&T State University offers tracks in bioprocess engineering and natural resources, designed to prepare students for medical school in the first case and jobs in environmental management in the second. Rensselaer Polytechnic Institute features a degree in biotechnology and health economics, preparing graduates for health-related business and technical career paths. And the Program in Applied Molecular Biology and Biotechnology at the University of Delaware emphasizes hands-on training, practical work experience, and readiness for certification in clinical pathology.

COMMON JOB TITLES

- Bioinformatics Analyst
- Biotechnology Technician
- Clinical Research Coordinator
- Compliance Specialist
- Environmental Health and Safety Technician
- Field Application Scientist
- Laboratory Technician
- Manufacturing Associate
- Process Development Associate
- Product Development Associate
- Quality Control Analyst/ Technician
- Regulatory Affairs Associate
- Research Associate/Assistant
- Sales Representative (Biotech/Biomedical)
- Technical Support Specialist
- Validation Specialist

University of Florida
GAINESVILLE

PICK A FIELD, ANY FIELD

Some biotechnology programs combine general courses of study with preparation for a range of career paths. Terms like "applied biology" or "applied biotechnology" will appear, alongside broadly identified fields for which students are preparing themselves. For example, biotechnology in the College of Agricultural and Life Sciences at the University of Florida features an emphasis on plant and animal science. The University of Georgia offers an Applied Biotechnology major with tracks in Animal Science, Plant Science, or Business. And the biotechnology "concentration" at University of North Carolina, Greensboro, points students towards work in medical, agricultural, or environmental sectors. Programs such as these mix academic and practical learning to give students a flavor for work in a field in addition to sufficiently general background to branch out into other directions.

North Carolina A&T
GREENSBORO

ACADEMICALLY AMBITIOUS

Another approach to biotechnology education puts subject matter learning first and foremost. With an assumption that smart people educated in a cutting-edge field will find their way to rewarding, purposeful work one way or another, these programs concentrate on deep, intellectual experiences in school. At Iowa State University, students can blend an "emphasis" on biotechnology with a major in subjects ranging from agronomy to computer science to philosophy and religious studies. At both Worcester Polytechnic Institute and the University of California, Davis, the idea of systems and design principles connects biology and technology subjects and forms the basis of degrees meant to prepare students in an open-ended way for varied career paths or graduate study at the master's or PhD level.

These are just some of the ways schools construct science-based biotechnology programs. As you consider your own options for college, think hard about what grabs your attention and look for programs that might be a good match. The more you can connect your own aptitudes and interests to what a particular program offers, the smoother your journey will be towards a biotechnology career.

PHOTOS COURTESY THE SCHOOLS

Purdue University
WEST LAFAYETTE, IN.

Georgia Tech
ATLANTA

University of Illinois
URBANA-CHAMPAIGN

University of California, Berkeley

North Carolina State
RALEIGH

Or Choose Engineering

With a heavier dose of math and physics, these degrees include practical learning and offer job-ready skills.

The environment for science-based degrees in biotechnology is like a wild, jumbled garden. It is filled with a rich diversity of programs, coming in many different shapes and sizes. General similarities exist, but the subject matter and learning outcomes can differ greatly among programs.

The engineering garden, on the other hand, features neatly ordered rows of programs, varying somewhat but all shaped by largely the same formula: a heavy dose of math, physics, and engineering design, with biology, computer science, chemistry, and materials science also in the mix. You will get an education meant to make you into a professional engineer, with job-ready skills in your chosen area of specialization.

ENGINEERING SHAPES OUR WORLD

Engineering education in general emphasizes practical learning. The products of engineering are supposed to work repeatedly, predictably, and safely. Buildings must stay upright, engines need to start, computers have to compute. Engineers design and create these and all the other technologies we use at home, work, and play. And to do so successfully, they need extensive instruction in how built objects can best work under the laws of nature and physics to serve human needs and wants.

This instruction is so important that strict rules govern what courses of study can be called “engineering” programs. To offer an “engineering” degree, a school must demonstrate that their program gives students command of the skills and knowledge they need to step into work as practicing engineers.

HOW TO FIND A PROGRAM

Colleges and universities offer about 190 programs in areas related to bio-

U OF ILLINOIS PHOTO BY FRED ZWICKY. ALL OTHERS COURTESY THE SCHOOLS.

education: ENGINEERING SCHOOL, BACHELOR OF SCIENCE DEGREES

technology. About a third offer general instruction in the field under names like “bioengineering” or “biological systems engineering.” Smaller numbers offer specializations like agricultural engineering, chemical and biological engineering, even food and forest engineering. However, the largest portion — almost two-thirds — is in “biomedical” engineering. To find a program in these areas (or in any other engineering fields), use this “Program Search” tool, available online at: https://www.abet.org/accreditation/find-programs/.

