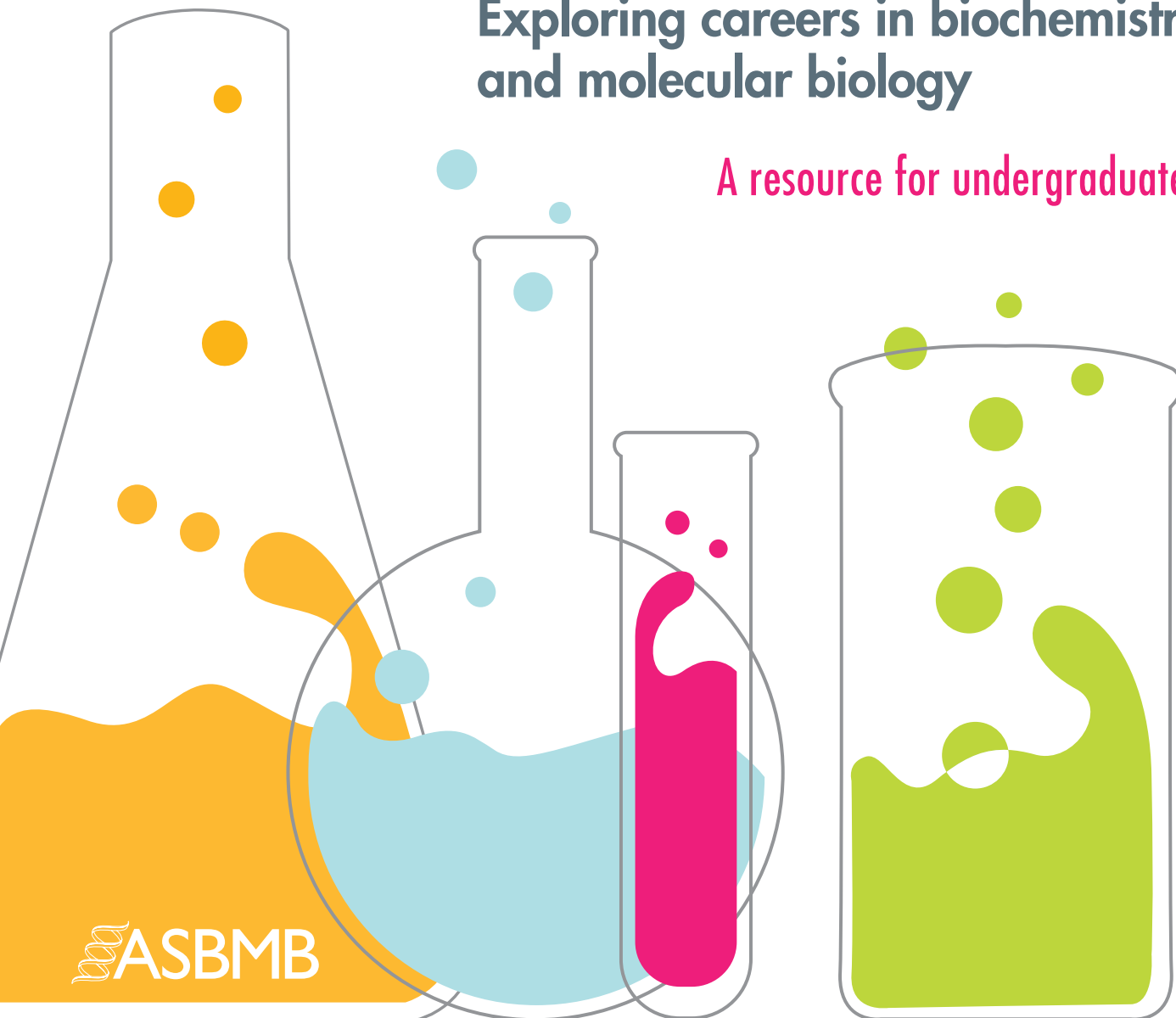


AMERICAN SOCIETY FOR BIOCHEMISTRY AND MOLECULAR BIOLOGY

Exploring careers in biochemistry and molecular biology

A resource for undergraduates



 ASBMB



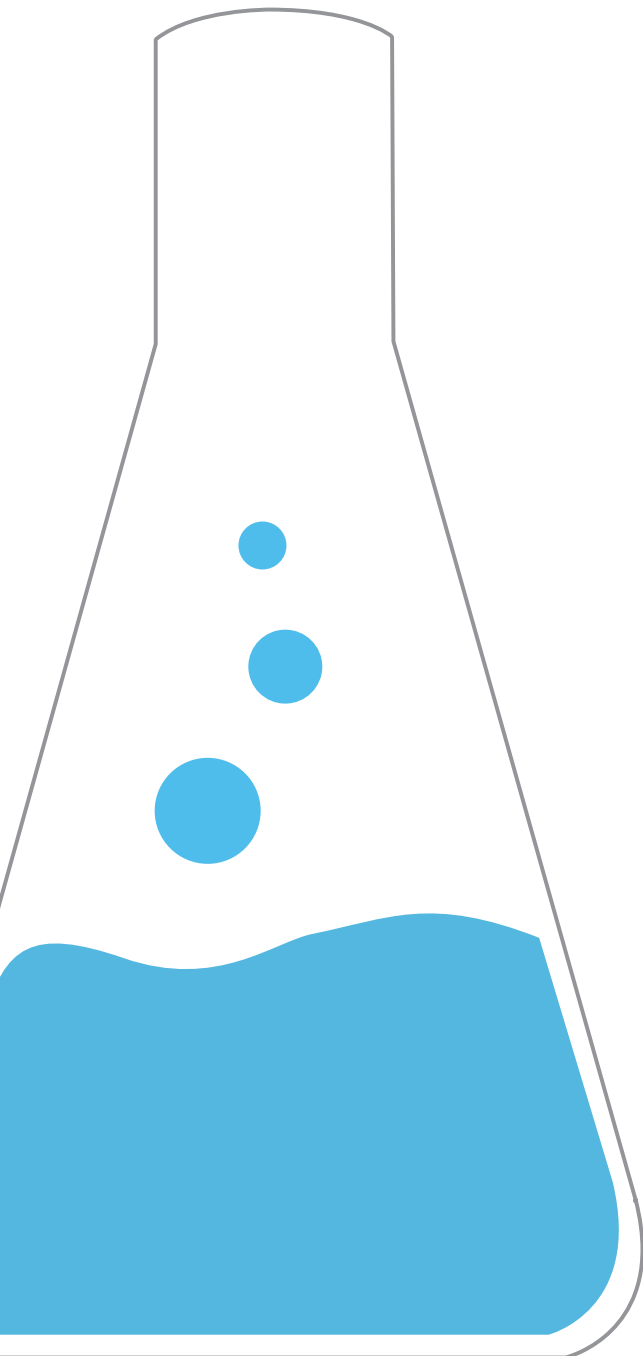


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INTRODUCTION

Why do living things age? Why do skin and blood cells continue growing and dividing throughout a human life while neurons do not? How can cancer cells multiply unrestricted?



Carol Greider, Ph.D., is a biochemist who has spent much of her life working on these questions. Carol grew up in California

and attended the University of California, Santa Barbara, where she majored in biology.¹ After college, Carol decided to pursue graduate studies at the University of California, Berkeley, where she earned her Ph.D. in molecular biology. When she was 24 years old, Carol discovered a protein that revolutionized the fields of biochemistry and molecular biology. She and her colleagues received the 2009 Nobel Prize in Physiology or Medicine for the discovery.

Let's take a closer look at Carol's finding. DNA and proteins are packaged into chromosomes in the

cell nucleus. Telomeres protect the chromosome ends from degradation but shorten each time a cell divides. When they reach a critical length, the cell stops dividing. Carol and her colleagues discovered the enzyme telomerase, which lengthens telomeres, allowing cells to continue dividing. This is especially important for continuously multiplying skin and blood cells. However, overactive telomerase can also contribute to cancerous cell growth. Today, biochemists and molecular biologists are working in cross-disciplinary teams to develop cancer treatments to block telomerase.

