UNLOCKING LIFE'S SECRETS

Career Opportunities in Biochemistry and Molecular Biology

ASBMB
The American Society for Biochemistry and Molecular Biology
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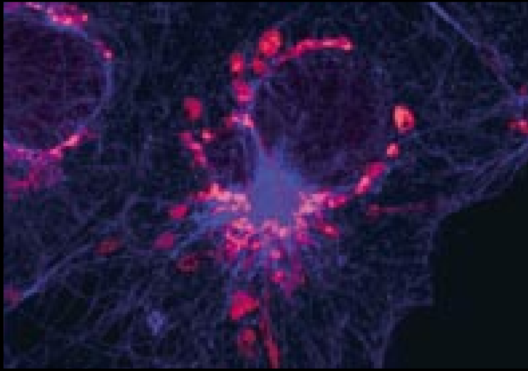
THERE'S A QUIET REVOLUTION GOING ON



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It's a revolution in our understanding of the chemicals and forces that give us life and produce illness and death.

Over the past several years, an evergrowing arsenal of techniques has helped researchers dissect the innermost secrets of the cell and develop new ways to detect and attack disease. The techniques also have been used to produce vast amounts of once rare drugs, trace the path of evolution, create instant tests for a host of illnesses, warn people when their children might inherit a deadly disease, and identify criminals and victims of disasters.

The leaders in this revolution have been the biochemists and molecular biologists who explore the chemical realm inside cells, study the development of illness, and search for ways to improve life on Earth.

If cancer is to be cured, if the planet's pollution is to be cleaned up, or if the aging process is ever to be slowed, it will probably be the biochemists and molecular biologists who will provide the knowledge for these breakthroughs.

Few fields are so interesting, so challenging and so potentially rewarding.

To become part of the revolution, it takes a willingness to learn, and a natural curiosity about how life works. It's an opportunity to be an explorer in a microscopic world that is as strange and breathtaking as any imaginable.

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The Challenges

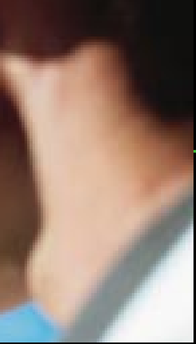
The molecular life sciences have grown to encompass virtually the entire spectrum of science, from physics and chemistry to biology and health care. Women and men in the field are studying life on every level from individual molecules to the interrelated web of Earth's organisms, and all the bacteria, yeast, plants, amphibians and mammals in between.

At the molecular level, there's the quest to understand the information in DNA, to discover how portions of genetic material are turned "on" and "off," and to learn how the exact shape of a protein determines what it will do.

On a larger scale, scientists are struggling to learn how different chemicals fit together to form cells, how those cells interact to build large organisms, and how seemingly subtle differences in the chemical instructions issued by DNA are able to sculpt Earth's vast array of life forms.

Because living things are always changing and adapting, there's an ongoing quest to understand the dynamics of life, from the secrets of cell-to-cell communication to the chemical changes in the brain that give us our memories.

Knowledge emerging from biochemistry and molecular biology will probably have a greater impact on our society than the splitting of the atom, as researchers in the field tackle a host of intriguing questions.



For example, biochemists and molecular biologists are:

- Perfecting techniques for identifying criminals based on a single strand of hair or a tiny bloodstain left at the scene of a crime.

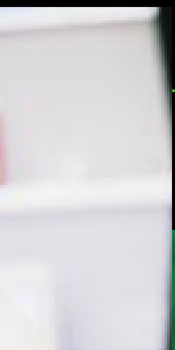
- Developing computerized portraits of enzymes and other important chemicals to see how they are made, how they are folded, and how they fit--both literally and figuratively--into the processes of life. That knowledge should help researchers design better vaccines, antibiotics, and anti-cancer drugs, and lead to pesticides that do less damage to human health and the environment.

- Comparing proteins from different species and recording the changes that have occurred through evolution. The result will be a family tree for life on Earth that is far more detailed than any developed from fossils.

- Creating genetically engineered crops that are more resistant to frost, drought, spoilage, diseases and pests.

- Mass producing life-saving chemicals that are usually found in the body in very tiny amounts. Some of those chemicals have been helping diabetics and heart attack victims for years.

- Learning how cells recognize one another and communicate with enough efficiency to assemble human beings composed of a hundred thousand billion cells.



- Discovering how certain diseases such as AIDS and cancer escape detection by the immune system, devising ways to enhance immunity to combat these diseases, and looking for ways to suppress the immune system to help people who have received a tissue transplant or have an immune system that has turned against them.