WHAT YOU WILL LEARN

Whatever the focus of a bioengineering program, instruction will include less biology and chemistry than a science-based program. Instead, it will include more math, physics, and materials science. And above all, it will include instruction in engineering design. To produce all the amazing technologies that benefit the world so much, engineers must be able to blend imaginative design with the ability to solve complex problems. Engineering design anchors the learning that equips engineers to do these things.

As a result, the first year of most engineering programs consists of general instruction in the core disciplines of engineering: math, physics, and engineering design. As you move through later years of an engineering program, you will get into more specialized areas of study.

MORE ABOUT OPTIONS

A general bioengineering program most closely resembles the kind of learning available in a science-based biotechnology program. Programs like those at Purdue University and the University of California, Berkeley, teach students about multiple applications of bioengineering, with substantive academic instruction in core disciplines and research opportunities for advanced undergraduates to explore frontiers of learning in the field.

The largest field of bioengineering — biomedical engineering — is offered at schools large and small in all parts of the country. You are almost sure to find a school that fits your needs and preferences, no matter where you live. Tufts University in Boston represents a common approach to biomedical engineering – basic engineering to start with, then in order of priority: math, statistics, biology, chemistry, and physics.

COMMON JOB TITLES

- Automation Engineer
- Biomedical Engineer
- Bioprocess Engineer
- Design Engineer
- Manufacturing Engineer
- Process Development Engineer
- Project Engineer
- Quality Assurance Engineer
- Research and Development Engineer
- Systems Engineer

University of Texas, Austin

Tufts University
MEDFORD, MA

The goal is to teach graduates how to create “tools, applications, and treatments” with medical value.

GETTING JOB-READY

Some engineering-related approaches to biotechnology are even more focused on industry imperatives. Biomanufacturing applies biotechnology learning to operations and procedures involved in creating biologically-based products. Particularly oriented to the biopharmaceutical industry, biomanufacturing degrees combine academic coursework with both business principles and technical training in relevant manufacturing methods. North Carolina State University offers biomanufacturing degrees through its innovative Biomanufacturing Training and Education Center. Meanwhile, engineering technology involves fewer academic courses and more hands-on learning experiences in programs that prepare students to operate and maintain complex machinery and systems in industrial work environments, including those in biomedical engineering. East Tennessee State University, for example, offers a concentration in biomedical engineering technology that prepares graduates for technical work in health care settings.

MANY APPROACHES

Collaboration across institutional boundaries marks many approaches to bioengineering.

Georgia Tech calls its biomedical engineering program the “liberal arts of science and technology” because of the wide variety of disciplines it features. And it offers a pathway into medical school through a partnership with nearby Emory University.

Florida A&M University, a historically black university, offers a biomedical engineering program in partnership with Florida State University, a major research university. This kind of program promotes diversity in bioengineering, making facilities and resources available to students who might otherwise lack access to opportunities in the field.

Agricultural engineering at the University of Illinois draws on classes at both the College of Engineering and the College of Agriculture, Consumer, and Environmental Sciences. Students can choose among concentrations such as ecological engineering, food and bioprocess engineering, and nanoscale biological engineering.

The engineering approach to biotechnology will challenge and extend your intellect as well as prepare you with practical skills to step into a job upon graduation. You will learn more about technical, quantitative topics like math, computer science, and of course engineering, and less about biology, chemistry, and other scientific subjects. But you will still learn a lot about all these subjects. Whether you choose a science or engineering degree, you will be learning about a field with the promise to reshape our world in almost unimaginable ways.

PHOTOS COURTESY THE SCHOOLS

How to Keep Learning

If you love biotech, pursue a certificate, a master's degree, or a PhD.

If studying biotechnology in college gets you excited to keep learning about the field, you have lots of options for doing so in graduate school. The hardest part might be zeroing in on how, because post-graduate study in the field takes many different forms. From long-term, intense PhD programs to academic or professionally focused master's degrees to short, skills-oriented certificate courses, some form of post-graduation education is sure to suit your biotechnology career plans.

THE MOST SCHOOL OF ALL

A PhD, or doctoral, program is for people who start studying biotechnology and just cannot imagine stopping. Getting a PhD involves extensive, additional coursework beyond the bachelor's degree and a significant, independent research project that advances the state of knowledge in the field. Look for a school with experts in your subject of choice and funding to support your degree work. Nearly every major research university in the country offers a program.

MASTER'S DEGREES

Serving a much broader array of personal and career interests are the many varieties of master's degrees available from schools also spread across the country. A master's degree mixes advanced learning, independent research, and professional training — look for a degree program that combines these elements in a way that suits your individual needs and interests.

AN ACADEMIC FLAVOR

Some master's degrees emphasize academic learning, like doctoral programs, and can be highly individualized. For example, Georgia Tech's bioengineering master's program — touted as the "most innovative and integrative program" at the school — is a joint effort of the Colleges of Engineering, Computing, Sciences, and Design, addressing nearly every imaginable approach to biotechnology.