Carol's research, which she now conducts at Johns Hopkins University,² is only one of many exciting investigations in the field of biochemistry and molecular biology. Biochemists and molecular biologists work on diverse topics, including human health, agriculture and the environment. They work in research

labs, boardrooms, classrooms and even the White House. This diverse group seeks to better understand the processes that control living organisms and apply their discoveries to improve society.

As important as Carol's discovery was, there are many equally important discoveries waiting to be made: How do bacteria resist death after exposure to antibiotics? What goes wrong in the brains of Alzheimer's patients? How can we make crops more resistant to drought and disease?

You are part of the next generation of scientists who will answer these questions and any others you can imagine.



A DIVERSE FIELD

Biochemists and molecular biologists study life at every level, from individual molecules to ecosystems. Biochemistry is the study of chemical properties of biologically important molecules and of chemical reactions in living organisms. Molecular biology is the study of life at the molecular level, with a focus on understanding how genetic material leads to life. While these two disciplines developed separately, they are now very closely related with overlapping skill sets and career paths.

Biochemists and molecular biologists are interested in the structures and chemical functions of cellular components such as proteins, carbohydrates, lipids, nucleic acids and other biomolecules. They are also interested in interactions among the various systems of the cell, including the processes of DNA replication and transcription, protein translation and synthesis and their regulation.

By studying how the foundational life processes work, biochemists and molecular biologists are at the forefront in investigating how cells and organisms develop, live, die and interact with one another.