- Teasing out the chemical secrets of fertility. For infertile couples, that knowledge could improve the success of in vitro fertilization. For a woman who is not ready (or no longer willing) to bear children, it could eliminate the risk of pregnancy. Such knowledge may also help preserve endangered species.

- Trying to program bacteria to clean up the environment by “eating“ toxic chemicals.

- Mining the data made available by the sequencing of the genomes of organisms ranging from microbes to man. Computationally intensive comparisons of these genetic blueprints will reveal why humans have 25,000 to 30,000 genes and seemingly less complicated creatures like fruit flies and nematodes have almost as many.

Early work using information from the human genome has pinpointed the genetic defects responsible for muscular dystrophy, hemophilia, cystic fibrosis and sickle cell anemia. Problems such as obesity, alcoholism, tooth decay, Alzheimer’s disease, heart disease and some forms of mental illness involve heredity. Knowing the source of a genetic trait or defect can open the way to testing and treatment.

Cataloging the human genetic code may also lead to the identification of the instructions for the 10,000 or more proteins believed to be related to aging and longevity. With that knowledge, researchers may discover ways to extend the human life span.

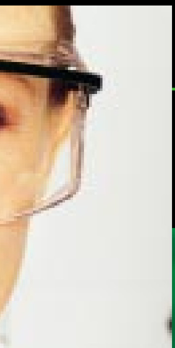
The legal, ethical, social, medical and environmental impact of these discoveries will be immense. Safeguards must be developed, for example, to ensure that the microorganisms designed to gobble up pollution are prevented from escaping to eat away natural resources. In another case, society must decide if it is okay for employers to discriminate against a job applicant whose genetic profile shows that he or she has an above-average risk of suffering a heart attack before retirement.

Thus, society will need scientists whose perspective extends beyond the laboratory, women and men able to provide the highest level of progress at the lowest level of risk. There is, for example, a need for science-trained ethicists and for scientists able to deal with legal issues, patent applications and government regulations.

And these are only today's challenges.

Someday if extraterrestrial organisms are ever discovered, biochemists and molecular biologists will be the ones asked to unlock the secrets of those alien life forms.

SOCIETY WILL NEED SCIENTISTS WHOSE PERSPECTIVE EXTENDS BEYOND THE LABORATORY, WOMEN AND MEN ABLE TO PROVIDE THE HIGHEST LEVEL OF PROGRESS AT THE LOWEST LEVEL OF RISK.



PREPARING FOR A CAREER IN BIOCHEMISTRY AND MOLECULAR BIOLOGY

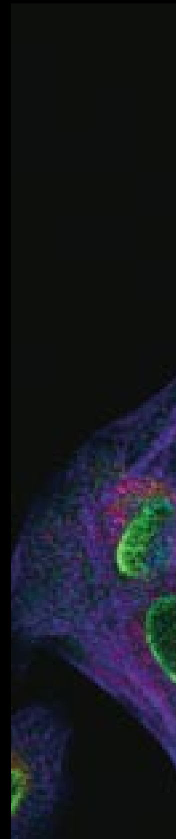
Biochemists and molecular biologists usually specialize in one of many areas in their field. But they also need to be familiar with several scientific disciplines. Their work often requires an understanding of chemistry, physics, mathematics and computer science, and is often related to areas such as genetics, toxicology, physiology, microbiology and immunology. High school provides the foundation for that knowledge, four years of college gives breadth to that knowledge, and post-graduate studies allow students to probe deeply into specific areas.

In some cases, high school students choose to train as laboratory technicians, who can carry out laboratory experiments after taking two years of courses in a community college program.

High School Foundation

High school students interested in biochemistry and molecular biology should take at least one year each of biology, chemistry, and physics, along with algebra, geometry, and trigonometry. Introductory calculus is also useful. English courses that emphasize writing skills are strongly recommended because scientists must communicate results clearly and accurately through speeches and articles in scientific journals. Critical thinking skills are often enhanced by humanities and social science courses. Many colleges and universities also require several years of a foreign language, which may be critical because scientists often exchange information with researchers from other countries.

Remember, individual colleges sometimes have their own special requirements for admission. Before applying, high school students should plan ahead and take any additional courses they'll need to get into the school they want. Also, check the catalogs of colleges or universities to be sure they offer the kind of program outlined in the next section.