Other types of degrees blend academic learning with general training in professional areas. The BioTechnology Institute at the University of Minnesota offers academically rich graduate studies that still reflect the needs of industry partners involved in shaping the program. Graduates gain both comprehensive field knowledge as well as advanced job-ready skills. Likewise, many schools offer five-year, combined bachelor's/master's degree programs in biotechnology that serve academic and professional goals. Students take graduate-level courses as undergrads and complete a substantive research project in the fifth year. Often oriented to industry-specific needs, these programs can give grads a big leg up on placements in the private sector.

Boston University
MASSACHUSETTS

University of Minnesota
MINNEAPOLIS

Northwestern University
ILLINOIS

University of Washington
SEATTLE

DEGREES TO BRING TO WORK

A common form of master's degree aligns learning with clearly defined career areas or job skills, often called "professional" master's degrees. Johns Hopkins University features master's degrees in areas like Biotechnology Enterprise and Entrepreneurship, Regulatory Science, Bioinformatics, and Food Safety Regulation, in addition to a joint Business Administration/Biotechnology degree.

The University of Washington runs master's degree programs in Pharmaceutical Bioengineering, Applied Chemical Science & Technology, and Biomedical Regulatory Affairs. Such applied degrees attract both recent grads looking to enter these fields as well as currently employed professionals aiming to advance their careers.

Biomanufacturing is a vital sector of the biotechnology industry. A means to produce in volume all the vital building blocks used in biologically-based products and systems, this area requires a unique blend of technical and business skills. A collaboration with the pharmaceutical company Novo Nordisk, North Carolina State University's Biomanufacturing Training and Education Center offers two master's degrees that prepare students to step into leadership roles on either the technical or management side of the field.

TARGETED LEARNING WITH CERTIFICATES

Even more aligned with job-related content and operations are certificate programs. Consisting of a small set of courses — three to six — and hands-on instruction in a lab or other work-like setting, certificates deliver concrete instruction in narrowly defined areas, anything from biostatistics to project management to clinical trials. Certificates are also frequently available as either online or on-site learning, making them accessible to already-busy students and professionals alike.

ALWAYS LEARNING

As fast as biotechnology is growing and changing, you will always need to be learning new things with a job in the field. With all the options available, you can find programs to help you keep up with advances in the field at almost any phase of your career. Just remember that whatever you learn and however you learn it, your newfound biotechnology skills will support the work you do to make the world a better place for all of us to live.

PHOTOS COURTESY THE SCHOOLS

How to Cut Your Tuition Bill

College scholarships available in biotech, science, and STEM fields.

If you're looking for financial aid, start with scholarships at the schools you are interested in attending. These are usually the most generous. But there are also numerous STEM scholarships from many sources, such as non-profits, foundations, institutions, government organizations, and corporations. Did you know that many available scholarships go unused? So apply for as many as you can! Note that some scholarships require government service in return for the award.

American Indian Science and Engineering Society (AISES) Scholarship
AWARD AMOUNT: **$1,000 per year.**
WHO IT'S FOR: Native American, Alaska Native, Pacific Islander, Native Hawaiian, and Indigenous Canadian students pursuing STEM degrees.

AISES Intel Scholarship
AWARD AMOUNT: **$5,000 per year.**
WHO IT'S FOR: Native American, Alaska Native, Pacific Islander, Native Hawaiian, and Indigenous Canadian students pursuing STEM degrees.

American Chemical Society Scholars Program
AWARD AMOUNT: **Up to $5,000 per year.**
WHO IT'S FOR: Underrepresented minority students who are pursuing degrees in chemistry or a related field.

A.T. Anderson Memorial Scholarship
AWARD AMOUNT: **$1,000 per year.**
WHO IT'S FOR: Native American, Alaska Native, Pacific Islander, Native Hawaiian, and Indigenous Canadian students pursuing STEM degrees.

Barry Goldwater Scholarship
AWARD AMOUNT: **Up to $7,500 per year for 2 years.**
WHO IT'S FOR: College sophomores and juniors pursuing STEM careers.

The Benjamin A. Gilman International Scholarship
AWARD AMOUNT: **Up to $5,000.**
WHO IT'S FOR: Undergraduate students who are studying abroad, including in STEM fields.

Bio-Rad Scholarship
AWARD AMOUNT: **Up to $3,000.**
WHO IT'S FOR: Undergraduate students pursuing degrees in science or engineering.

Buick Achievers Scholarship Program
AWARD AMOUNT: **$500 per year.**
WHO IT'S FOR: Students pursuing engineering degrees.

BHW Scholarship
AWARD AMOUNT: **$3,000.**
WHO IT'S FOR: Women who are majoring in STEM fields.

Davidson Fellows Scholarship
AWARD AMOUNT: **$50,000, $25,000, or $10,000.**
WHO IT'S FOR: Students under the age of 18 who have completed a significant piece of work in a STEM field.