CAREERS IN BIOCHEMISTRY AND MOLECULAR BIOLOGY

As you explore the world of biochemistry and molecular biology, consider the diverse career paths open to scientists in this field. Many biochemists perform scientific research in university research labs, industrial labs and government labs. Other biochemists work outside the lab for companies, nonprofit organizations and the government. The following are excerpts from the ASBMB member magazine, *ASBMB Today*, which will help you gain a better understanding of the different careers open to biochemists and molecular biologists.



Career: academic scientist³

Name: Michael Snyder, Ph.D.

Undergraduate degree: B.A. in chemistry and biology from the University of Rochester

Graduate degree: Ph.D. in biology from the California Institute of Technology

Dr. Michael Snyder is the fifth of three boys and three girls and grew up in Pennsylvania dairy land. He credits his interest in science to his mother and a high school chemistry teacher. After applying to several undergraduate schools, the University of Rochester offered him a scholarship. "We didn't have a lot of money," says Mike, "so I went there."

After becoming a professor at Stanford University, Mike led a project that catapulted him into the headlines of science media outlets. Mike and his team gathered many types of biological data from one person (himself) to see what kinds of information could be obtained by integrating the statuses of thousands of molecules at once.

The project yielded results that couldn't be seen with standard clinical diagnostics.

For example, during the project, Mike's data began to display the telltale signs of diabetes, with which he was later diagnosed. The experiment now has Mike interested in studying people who are known as prediabetic. "We hope to learn what triggers this conversion and what the final disease profile looks like. We also want to learn why some people respond to some drugs and others do not," Mike says.

Mike's enthusiasm for science is unrestrained. "Every morning, I tell my kids, 'I'm going to fun!' They always tease me back and say, 'No, you're not. You're going to work!'" says Mike. But he truly means it when he calls work fun. "That's why I do science. I love it."
– Rajendrani Mukhopadhyay



Career: professor at a primarily undergraduate institution

Name: Takita Felder Sumter, Ph.D.

Undergraduate degree: B.S. in chemistry from the University of South Carolina

Graduate degree: Ph.D. in biochemistry from the University of South Carolina

Dr. Takita Sumter's interest in science started in seventh grade when she won the science fair. She said, "I was excited. I don't think I realized I was good at science." The experience encouraged Takita to take more science classes in high school, including chemistry, which she loved and chose as her undergraduate major.

Takita was initially interested in a career in the pharmaceutical industry and completed a postdoctoral fellowship in order to pursue that path after earning her Ph.D. However, after mentoring undergraduates in the lab, she realized she found teaching and working with younger scientists most enjoyable. Today, Takita leads a research team of undergraduates in studying transcription

factors, supporting her work with funding from the National Institutes of Health and the National Science Foundation. Takita also teaches several chemistry courses, including biochemistry, and works to improve biochemistry education across the U.S.

Takita recommends that undergraduates pursuing graduate education develop a general career plan before going to graduate school. She said, "If you know what inspires you from the beginning, it will keep you going when times feel more difficult than they should be." Although your plan may change over time, she said, "Getting the Ph.D. will open up so many opportunities that you may never have considered." – Erica Siebrasse

CAREERS IN BIOCHEMISTRY AND MOLECULAR BIOLOGY



Career: industry scientist ⁴

Name: Saurabh Sen, Ph.D.

Undergraduate degree: B.S. from the University of Calcutta

Graduate degrees: M.S. from the Indian Institute of Technology, Bombay, and Ph.D. from the University of Helsinki

Dr. Saurabh Sen harnessed his biochemistry training to build a successful career in industry. Saurabh was born and raised in India. After completing a Ph.D. in Finland, he went to the United States to complete postdoctoral research. In graduate school and during part of his postdoctoral training, Saurabh worked with G-protein-coupled receptors (GPCRs). "To transform a GPCR project into a success story is my dream. These receptors are the broadest target in the pharmaceutical industry. More than 50 percent of the currently available prescription drugs target GPCRs, making them the most sought-after drug class," said Saurabh.

His interest in GPCRs led him to Lucigen Corporation. Remarking about his feelings on working in industry, Saurabh said, "One of the things that I love best about working at Lucigen is the chance to participate in innovative and exploratory research projects, marketing efforts and business development. Being a small company, we are a well-built, cohesive family – all working together to do good science and deliver novel products to the scientific community." He continued, "Coming to work every morning with the challenge of discovering a novel solution for an unsolved scientific problem keeps me on my toes for the whole day." –*ASBMB Today* staff



Career: science policy expert ⁵

Name: David R. Wilson, Ph.D.

Undergraduate degree: B.S. in molecular and cellular biology from Arizona State University

Graduate degree: Ph.D. in molecular immunology from Arizona State University

Dr. David Wilson is director of American Indian Affairs & Policy for the Society for the non-profit Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS). He grew up in rural New Mexico, nestled in the Navajo Nation Reservation. While David's grades earned him a full ride to major in mechanical engineering, a summer spent chasing and researching butterflies hooked him on biology.