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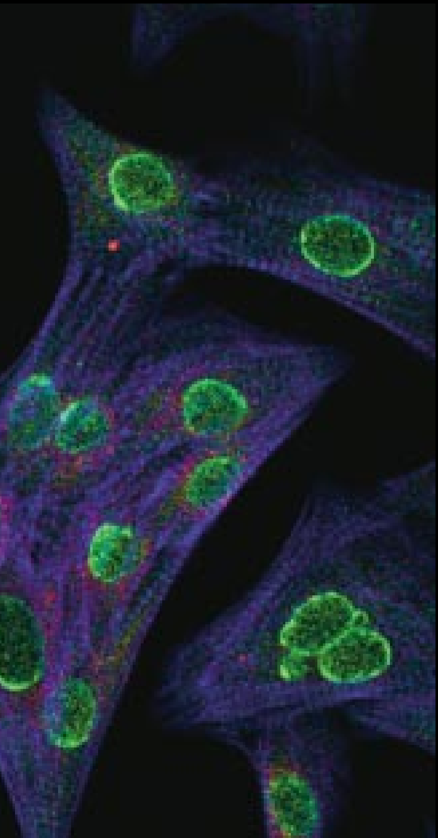


Many colleges expect high school students to take the Scholastic Aptitude Test (SAT) or the ACT Assessment (ACT), but it is important to prepare for this test by taking the Preliminary Scholarship Aptitude Test/National Merit Scholarship Qualifying Test. The PSAT/ NMSQT is given in October of the sophomore and junior years.

The PSAT/NMSQT is especially important for members of some minority groups who are in their junior year. It automatically makes Hispanic students eligible for the College Board's National Hispanic Scholar Awards Program and black students eligible for the National Achievement Scholarship Program for Outstanding Negro Students.

Community Colleges
Laboratory Technician Training

For a high school graduate who wants to work in a laboratory and enter the job market with a minimal amount of preparation, an increasing number of community colleges offer special two year programs that lead to an associate of arts (A.A.) or associate of applied science (A.A.S.) degree in the field. Students in these programs typically take courses in the molecular life sciences, analytical chemistry, biology, applied physics, precalculus, instrumental analysis, and technical communication.

College Education

The best way for a college student to prepare for a career in biochemistry and molecular biology is to earn a bachelor degree in either of these areas. Although many schools do not offer these programs, there are two ways for students to receive somewhat comparable training. First, they can work toward a bachelor degree in

chemistry and choose courses in biology, molecular genetics, and biochemistry, including biochemistry laboratory. Second, they may earn a bachelor degree in biology, but they should take more chemistry, mathematics and physics courses than may be required of a biology major, and they should choose a biochemistry course with laboratory work.

Some schools offer both a Bachelor of Science (B.S.) and a Bachelor of Arts (B.A.) degree, but some only offer one of these two. Either degree will prepare you for a career in biochemistry and molecular biology. What's important is to choose your courses carefully and to consult with a faculty adviser familiar with biochemistry and molecular biology early in your first year in college.

In addition to getting the bachelor degree, opportunities that provide on-the-job experience in a biochemistry or a molecular biology laboratory can be invaluable (see next section). The National Science Foundation and the National Institutes of Health sponsor research programs for undergraduates, particularly women, Hispanics, African Americans, American Indians, Native Alaskans and disabled students. In addition, your college or university may offer undergraduate research experiences that provide hands-on laboratory work, but students need to plan ahead so they have time in their undergraduate career for an independent project. Another way to acquire research experience and sample potential graduate schools is to take advantage of the many summer internships made available by diverse institutions.

IN ADDITION TO GETTING THE BACHELOR DEGREE, OPPORTUNITIES THAT PROVIDE ON-THE-JOB EXPERIENCE IN A BIOCHEMISTRY OR A MOLECULAR BIOLOGY LABORATORY CAN BE INVALUABLE.

Specialized Laboratory Training

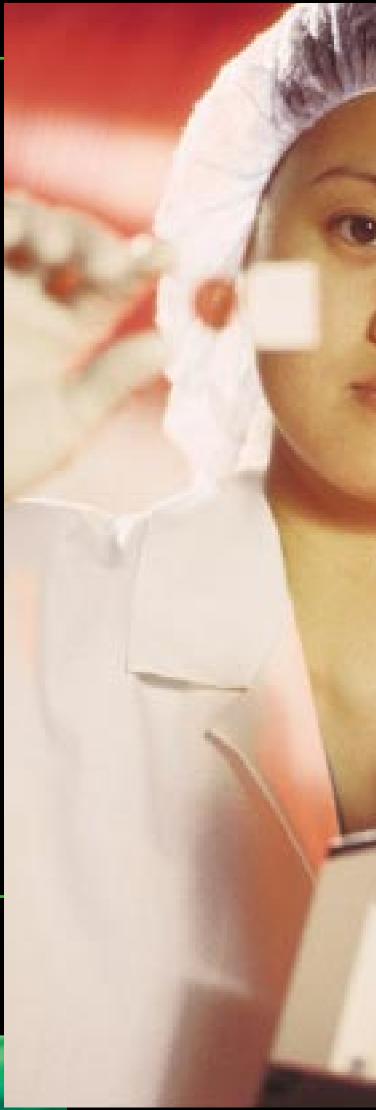
There are many career opportunities for a person with a bachelors degree in biochemistry and molecular biology. One way to enhance the prospects of getting a job is to spend another year at a university that offers training programs for specialized laboratory techniques that other researchers and companies find extremely valuable. A “certificate program” may teach skills such as cell culture, genetic engineering, recombinant DNA technology, biotechnology, in vitro cell biology, protein engineering, or DNA sequencing and synthesis. In some universities, students can work simultaneously towards the bachelors degree and a certificate.