Department of Defense SMART Scholarship for Service
AWARD AMOUNT: **Full tuition, annual stipends, internships, and guaranteed employment with the Department of Defense after graduation.**
WHO IT'S FOR: Students studying STEM fields

Diversification of Our Research Scientists (D.O.O.R.S) Scholarship
AWARD AMOUNT: **$5,000.**
WHO IT'S FOR: Underrepresented students in STEM pursuing a biotechnology-related major.

Future Farmers of America (FFA) Future Leaders Scholarship
AWARD AMOUNT: **$5,000 or $10,000.**
WHO IT'S FOR: FFA member students members pursuing agriculture-related majors.

Google Lime Scholarship
AWARD AMOUNT: **$10,000 as well as the opportunity to attend a Google retreat.**
WHO IT'S FOR: Students with disabilities pursuing degrees in computer science, engineering, or a related field.

Great Minds In STEM Scholarship
AWARD AMOUNT: **$500-5,000.**
WHO IT'S FOR: Students of Hispanic descent pursuing a STEM degree.

Grow Ag Leaders Scholarship
AWARD AMOUNT: **$1,500.**
WHO IT'S FOR: Students pursuing a career in various sectors of agriculture.

National Institutes of Health (NIH) Undergraduate Scholarship Program
AWARD AMOUNT: **Up to $20,000 per year.**
WHO IT'S FOR: Students from disadvantaged backgrounds who are committed to careers in biomedical research. There is a service requirement.

Out to Innovate Scholarships
AWARD AMOUNT: **Up to $5,000.**
WHO IT'S FOR: LGBTQ+ students pursuing degrees in STEM.

Scholarship America Dream Award
AWARD AMOUNT: **$5,000 - 15,000 per year.**
WHO IT'S FOR: Students who have completed at least one year of college and have overcome incredible challenges ranging from family tragedies to physical struggles to systematic inequities.

Society of Hispanic Professional Engineers (SHPE) Foundation Scholarships
AWARD AMOUNT: **Up to $5,000.**
WHO IT'S FOR: Hispanic students pursuing degrees in STEM fields at 2-year or 4-year colleges.

Society of Women Engineers Scholarships
AWARD AMOUNT: **Up to $16,000 per year.**
WHO IT'S FOR: Women who are pursuing degrees in engineering or computer science.

Thermo Fisher Scientific Antibody Scholarship
AWARD AMOUNT: **$10,000.**
WHO IT'S FOR: Students pursuing degrees in biology, chemistry, biochemistry, or a related life science field.

Women in Defense
AWARD AMOUNT: **Up to $10,000 per year.**
WHO IT'S FOR: Female students who are pursuing degrees in fields related to national security or defense.

STATE-SPECIFIC SCHOLARSHIPS

AISES Burlington Northern Santa Fe (BNSF) Foundation Scholarship
AWARD AMOUNT: **$2,500 per year, up to 4 years.**
WHO IT'S FOR: Native American, Alaska Native, Pacific Islander, or Native Hawaiian students who reside in one of the 23 states serviced by the BNSF Pacific Corporation: AZ, CA, CO, KS, MN, MT, NM, ND, OK, OR, SD, TX, WA, AK, LA, UT, NV, WY, IL, MO, NE, WI, or IO.

Thurgood Marshall College Fund and Cargill
AWARD AMOUNT: **Up to $16,000.**
WHO IT'S FOR: Sophomore women and minorities who are pursuing agriculture or STEM degrees at one of twenty 1890 land grant institutions.

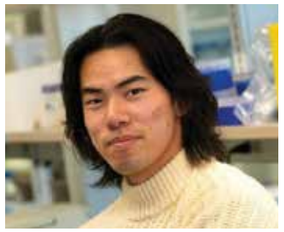
NOTE: Some states like Illinois, New Mexico, and Nebraska offer scholarships specifically for their residents.

meet a few biotech students

Cosmo Cao
School: U.S. Air Force Academy
Major: Biochemistry
My passion is investigating the details of the natural world, whether it be lab-based experiments with cyanobacteria and Lyme disease or conducting field research in the New Zealand bush. I hope to continue this journey in medical school and beyond.

Janice Rullan
School: University of Massachusetts, Dartmouth
Major: Biomedical Engineering and Biotechnology
I'm drawn to the field for its ability to solve problems and make a big difference with just one discovery. I admire how research, like that at the DoD, directly protects soldiers, and I aspire to contribute to such impactful work.

Michelle Vega Medina
School: Solano Community College
Major: Biotechnology
I am a first-generation student who enjoys working in a laboratory, whether it be culturing CHO cells (important for research and making therapeutic proteins) or purifying protein in a biosafety cabinet. I hope to graduate in the spring of 2025 and to someday create a medicine that will cure the incurable.



Christian Mei
School: Boston University (BS)
Major: Molecular Biology
I currently work in a lab at Boston University where I study how genes work in tiny flies. I am developing a new gene prediction algorithm to find specific parts of DNA in these flies. If it works, we could discover new gene controls, improving our understanding of genes.