After earning his bachelor's degree, he worked at a startup company. David later applied to the Ph.D. program at Arizona State – and nowhere else. No one in his family had gone to graduate school, he explains, so he didn't know that he should apply to several schools. As a postdoctoral

fellow at the National Institutes of Health, David participated in a summer leadership institute offered by SACNAS. "My career came to a crossroads," he explains. "I was wondering whether it was more beneficial for me to be the lone Native American scientist doing elite research at the government or whether it was more important for me to help promote opportunities and share my experiences with upcoming Natives who were going through the same struggles."

He chose the latter, and today David regularly serves on federal and White House roundtables, weighing in on policy matters in the interest of scientists both young and old. David is living proof that skills and knowledge learned in the lab are transferrable. –Angela Hopp

CAREERS IN BIOCHEMISTRY AND MOLECULAR BIOLOGY



Career: astronaut ⁶

Name: Peggy A. Whitson, Ph.D.

Undergraduate degree: B.S. in biology and chemistry from Iowa Wesleyan College

Graduate degree: Ph.D. in biochemistry from Rice University

Dr. Peggy Whitson is one of very few U.S. astronauts with biochemistry or molecular biology backgrounds. She grew up in a small farming town in southern Iowa, and, like many others, she watched awestruck on July 21, 1969, as humans first walked on the moon. "I wanted to be an astronaut from a very young age," Peggy recalls. The January before Peggy graduated from high school, NASA selected the first female astronauts, including Shannon Lucid, a biochemist.

After finishing her Ph.D. in Houston, Peggy went to work at the nearby Johnson Space Center as a research biochemist. There,

she studied urine biochemistry, focusing on the increased risk of forming kidney stones during spaceflight. A potassium citrate therapy she developed is used today as an on-orbit countermeasure in those astronauts with a propensity to form kidney stones.

In 1996, after almost 10 years working at the space center, Peggy's chance came. She was selected as a member of NASA's 16th class of astronauts. Since then, she has been to space several times. Peggy says, "It was a blast for me, because I enjoy being the hands of different investigators and making their experiments work on orbit." –Mollie Rappe


These stories represent only a handful of career paths open to biochemists and molecular biologists. People in the field also have created life-saving vaccines, developed national ice cream companies and even directed Hollywood films. Other potential career paths are noted on the next page, but your career possibilities are limited only by your drive and imagination.

CAREERS



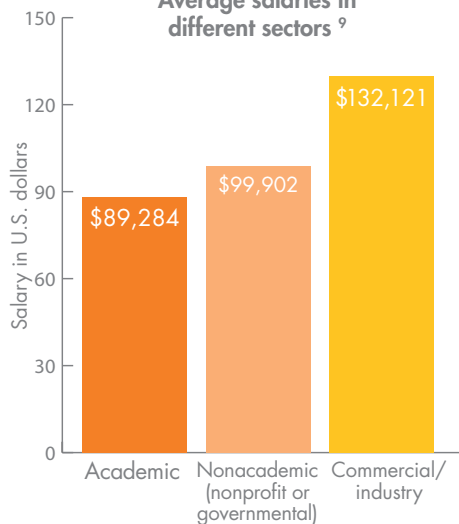
Agricultural scientist
Beer and wine maker
Bio-animator and filmmaker
Bioethicist
Bioinformatician
Biological and medical illustrator
Biomedical engineer
Biomedical researcher
Bioremediator
Biostatistician
Biotechnology researcher
Bioterrorism expert
Business administrator
Clinical researcher
Conservation biologist
Criminal investigator
Dentist
Dietician
Entrepreneur
Environmental attorney
Environmental scientist
Epidemiologist
Food safety expert
Forensic scientist
Genetic counselor
Government health official
Grant administrator

Grant writer
High school teacher
Marine biologist
Museum curator
Museum exhibit preparer
Nurse
Occupational therapist
Optometrist
Patent agent
Patent attorney
Pharmaceutical researcher
Pharmacist
Physical therapist
Physician
Physician's assistant
Professor
Public health administrator
Public information officer
Public outreach expert
Regulatory affairs expert
Sales and marketing professional
Science policy expert
Science reporter
Science writer/editor
Toxicologist
Veterinarian
Zookeeper