Graduate School

Careers that involve teaching in a college or directing scientific research in a university, a government laboratory or a commercial company require at least the masters degree (M.S.) and, preferably, the doctorate (Ph.D.) degree. It is typical in this field for students to bypass the M.S. degree and proceed directly to a Ph.D. program. It is not uncommon for students to return to graduate school after working in a job that only required a lower degree. Having a doctorate allows you to design the research and direct others to carry out experiments.

A graduate education program is intensive, but many students thrive on the concept that they are being paid to think.

Initially, graduate school involves specialized courses and seminars. For a masters degree, about a year of course work is typically required and many schools require completion of a research project. For a Ph.D. degree, full-time course work can last up to two years. Most graduate programs require one or more special examinations at the end of this initial phase.



The most important part of all Ph.D. training is the requirement for the student to conduct an extensive original research project leading to significant new scientific findings. This work is presented in a formal thesis written by the student and usually published as articles in scientific journals. Most students work under the direction of a faculty member on a project of mutual interest in the faculty member's area of expertise. The research project is vital because it is designed to help the Ph.D. candidate develop the ability to frame scientific questions and discover ways to answer them, as well as to teach the laboratory skills needed to tackle a wide range of other biochemical problems. Earning a Ph.D. means that you know how to conduct important research in biochemistry or molecular biology with little or no guidance from others. In all, most students complete a Ph.D. in four or five years.

Admission Requirements

The most frequent requirement for acceptance to graduate school is a bachelors degree in biochemistry (or in chemistry or biology if the supplemental courses described in the previous section have been taken). However, because biochemistry and molecular biology have such a broad base, students may enter these graduate programs from diverse fields such as physics, psychology, nutrition, microbiology, or engineering.

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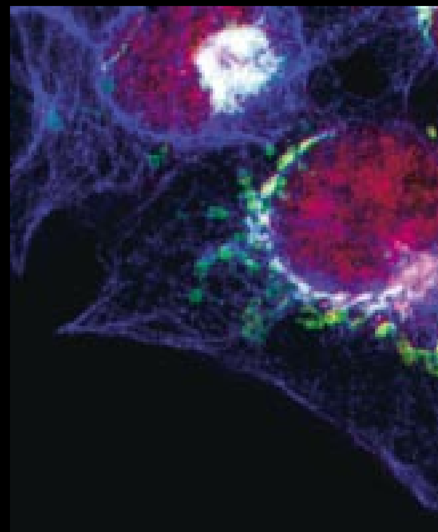


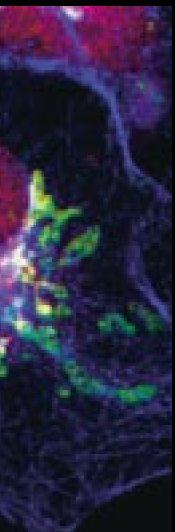
Students should have graduated from college with at least a B average, although a lower overall grade average may be acceptable if the student shows other signs of promise. Applicants should take the Graduate Record Examination (GRE), including the advanced test in biology, chemistry or biochemistry, cell and molecular biology. Scores from the tests must be submitted to the graduate schools they are considering. Letters of recommendation from persons familiar with the students' scientific and academic abilities are usually required. Graduate schools prefer students with laboratory or research experience.

Applications to graduate schools and detailed information can be obtained by writing to the individual departments or checking their websites. The applications and supporting documents must normally be submitted to the school in the middle of the applicant's senior year. Decisions for admission are made in the spring of that year. The program typically begins in the summer or fall.

Which Graduate School to Choose

There are many opportunities for graduate school, and good students are actively recruited.