Juan Perez
Schools: Montgomery County Community College (AS) and Thomas Jefferson University (BS)
Major: Biotechnology
My aspirations lie in pursuing further education in bioscience to drive groundbreaking solutions that enhance the quality of life for individuals.

Skyler Hope Michaud
School: MassBay Community College
Major: General Studies in Science (AS)
With hands-on experience in MassBay's Biotech lab, I secured a high-paying scientist position at EverCell Bio which focuses on stem cells. I never thought I could see myself as a scientist, but all you need is an interest and motivation in this lucrative field.

PHOTOS COURTESY THE STUDENTS AND PROFESSIONALS

meet a few biotech professionals

Reshma Shetty is a co-founder of Ginkgo Bioworks, a synthetic biology company that programs cells to manufacture a wide range of products, including food, materials, and therapeutics. She has played a big role in advancing the synthetic biology industry and has been recognized for her contributions. Fast Company named her one of the 100 Most Creative People in Business in 2011. She has a BS degree in computer science from the University of Utah and a PhD in biological engineering from MIT.

Cameron Pitt is Chief Business Officer and Founder at Quanta Therapeutics, a biotech company that focuses on developing therapies for oncology, specifically targeting RAS, which is a prevalent and elusive target in cancer treatment. Cameron graduated from Stanford University with a BS in biology and then received a PhD in biomedical sciences from UCSF, focusing on cancer. After graduate school, he went to work in venture capital, first at Versant Ventures and then at Sofinnova Investments.

Michaeline Albright is Technical Project Manager, Environmental Microbiology, at Allonnia, which aims to revolutionize the waste markets and create a waste- and pollution-free world. Michaeline is passionate about using microbes to solve the challenge of global waste. She holds a BS in Geological Sciences from Brown University and a PhD in Biological Sciences from the University of California, Irvine.

Jen Nwankwo is founder and CEO of 1910 Genetics, whose mission is to decrease the timeline and cost of drug discovery by leveraging the power of biology and AI. Jen got her PhD in pharmacology at Tufts University School of Medicine, where she did her dissertation on sickle cell disease — a traditionally understudied area of biology that disproportionately affects Black people.

Anna Crumbley is a research chemical engineer at the U.S. Army Combat Capabilities Development Command Chemical Biological Center where she is working on biomanufacturing advances that will free the U.S. from dependence on foreign sources for critical manufacturing materials. She holds a BS in chemical engineering from the University of Alabama and a PhD from Rice University in chemical and biomolecular engineering.

Jeff Nobbs is a co-founder of Zero Acre Farms which has developed a new type of cooking oil generated by microbes through the process of fermentation. The result is a healthier all-purpose oil with more good fats than olive oil and a tiny environmental footprint — production of the oil uses 99% less water than olive oil and 87% less land than canola oil. Jeff received a Business Administration and Entrepreneurship degree from the University of Southern California.

A Focus On Our Planet

Many biotech companies work to make our world healthier. Here are a few.

Saving the planet means cleaning up and protecting everything from the seas to the trees, from the air we breathe to the soil beneath our feet to the water we drink, clean with, and use to grow food. If you care about healing the environment and fighting global climate change, biotechnology can be a great way for you to contribute. Read below to discover how biotech companies are developing incredible solutions to these challenges.

BioCarbon Engineering

Biotech innovation: Use drones and biotechnology to plant trees in deforested areas.
How? Drones flying very low to the ground shoot specialized tree seedpods into sites identified as viable for new growth. Ten times faster and vastly cheaper than replanting forests by hand, this technology can help restore ecosystems, promote biodiversity, and combat climate change by removing carbon dioxide from the atmosphere.

Carbon Clean Solutions

Biotech innovation: Develop technologies to scrub carbon dioxide (CO2) out of factory emissions.
How? Highly efficient, cost-effective biotech processes help capture CO2 in waste generated by power plants, cement production, and steel manufacturing before it can escape into the atmosphere. These captured CO2 emissions can then be converted into raw materials suitable for making useful, biodegradable products or into non-toxic chemicals easy and safe to store. By cleaning up streams of industrial waste, these technologies contribute to reducing greenhouse gas emissions and combating climate change.

Ecovative Design

Biotech innovation: Use mycelium, the root structure of mushrooms, to create sustainable alternatives to traditional materials.
How? Mycelium-based materials are used for packaging, insulation, and other applications, offering eco-friendly alternatives to single-use plastics and harmful materials. These mushroom-based alternatives are renewable, biodegradable, and have a low environmental impact compared to conventional materials.

Indigo Agriculture

Biotech innovation: Craft coatings for seeds laced with beneficial microbes that enhance crop yields and reduce reliance on synthetic fertilizers and pesticides.
How? Specially developed microbes supercharge the ability of crops to grow, resist disease, and thrive even under harsh conditions. Fortifying plants to protect themselves helps to promote sustainable farming practices, increase agricultural productivity, and minimize the use of harmful chemicals.