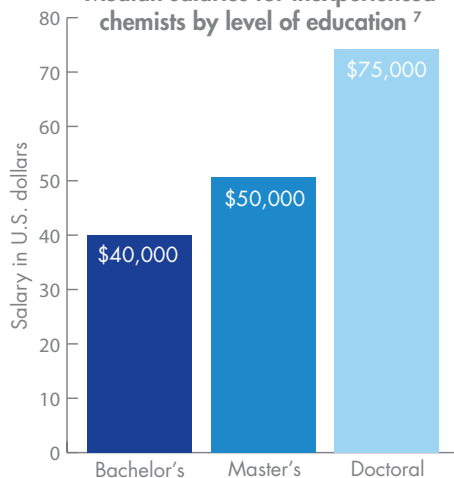


CAREER PROSPECTS

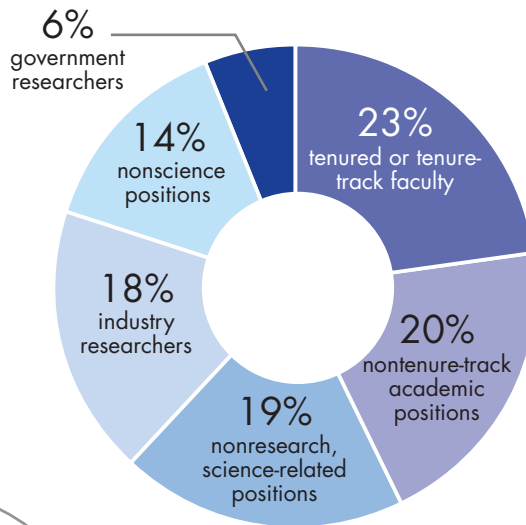
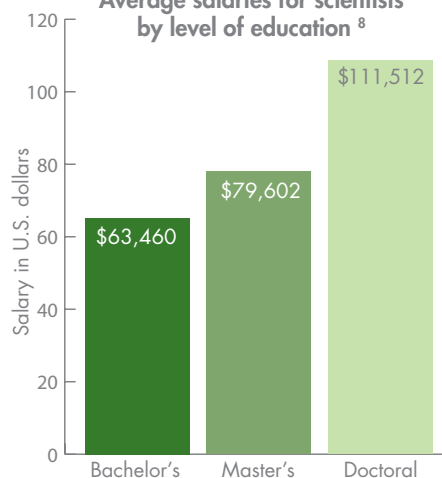
Average salaries in different sectors ⁹



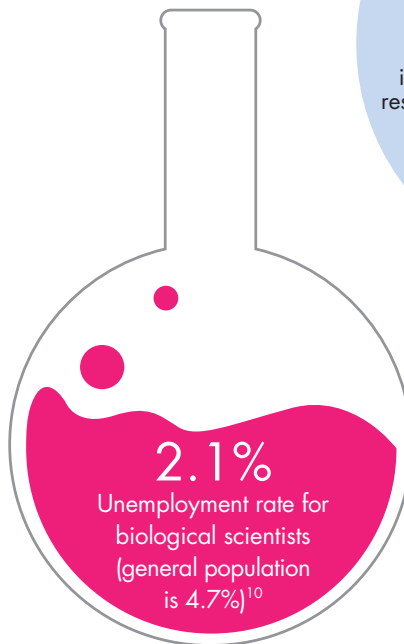
Median salaries for inexperienced chemists by level of education ⁷



Average salaries for scientists by level of education ⁸



Current employment of life science Ph.D.s. ¹¹



PREPARING FOR A CAREER IN BIOCHEMISTRY AND MOLECULAR BIOLOGY

The best way to prepare for a career in biochemistry and molecular biology is to earn a bachelor's degree. The checklist on the next page will help you navigate your undergraduate years, but it is important to seek out an experienced faculty member or career adviser at your institution and proactively chart a course specific to your career and personal goals.



UNDERGRADUATE TRAINING

Year 1

- Fall - Consult with a faculty adviser or career counselor who is familiar with careers in biochemistry and molecular biology to begin developing your personalized career plan.
- Fall – If you plan to transfer from a two-year institution to a four-year institution, begin planning early and ensure your credits will transfer.
- Complete introductory courses in biology, chemistry and math.
- Explore extracurricular science activities, such as the ASBMB Student Chapters program.¹² If a Student Chapter is not available on your campus, consider starting one.
- Begin looking for and applying to science-specific scholarships and awards.

Year 2

- Fall - Meet with your adviser to continue developing your career plan.

- Fall - Explore options for starting independent undergraduate research, either through an on-campus internship or at an external research institution. The ASBMB has a national database of research opportunities.¹³
- Spring - Decide on a major. Many institutions have interdisciplinary “biochemistry and molecular biology” majors. However, majors in chemistry or biology also can provide a solid foundation.
- Continue introductory courses from year one. Also consider completing physics coursework.
- Get involved in science-related extracurricular activities on your campus or in the local community.
- Apply for science-specific scholarships and awards.
- Consider doing internships, shadowing experiences and informational interviews to explore your career options. (see “Resources” section on page 18)
- If you will be transferring to a four-year institution in the fall, complete any necessary paperwork.