Most major universities offer programs leading to the Ph.D. in biochemistry or molecular biology. Some have separate departments of biochemistry, while others offer training in biochemistry in departments of chemistry, biology, molecular biology, microbiology or plant science. Graduate programs are also available at medical schools, even when those schools do not have undergraduate programs or a comprehensive array of graduate programs in other fields.



Many factors enter into a student's choice of graduate schools, including the presence of outstanding faculty in the subspecialty that the student finds interesting, the breadth of course and research experiences available, the reputation of the program, as well as personal considerations such as location. The faculty at your undergraduate institution should be able to give you information and advice. In addition, three of the most useful sources of information about graduate programs in biochemistry are the ASBMB web site (www.asbmb.org), Peterson's Annual Guides to Graduate Study Programs in Biological, Agricultural, and Health Sciences, and the American Chemical Society (ACS) Directory of Graduate Research.

Financial Aid

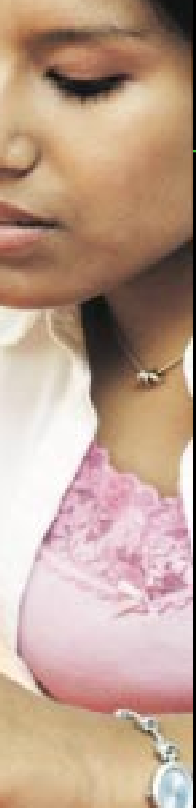
Most students in Ph.D. programs have all their education expenses covered, including tuition and fees, and receive a stipend for living expenses.

U.S. citizens studying for a Ph.D. can usually obtain teaching assistantships, where they assist the instructors of a course, help students, and correct homework and exams. A smaller number of students with outstanding academic records are supported by fellowships and research traineeships, for which the students are assigned to help with research. Ask the schools to which you are applying about their programs.

Post-doctoral Research

Even after earning the highest degree, a scientist never stops learning, especially in biochemistry and molecular biology, where the field is always changing with major advances in knowledge and frequent breakthroughs in technology.

Most Ph.Ds get further research experience doing post-doctoral research before they take permanent jobs. Such "post-docs" take no formal course work, earn no degree and usually do not teach. But they have an opportunity to work full-time on a high-level research project in the laboratory of an established scientist. Usually the scientist is at a different institution than the one where the student's Ph.D. work was completed. The typical post-doctoral period is 2-3 years. Post-doctoral researchers are generally paid a salary or supported by a fellowship. Post-doctoral research is not essential for many industrial research jobs, but it is generally expected of persons who wish to become professors. Because biochemistry is so closely tied to medicine, some Ph.D. scientists also earn a medical degree (and some M.Ds complete a Ph.D.) to get the broadest base possible for a career in medical research.



CAREERS IN BIOCHEMISTRY AND MOLECULAR BIOLOGY

Career prospects seem bright for someone trained in the molecular life sciences. Projections for the next 20 years indicate that there will be thousands of unfilled science and engineering jobs. A large fraction of the shortage will be in the fields of biochemistry and molecular biology.

The demand for highly trained workers and scholars will be great. Scientists are rushing to use their new techniques to unravel the secrets of life, to tap that knowledge to create valuable products, and to develop a new generation of sophisticated techniques that will unlock new knowledge.

The greater a person's education, the greater the potential for rewards.

Over the next 10 years it is estimated that 47% of those entering the work force will be women and 31% will be members of minority groups. We need some of these people to be educated as scientists to assume positions that will be available. The government has recognized these circumstances. Opportunities for women, members of minority groups and disabled persons are especially promising because the federal government, including the National Science Foundation and the National Institutes of Health, offers a variety of special programs designed to bring them into the field.

Community College Graduates

The demand for technicians with specialized (if limited) training in the field has prompted many community colleges to begin programs that teach students how to do routine laboratory work in hospital, commercial, public health, and biomedical research facilities. Technicians give researchers the time they need to develop new state-of-the-art techniques.

College Graduates

Someone with a bachelor degree in biochemistry or molecular biology can use it to go to medical, dental, veterinary, law or business school. Some use their training as a stepping stone to careers in biotechnology, toxicology, biomedical engineering, clinical chemistry, plant pathology, animal science or other fields. Some bachelor degree graduates enter the job market directly. Many employers have jobs that require their talents:

- Government agencies, such as the National Institutes of Health, the U.S. Food and Drug Administration, the Environmental Protection Agency, the U.S. Department of Agriculture, and individual states have laboratories that employ skilled personnel in basic research programs and in the analyses of samples of food, drugs, air, water, wastes, or animal tissue.