Newlight Technologies

Biotech innovation: Convert methane, a potent greenhouse gas, into a biodegradable plastic called AirCarbon.
How? In nature, trees remove carbon from the air in the process of making leaves. This technology does the same, using microorganisms to pull greenhouse gases out of the atmosphere and convert them into an eco-friendly plastic substitute — which is both dishwasher-safe and compostable! The result? Less pollution, cleaner air, and a versatile, biodegradable alternative to fossil fuel-derived plastics.

Better Foods & Clean Water

These companies are working on technologies to increase food production and clean our water.

The population of Earth continues to grow year by year. For all of us to survive and thrive, we need reliable sources of good food and clean water. Biotech companies work at the cutting edge of agricultural technologies that can increase rates of food production, create sustainable sources of healthy foods, and provide clean water for use all over the world. Read on to learn about just a few of these companies.

Blue Nalu

Biotech innovation: Provide premium-grade seafood products with methods more sustainable than traditional fishing or aquaculture.
How? They use cellular agriculture to make flavorful seafood products, resulting, for example, in "cultured" or lab-grown tuna. Using actual fish cells, this process yields seafood that looks and tastes like tuna caught in the ocean. Producing tuna this way can reduce overfishing, avoid injuring and killing other types of fish accidentally caught along with tuna, and reduce stresses on the ocean environment, such as habitat destruction and pollution.

Plenty

Biotech innovation: Grow abundant supplies of leafy greens in indoor vertical farms.
How? Indoor vertical farms provide stable, space-efficient, reliable conditions for raising high-yield crops of lettuce, kale, spinach, and other leafy vegetables. How high-yield? Over 350 times that of traditional agriculture. And the indoor conditions never vary, meaning weather, climate change, and pests become non-issues. Not to mention pesticides used to get rid of the pests.

Just Egg

Biotech innovation: Make plant-based eggs that scramble just like real eggs.
How? Just Egg makes eggs out of the mung bean, a legume that humans have grown for over 4,000 years. This plant-based egg delivers a versatile, cholesterol-free option, rich in nourishing protein. And Just Egg production uses 98 percent less water and 83 percent less land than maintaining hens on a dairy farm.

Strella

Biotech innovation: "Listen" to produce to predict shelf life, reducing waste and improving freshness.
How? Using sensors and algorithms, Strella can monitor the condition of fruits and veggies on the shelf and calculate how long they will remain fresh and tasty. This information enables grocers to make better supply chain decisions — like helping a supplier store their apples, an exporter ship kiwis, or a retailer display the most deliciously ripe bananas.

Xylem

Biotech innovation: Develop advanced water treatment solutions for companies' contaminated water.
How? Their water-saving and water-cleaning technologies allow industries from agriculture to pharmaceuticals to recycle, reuse, and reduce water that would otherwise go into the environment as dangerous waste.

Healthier Lives for All

Knowledge of biotechnology can put you on any of several paths into a career in healthcare.

The convergence of biology, engineering, and data science has opened up a wealth of new opportunities in medicine. Innovative technologies that integrate all three of these areas of learning are helping doctors, scientists, and engineers develop revolutionary therapies and tools for curing diseases and solving medical problems. You read about some of these advances on pp. 10-11. If you have your heart set on a career in medicine, learn more below about how biotechnology can land you in the middle of some of the most exciting work taking place in the field.

Personalized, gene-based medicine

Superpowered computers and microscopic-level manipulation of DNA now make it possible to tailor therapies and treatments to the unique genetic codes we all carry in our cells. Beam Technologies offers a tool to "edit" a patient's genome to fight disease in various ways. The tool can correct a harmful mutation, alter a gene to prevent disease, and even turn on or turn off a gene to improve health outcomes. And bioSyntagma uses artificial intelligence to eliminate trial-and-error cancer treatments by taking a patient's "molecular fingerprint" and identifying the best among various therapies for that particular person.

Designer drugs

Covid taught drug-makers new DNA-based vaccine production techniques, resulting in shots that protected millions from the virus. Biotech companies like Resilience play a crucial role in large-scale production and distribution of these designer drugs. They provide robust, reliable biomanufacturing services to keep sizable populations safer and healthier when bad bugs like Covid strike.

Immunotherapy

The ability to tinker with sick people's T cells — the cells in our immune system that fight off disease — means that biotechnology companies can activate a patient's own body to heal itself without need for drugs. Fannin Biotech, for example, developed a procedure for using people's own immune systems to aid in recovery from respiratory ailments, ranging from asthma all the way to lung cancer.

Biocompatible implants

Human bodies protect themselves by identifying and rejecting foreign objects that get inside them. But foreign objects — in the form of new organs, tissue transplants, or drug delivery systems — can serve important health purposes. Biolin Scientific developed coatings and materials that can be used to make many kinds of implants biocompatible, tuned to an individual's unique body chemistry, to be welcomed and integrated into the body as a safe, normal part of its natural function.