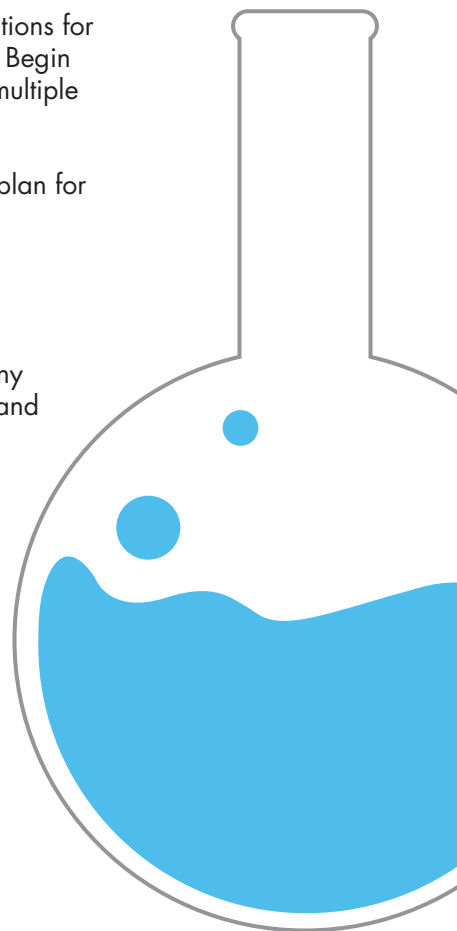
Year 3

- Fall - Meet with your faculty adviser to finalize your career plan.
- Fall - Begin or continue conducting independent undergraduate research. Discuss the possibility of attending a scientific meeting and presenting a poster with your research adviser. The ASBMB annual meeting has a poster competition exclusively for undergraduate research.¹⁴
- Begin taking advanced courses in biochemistry and molecular biology. Complete physics coursework if not already done.
- Complete internships, shadowing experiences and informational interviews as desired. (see “Resources” section on page 18)
- Decide if you will apply for graduate or professional school. If so, begin developing a competitive application packet. (see “Graduate training” section on page 14)
- Begin studying for the Graduate Record Exam (GRE) or other required standardized tests, depending on your career plans.

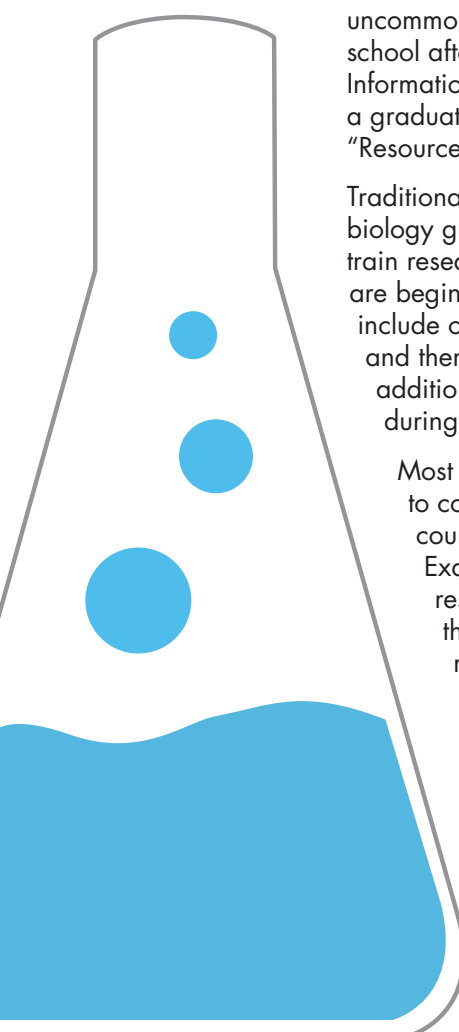
- Consider taking electives to strengthen writing and public speaking skills and learn general business skills.

Year 4

- Summer/fall – Complete applications for graduate or professional school. Begin early and solicit feedback from multiple advisers and/or mentors.
- Fall – Meet with your adviser to plan for your final year of college.
- Spring – Begin submitting job applications.
- Finish major requirements and any elective advanced biochemistry and molecular biology coursework.
- Complete your undergraduate research experience and present results at a local, regional or national scientific meeting.



GRADUATE TRAINING



Many biochemistry and molecular biology careers require an advanced (master's or doctoral) degree. However, it is not uncommon for scientists to enter graduate school after working for a few years. Information on how to apply to and choose a graduate program can be found in the "Resources" section on page 18.

Traditional biochemistry and molecular biology graduate programs are designed to train research scientists. However, programs are beginning to broaden their training to include other non-research science careers, and there are often opportunities to gain additional experience outside the lab during graduate school.

Most graduate schools require applicants to complete specific undergraduate courses, take the Graduate Record Exam (GRE) and have substantial research experience (usually more than one year). The coursework requirements are generally met through most biochemistry and molecular biology degree programs. While grades and test scores are important, applicants' research experiences and reference letters from their advisers are critical.

Master of Science (M.S.) degrees typically require one year of coursework and the completion of an independent research project. Most master's students receive their degrees after two years of full-time study. Students are typically required to pay tuition and fees for a master's degree.

In the life sciences, many students bypass master's programs and enter a Doctor of Philosophy (Ph.D.) program directly. Biochemistry and molecular biology Ph.D. students typically receive stipends and do not pay tuition or fees. The recommended stipend in 2016 was \$23,376, although many programs offer higher stipends.¹⁵ In addition, some programs may offer health insurance or other benefits.