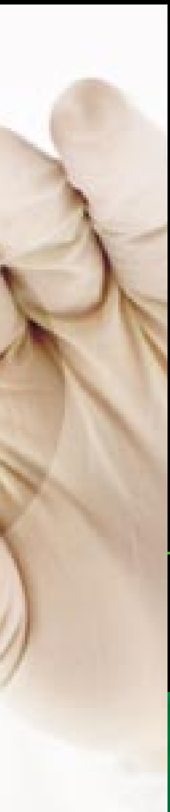
- Drug companies have basic research programs on the causes of disease and applied programs to develop drugs to combat disease.

- The FBI, state governments and private forensics laboratories require increasingly science oriented individuals in order to take advantage of the powerful tools of DNA fingerprinting and other molecular analyses.

- Biotechnology companies, which have interests in the environment, energy, human health care, agriculture and animal health, hire B.S. graduates for research, quality control, clinical research, manufacturing/production and information systems.

In addition, a bachelor degree graduate has knowledge that can be valuable in the fields of management, sales, marketing, regulatory affairs, technical writing, or scientific journalism.
With additional courses in the education field, someone with a molecular life science degree is ideally suited to teach science in elementary, junior high and high school. An enthusiastic teacher can help inspire the next generation of scientists to tackle challenges that still, by today's standards, seem insurmountable.

Master of Science (M.S.) Graduates



The education, research training, and skills acquired with a master's degree make M.S. recipients far more attractive as prospects for advancement, a higher salary, and more responsibility and independence. Some corporations favor M.S. graduates whose degree program has involved substantial research because they have proven problem-solving and technical experience. In addition to standard M.S. programs, new ones have recently arisen in the areas of biotechnology, bioinformatics, and computational biology. A relatively new area of interest is in students who have received an M.S. degree that does not involve a research component. These students have been exposed to substantial course work that emphasizes the theoretical concepts in molecular biology and biochemistry. Their employers in the biotechnology and pharmacology industries then provide the specific laboratory training they desire for their employees.

Other M.S. graduates specialize in an additional area such as law, business or journalism. They pursue careers that combine science with regulatory affairs, management or writing.

Doctorate (Ph.D.) Graduates

A Ph.D. degree is almost always required for a person who plans to direct research programs or be involved in state-of-the-art projects in the molecular life sciences. The degree is a requirement for becoming a professor in a college or university, or an executive in the science-related areas of government or industry.

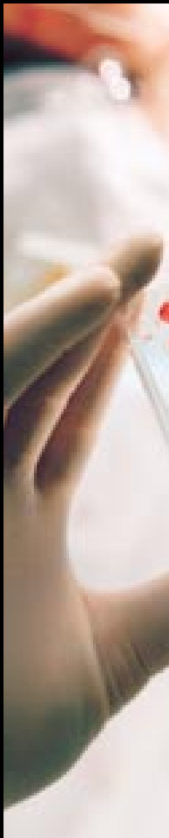
Only a limited number of people earn a Ph.D. in biochemistry or molecular biology, and the field has been growing so rapidly that students who pursue the doctoral degree, particularly minorities and women, can expect excellent job opportunities.

College and University Employment

Ph.D. scientists who enter the highest levels of academic life combine teaching and research. In addition to classroom and laboratory instruction, they do basic research designed to increase the knowledge of biochemistry and molecular biology. The research is usually supported by grants from the federal government, states, private foundations and industry.

Many Ph.D. graduates work at colleges and universities where the emphasis is on teaching. The work is important because these schools produce over 50 percent of the bachelors and 70 percent of the masters degrees in the molecular life sciences. The amount of research conducted at such an institution depends on its size and resources.

College and university jobs should be plentiful in the future. First, between 40 and 65 percent of the faculty members who specialize in the molecular life sciences will reach retirement age by the year 2010. Second, after the year 2010 there will be a steady increase in the number of college-age students, so schools may not just replace faculty but create more positions.