Regenerating tissue and body parts

When soft tissues like tendons and ligaments break down, the body cannot repair them on its own. A firm called Embody invented a synthetic, collagen-based soft tissue repair material that provides a platform for new soft tissue cells to grow and spread and connect organically to remaining healthy tissue. Then the material dissolves into waste, leaving nothing behind but the newly grown, fully functional tissue.

Tech Solutions for Our Troops

If you'd like to contribute to our country's defense, take a look at these amazingly innovative initiatives.

"A strength of U.S. national security is the willingness to look over the horizon and plan for what the future will bring. There is an inflection point now with the coming biotechnology revolution. It will disrupt and transform all facets of life." So says Peter Emanuel, one of the Army's leading biotechnology visionaries, underscoring how advantages in technology can amplify a country's military capabilities. America has long led the world in innovative defense technologies. But our historical leadership in this area does not guarantee the same supremacy in the future.

In the fall of 2022, the White House identified biotechnology as a "critical technology area" for the country. As a result — and as much as any of the other career paths you have read about — biotechnology in the service of national defense will be offering only more opportunities to service-minded, smart people interested in protecting the country through science and technology.

The incredible advances enabled by biotechnology make projects under way at the Department of Defense seem like glimpses into the far future. But these are real-world efforts, with prospects for success that would revolutionize our military capabilities.

DETECT AND PROTECT:

Identifying and neutralizing new kinds of threats to personnel and military assets.

Imagine putting plants, animals on land and underwater, and even insects to work as far-flung, widely distributed sensors making up vast, interconnected, self-perpetuating surveillance networks. These biological "assets" would monitor the environment for chemical and biological weapons, novel viruses and harmful bacteria, or threats in the ocean ranging from small, unmanned drones to nuclear submarines. Examples of programs doing this work are: **Advanced Plant Technologies (APT)**, **Persistent Aquatic Living Sensors (PALS)**, and **Preventing Emerging Pathogenic Threats (PREEMPT)**.

WARFIGHTER READINESS:

Preparing and restoring troops for functioning at their highest levels of ability.

Replacing troops' lost blood in the field of battle is a huge challenge. Whole blood gets heavy in large volume, requires expensive, cold storage, and must match multiple types to be useful for high numbers of wounded personnel. A bio-synthetic blood substitute is under development that would work something like freeze-dried milk: easy to transport with a long shelf life and adaptable to the unique body chemistry of any wounded warfighter. This is the goal of **FSHARP, Fieldable Solutions for Hemorrhage with bio-Artificial Resuscitation Products**.

Restoring Active Memory (RAM) seeks to restore or enhance troops' memory and learning capabilities — with something no more invasive than a headband that subjects could wear while sleeping. The device would send electronic signals into the brain to interact with ongoing neural activity, helping people recover memories lost to brain trauma or just learn and retain information studied while awake in deeper, more lasting fashion.

OPERATIONAL BIOTECHNOLOGY:

Fortifying and maximizing efforts to keep troops supplied, safe, and fully equipped in any kind of environment.

An active battlespace is as complicated and multi-dimensional as a small city constantly on the move and under threat of attack. Water, shelter, health and well-being, supplies, and food are always at risk and in demand.

Atmospheric Water Extraction (AWE) would yield devices to extract and store clean, drinkable water straight out of the air in volumes large enough to meet daily drinking needs for up to 150 people.

Engineered Living Materials (ELM) envisions living biomaterials that could "grow" into buildings, meld into existing structures to repair them, and even detect the presence of hazardous elements in the surrounding environment.

Cornucopia seeks to enable on-site production of nourishing, even tasty food out of nothing more than water, air, electricity, and easily stored and transported microbial feedstock.

And the **Advanced Acclimation and Protection Tool for Environmental Readiness (ADAPTER)** program would develop a bioelectronic device unique to a person's body chemistry that could produce and release treatments for afflictions as varied as diarrhea, infections, and jet lag.

Organizations doing work of this kind are widely distributed throughout the Department of Defense. They include the Defense Advanced Research Projects Administration (DARPA), the Office of Naval Research (ONR), the Army Research Laboratory (ARL), and the Air Force Office of Scientific Research (AFOSR), just to name a few. Jobs at these and other government agencies can require background checks, drug tests, and security clearances.

To read more about defense-related biotechnology programs, go to the website of the Biological Technologies Office at the Department of Defense at https://www.darpa.mil/about-us/offices/bto.