The first year of many doctoral programs begins with students rotating through two to four research labs and completing advanced coursework in their disciplines of choice. At the end of the first year, students select their thesis research mentors and begin conducting research in their labs. Students continue their research and coursework during their second year. Coursework culminates with a special exam, often called a preliminary, qualification or qualifying exam. Some graduate programs also require students to serve as teaching assistants for one or more semesters.

POSTDOCTORAL TRAINING

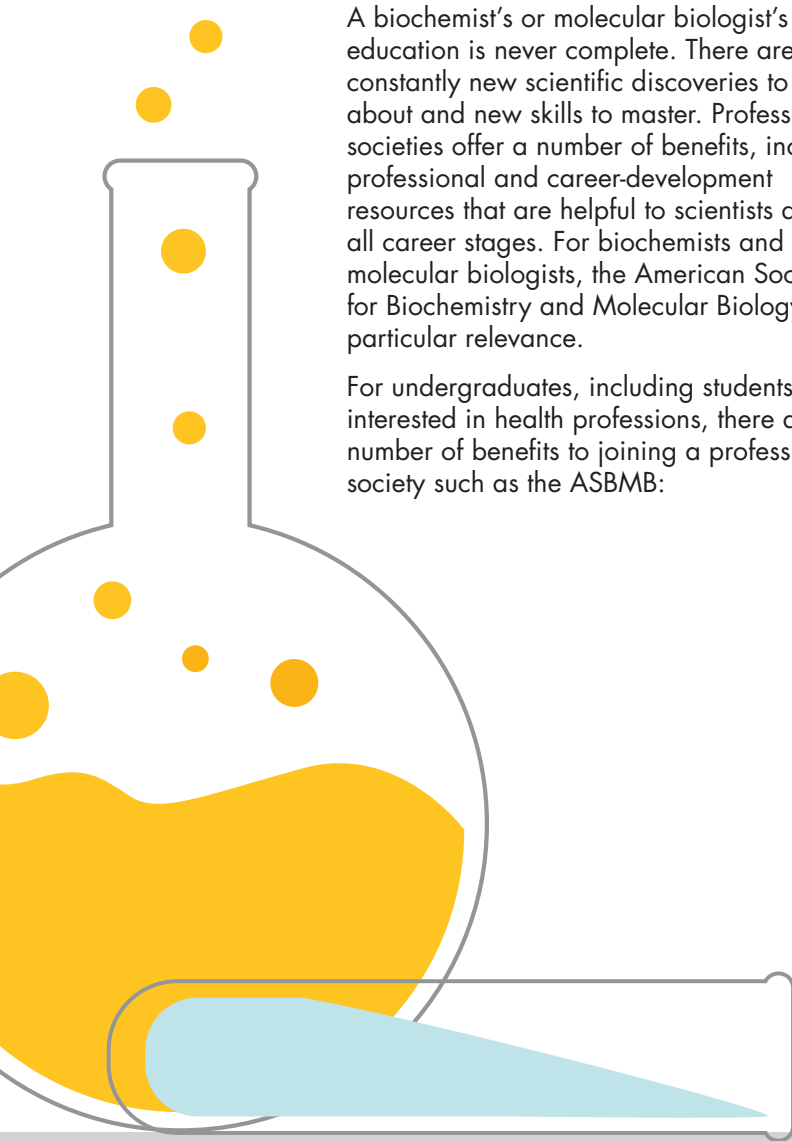
After the qualifying exam, students assemble their thesis committees, groups of experts in their fields, and propose their dissertation research. Over the next several years, students will continue their dissertation research, which culminates in written dissertations and oral defenses. A complete dissertation represents original research leading to significant new scientific information. The average time to completion of a biological sciences Ph.D. in the U.S. is 6.7 years.¹⁶

Some students choose to pursue professional studies such as medical, veterinary, law or dental degrees. In addition, joint programs, such as an M.D./Ph.D., are available. For more information on these paths, please see the "Resources" section on page 18.

After completing a Ph.D., 70% of graduates pursue postdoctoral training before they seek permanent jobs.¹⁷ Postdoctoral training typically is required when a scientist wishes to lead his or her own independent research lab at a university or in industry. This type of training does not lead to a formal degree and requires no coursework. Postdoctoral positions are full time, and the typical starting salary was \$47,484 per year in 2016.¹⁸ Postdoctoral positions vary in length; however, they are generally capped at five years at any one institution.



THE ROLE OF PROFESSIONAL SOCIETIES IN YOUR CAREER



A biochemist's or molecular biologist's education is never complete. There are constantly new scientific discoveries to learn about and new skills to master. Professional societies offer a number of benefits, including professional and career-development resources that are helpful to scientists at all career stages. For biochemists and molecular biologists, the American Society for Biochemistry and Molecular Biology is of particular relevance.