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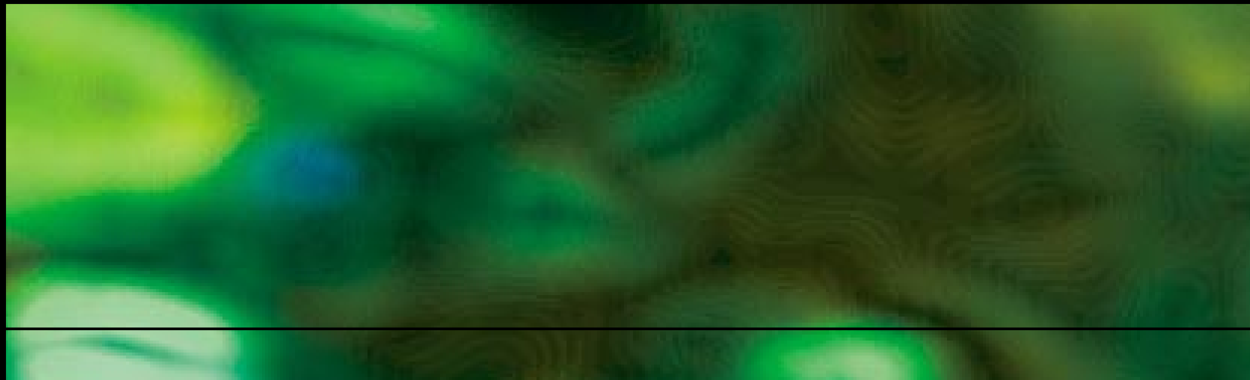
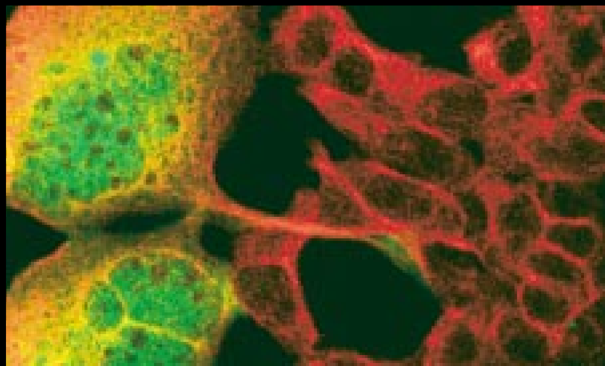




Industry and Government Employment

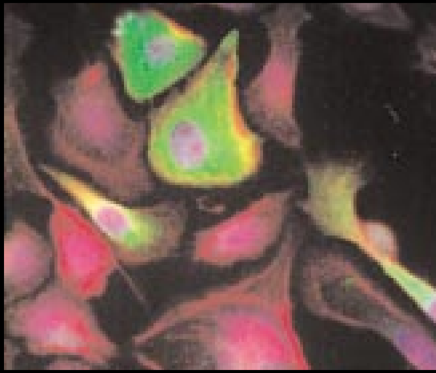
Industry and government laboratories hire Ph.D. scientists for basic research, or to work in research and development programs. The problems studied, research styles and types of organization vary widely from laboratory to laboratory. The Ph.D. scientist may lead a research group or be part of a small team of Ph.D. researchers.

Other Ph.D. scientists choose administrative positions. In government, for example, they lead programs that are concerned with the safety of new devices, food, drugs and pesticides or other chemicals, or they influence which projects the National Institutes of Health, the National Science Foundation, and the Department of Agriculture will support.

CAREERS IN THE BIOTECHNOLOGY INDUSTRY

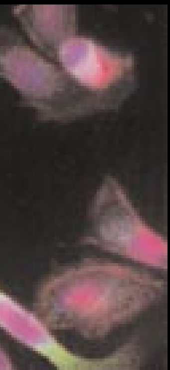
An especially interesting and important area for employment is biotechnology. Publicly- and privately-held corporations belonging to the biotechnology, medical device, pharmaceutical, biopharmaceutical, and agricultural biotechnology family of industries are commonly and collectively lumped together into the generic biotechnology industry. They share a dependency upon a cluster of exciting, new technologies flowing from biochemistry and the other molecular life sciences, chemistry, biology, applied physics, several engineering sectors, and applied mathematics/computational sciences.

While biotechnology is being applied in a number of market sectors, including agricultural biotechnology, genomics, proteomics, human diagnostics, medical devices, medical therapeutics, scientific equipment/supplies,