U.S. AIR FORCE PHOTO BY STAFF SGT. WILLIAM RIO ROSADO

facts & figures

Number of biotechnology companies in the United States:

8,490*

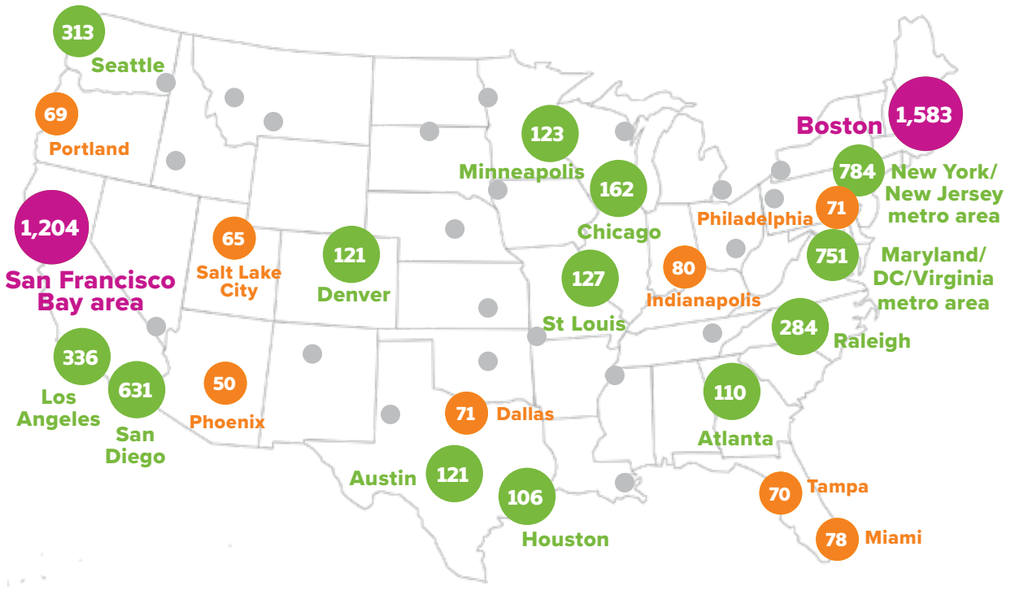
Number of people working in biotech in the United States:

283,645*

*2023 FIGURES. SOURCE: WWW.BIOTECH-CAREERS.ORG

BIOTECH COMPANIES ACROSS THE U.S.

You will find biotech jobs nearly everywhere in the U.S. but there are high concentrations in Boston and the San Francisco Bay area. Other hot areas include southern California, the DC-metro area, the Raleigh-Durham area of North Carolina, and the Chicago metropolitan area. The gray dots indicate smaller groupings of biotech firms, numbering fewer than 50 in each area.



FAST GROWING & WELL PAID

Jobs for **biotech technicians** are expected to grow by

5%*

between now and 2032, with a 2023 median annual salary of

$49,650.

Number of jobs in 2022:

81,400

Jobs for **biotech engineers** are expected to grow by

5%*

between now and 2032, with a 2023 median annual salary of

$99,550.

Number of jobs in 2022:

19,700

*2.8% IS THE AVERAGE FOR ALL OCCUPATIONS

SOURCE: U.S. BUREAU OF LABOR STATISTICS

TOP 5 IN-DEMAND BIOTECH JOBS

#1. Medical and Clinical Laboratory Technologists and Technicians*
Duties: *Collect samples and perform tests to analyze body fluids, tissue, and other substances.*

#2. Medical Scientists
Duties: *Conduct research and develop clinical trials aimed at improving overall human health.*

#3. Biological Technicians*
Duties: *Help biological and medical scientists conduct laboratory tests and experiments.*

#4. Biochemists and Biophysicists
Duties: *Study the chemical and physical principles of living things and of biological processes, such as cell development, growth, heredity, and disease.*

#5. Chemical Technicians*
Duties: *Use special instruments and techniques to help chemists and chemical engineers research, develop, produce, and test chemical products and processes.*

***5-7 technicians are needed for every 1 scientist!**

THREE GREAT BIOTECH RESOURCES

BioBuilder.org: Find out about summer programs, internships, online classes, podcasts, and more.

InnovATEBIO.org: Learn about college programs that offer biotech-related degrees and certificates, events, career pathways and more.

Biotech-careers.org: Explore the industry and learn about entry-level positions and career advancement.

Start Engineering

Publisher: Robert F. Black
Creative Director: Stacie A. Harrison
VP, Learning and Communications: Eric Iversen
Editors/Writers: Stacie A. Harrison, Eric Iversen

To purchase more biotechnolgy career guides, go to: start-engineering.com/shop/
Contact us at bblack@start-engineering.com

www.start-engineering.com

Building a Robust STEM Future: DoD's Investment in Biotechnology

The Vision of DoD STEM is a diverse and sustainable Science, Technology, Engineering, and Mathematics (STEM) talent pool ready to serve our Nation and evolve the Department of Defense's competitive edge.

The Department of Defense is cultivating an environment where the United States of America is the world leader in biotechnology and other critical priority areas. By inspiring new and future talent in Science, Technology, Engineering and Mathematics (STEM) fields, we are poised to prepare the next generation for the ever changing landscapes of threats that our nation may face.

Department of Defense
DoDSTEM
Science · Technology · Engineering · Mathematics

https://dodstem.us/

PHOTO BY SARAH PETERSON, U.S. NAVAL RESEARCH LABORATORY