For undergraduates, including students interested in health professions, there are a number of benefits to joining a professional society such as the ASBMB:

Networking

As a member of the ASBMB, undergraduates are part of an organization of nearly 12,000 biochemists and molecular biologists. ASBMB meetings bring undergraduate scientists together with more experienced researchers. In addition, through the Student Chapters program,¹⁹ undergraduates meet other students interested in biochemistry and molecular biology careers.

Research internships and jobs

The ASBMB hosts an extensive job board and research internship database.²¹ In addition, the ASBMB Careers Blog²² profiles different biochemistry and molecular biology careers.

Scholarships and fellowships

The ASBMB funds numerous awards and scholarships for undergraduate students. There are also special awards available to fund undergraduates' travel to ASBMB meetings. While many of these awards are associated with the Student Chapters program,²³ others are available to all undergraduate members.²⁴ The ASBMB also maintains a list of external scholarships, fellowships and awards for biochemists and molecular biologists.²⁵

Publications

ASBMB members have access to the three scientific journals the society publishes and the member magazine, *ASBMB Today*. Undergraduates can write for the magazine or the undergraduate blog, *The Substrate*,²⁶ to gain valuable writing experience and to share their experiences with other scientists.

Recognition

The ASBMB administers the national biochemistry and molecular biology honor society, Chi Omega Lambda,²⁷ which recognizes outstanding undergraduate scientists.

As you complete your undergraduate studies and continue along your biochemistry and molecular biology career path, the ASBMB will continue to keep you informed about the latest news in biochemistry and molecular biology and provide you with outstanding career-development resources. Becoming a member of the society as an undergraduate will help you begin your path to a successful and exciting career. (see "Resources" section on page 18) The ASBMB looks forward to your contributions to the field.



RESOURCES

Becoming a member of the ASBMB

Membership is only \$10 for undergraduates.

www.asbmb.org/membertypes

ASBMB Student Chapters program for undergraduates

www.asbmb.org/studentchapters

Resources on the following topics are available at

www.asbmb.org/brochureresources

Careers in science

Becoming a graduate student

Finding a graduate program

Choosing a graduate program

Becoming a physician

Becoming a dentist

Becoming a veterinarian

Becoming a medical scientist (M.D./Ph.D.)

Conducting an informational interview

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- 2 www.greiderlab.org
- 3 www.asbmb.org/asbmbtoday/201207/features/Snyder
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- 5 www.asbmb.org/asbmbtoday/201203/minorityaffairs/Wilson
- 6 www.asbmb.org/asbmbtoday/201505/Features/Biochemist
- 7 <http://cen.acs.org/articles/94/i35/job-landscape-new-chemistry-graduates.html>
- 8 www.the-scientist.com/?articles.view/articleNo/44275/title/2015-Life-Sciences-Salary-Survey/
- 9 www.the-scientist.com/?articles.view/articleNo/47311/title/2016-Life-Sciences-Salary-Survey/
- 10 www.sciencemag.org/careers/2016/05/employment-crisis-new-phds-illusion
<https://data.bls.gov/timeseries/LNS14000000>
- 11 www.ascb.org/where-will-a-biology-phd-take-you
- 12 www.asbmb.org/education/studentchapters
- 13 www.asbmb.org/summerresearch
- 14 www.asbmb.org/meetings
- 15 <https://grants.nih.gov/grants/guide/notice-files/NOT-OD-16-062.html>
- 16 <https://www.nsf.gov/statistics/2016/nsb20161/#/report/chapter-2/graduate-education-enrollment-and-degrees-in-the-united-states>
- 17 www.ascb.org/where-will-a-biology-phd-take-you
- 18 <https://grants.nih.gov/grants/guide/notice-files/NOT-OD-17-003.html>
- 19 www.asbmb.org/education/studentchapters
- 20 www.asbmb.org/careers
- 21 www.asbmb.org/summerresearch
- 22 www.asbmb.org/Careers/Blog
- 23 www.asbmb.org/Education/StudentChapters/Awards
- 24 www.asbmb.org/MinorityAffairs/UndergraduateScholarship
- 25 www.asbmb.org/careers/researchandfellowships
- 26 www.substrate.asbmb.org
- 27 www.asbmb.org/education/honorsociety

For additional information about careers in biochemistry and molecular biology, visit the ASBMB website (www.asbmb.org). You also may contact the ASBMB education office at education@asbmb.org.

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American Society for Biochemistry and Molecular Biology



ABOUT THE AMERICAN SOCIETY FOR BIOCHEMISTRY AND MOLECULAR BIOLOGY

The American Society for Biochemistry and Molecular Biology (ASBMB) is a nonprofit scientific and educational organization with nearly 12,000 members.

Founded in 1906, the society is based in Rockville, Md. The society's purpose is to advance the science of biochemistry and molecular biology through publication of scientific journals; organization of scientific meetings; advocacy for funding of basic research and education; support of science education at all levels; and promotion of the diversity of individuals entering the scientific workforce.