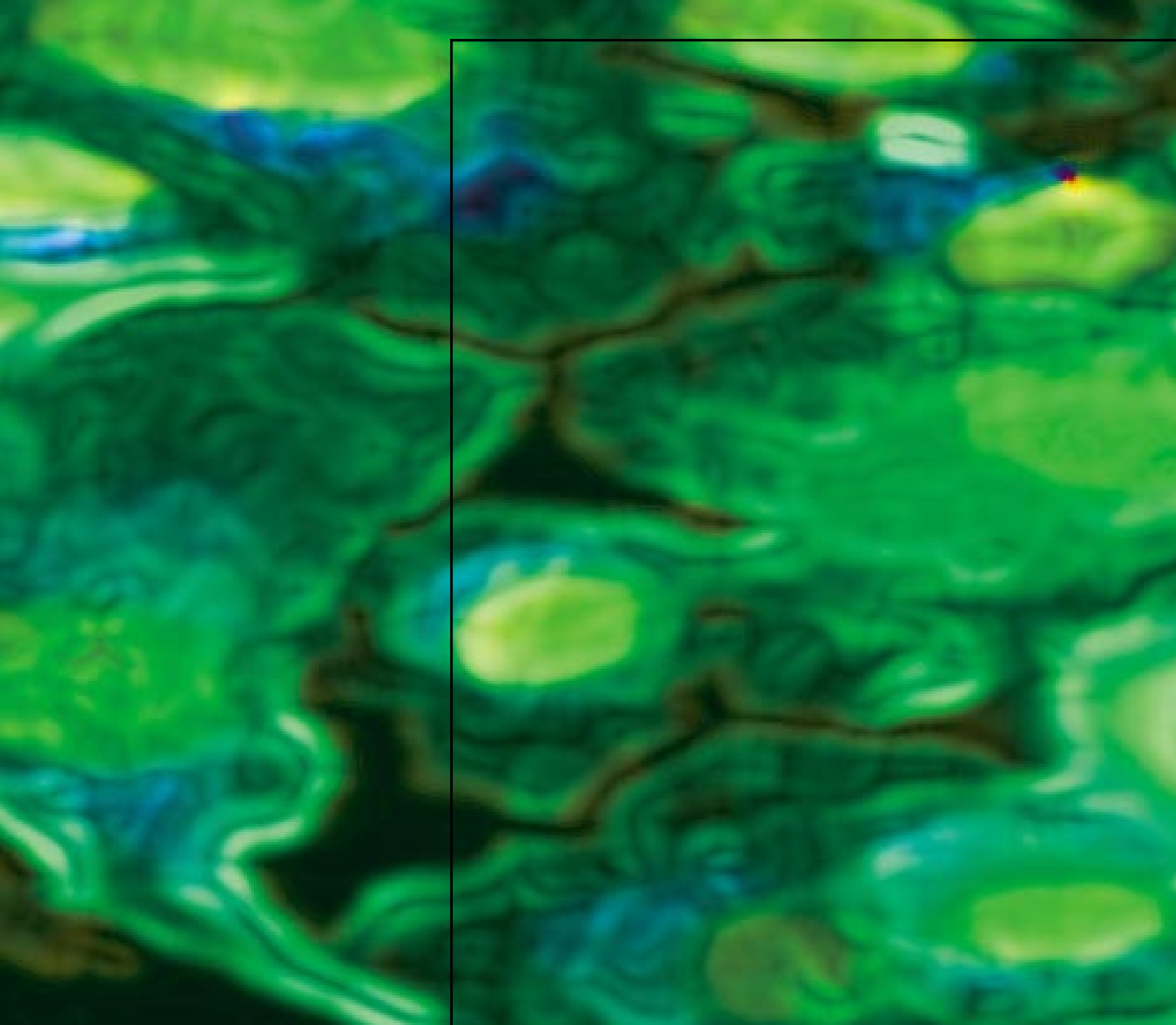
scientific services and other areas such as environmental protection and veterinary medical applications, the largest sector in the nation and in the world is the medical therapeutics sector, almost 90%.

The workforce of the U.S. biotechnology industry is in excess of 200,000, growing at 12-17% annually over the last five years, with conservative predictions of its doubling by 2012. The biotechnical workforce is estimated to be 19% Ph.D., 17% M.S., 50% B.S., and 14% combined vocational-education/community college trained. The biotechnology industry is in a state of dynamic flux and dramatic increases in the workforce are expected in phase with the new discovery research, applied research, and development research, associated with unanticipated new technologies and the human genome and human proteome initiatives, impacts that might accelerate the growth of the industry beyond 700,000 employees by 2015.



The biotechnology industry offers magnificent career opportunities for people trained in the molecular life sciences, with opportunities across the spectrum of all company activities, many or most of these exciting opportunities lying outside of the basic research laboratory. Industry leaders identify the most critical short-term and long-term industry workforce needs being in the applied sector (pertaining to those skill sets associated with the transition of companies from the discovery, basic research mode into applied research, development, commercialization and manufacturing.)

This is a most exciting time to be a biochemist/molecular biologist. This field offers a fantastic and well-compensated future for the next generation of molecular life science voyagers, for those daring to venture into the excitements and beauty of the unknown.



This brochure was prepared for publication by the Education and Professional Development Committee of the American Society for Biochemistry and Molecular Biology (ASBMB) in May 2004. For additional Information about careers in biochemistry and molecular biology or for additional copies of this brochure, please write to:

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