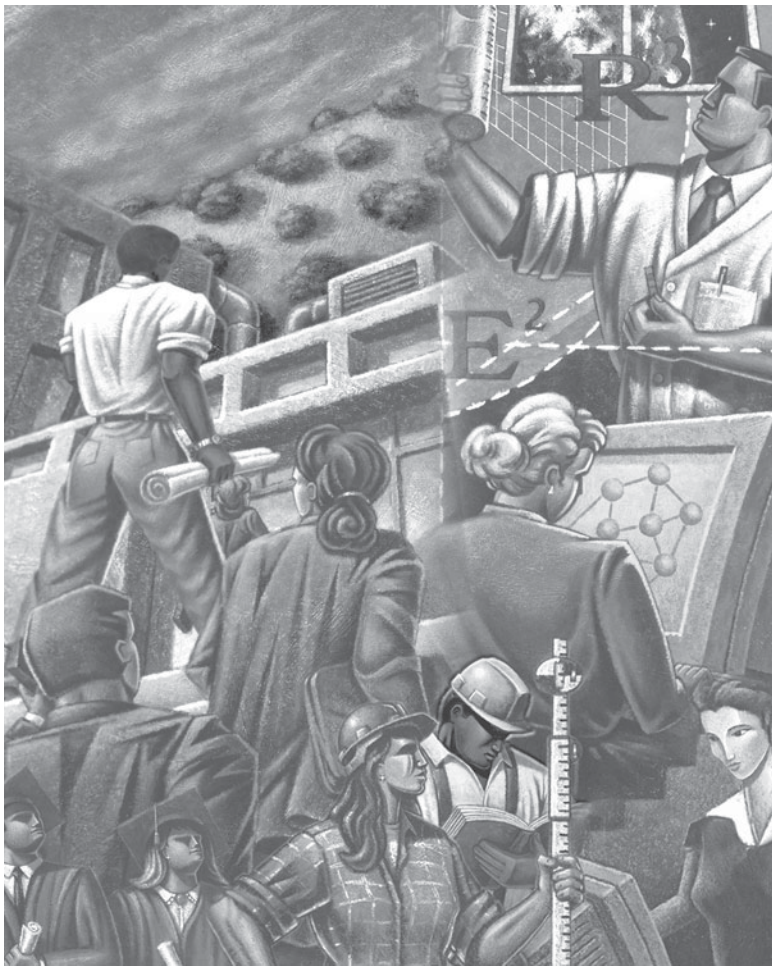
Engineers, Life and Physical Scientists, and Related Occupations

Reprinted from the
Occupational Oulook Handbook, 2004-05 Edition

U.S. Department of Labor
Bureau of Labor Statistics



Occupations Included in this Reprint

Agricultural and food scientists
Architects, except landscape and naval
Atmospheric scientists
Biological scientists
Chemists and materials scientists
Conservation scientists and foresters
Drafters
Engineering and natural sciences managers
Engineering technicians
Engineers
- Aerospace engineers
- Agricultural engineers
- Biomedical engineers
- Chemical engineers
- Civil engineers
- Computer hardware engineers
- Electrical and electronics engineers, except computer
- Environmental engineers
- Industrial engineers, including health and safety
- Materials engineers
- Mechanical engineers
- Mining and geological engineers, including mining safety engineers
- Nuclear engineers
- Petroleum engineers

Environmental scientists and geoscientists
Landscape architects
Medical scientists
Physicists and astronomers
Science technicians
Surveyors, cartographers, photogrammetrists, and surveying technicians

Agricultural and Food Scientists

(0*NET 19-1011.00, 19-1012.00, 19-1013.01, 19-1013.02)

Significant Points

- Almost 4 in 10 salaried agricultural and food scientists work for Federal, State, or local governments.
- A bachelor's degree in agricultural science is sufficient for some jobs in applied research; a master's or doctoral degree is required for basic research.
- Slower-than-average job growth is projected because of limited growth in the Federal Government and modest growth in State and local governments, the largest employers of these scientists.

Nature of the Work

The work of agricultural and food scientists plays an important part in maintaining the Nation's food supply by ensuring agricultural productivity and the safety of the food supply. Agricultural scientists study farm crops and animals, and develop ways of improving their quantity and quality. They look for ways to improve crop yield with less labor, control pests and weeds more safely and effectively, and conserve soil and water. They research methods of converting raw agricultural commodities into attractive and healthy food products for consumers.

Agricultural science is closely related to biological science, and agricultural scientists use the principles of biology, chemistry, physics, mathematics, and other sciences to solve problems in agriculture. They often work with biological scientists on basic biological research and on applying to agriculture the advances in knowledge brought about by biotechnology.

In the past two decades, rapid advances in basic biological knowledge related to genetics spurred growth in the field of biotechnology. Some agricultural and food scientists use this technology to manipulate the genetic material of plants and crops, attempting to make organisms more productive or resistant to disease. These advances in biotechnology have opened up research opportunities in many areas of agricultural and food science, including commercial applications in agriculture, environmental remediation, and the food industry.

Many agricultural scientists work in basic or applied research and development. Others manage or administer research and development programs, or manage marketing or production operations in companies that produce food products or agricultural chemicals, supplies, and machinery. Some agricultural scientists are consultants to business firms, private clients, or government.

Depending on the agricultural or food scientist's area of specialization, the nature of the work performed varies.

Food science. Food scientists and technologists usually work in the food processing industry, universities, or the Federal Government, and help to meet consumer demand for food products that are healthful, safe, palatable, and convenient. To do this, they use their knowledge of chemistry, physics, engineering, microbiology, biotechnology, and other sciences to develop new or better ways of preserving, processing, packaging, storing, and delivering foods. Some food scientists engage in basic research, discovering new food sources; analyzing food content to determine levels of vitamins, fat, sugar, or protein; or searching for substitutes for harmful or undesirable additives, such as nitrites. They also develop ways to process, preserve, package, or store food according to industry and government regulations. Traditional food processing research into functions involving baking, blanching, canning, drying, evaporation, and pasteurization will continue to be conducted and will find new applications. Other food scientists enforce government regulations, inspecting food processing areas and ensuring that sanitation, safety, quality, and waste management standards are met. Food technologists generally work in product development, applying the findings from food science research to the selection, preservation, processing, packaging, distribution, and use of safe, nutritious, and wholesome food.

Plant science. Agronomy, crop science, entomology, and plant breeding are included in plant science. Scientists in these disciplines study plants and their growth in soils, helping producers of food, feed, and fiber crops to continue to feed a growing population while conserving natural resources and maintaining the environment. Agronomists and crop scientists not only help increase productivity, but also study ways to improve the nutritional value of crops and the quality of seed, often through biotechnology. Some crop scientists study the breeding, physiology, and management of crops and use genetic engineering to develop crops resistant to pests and drought. Entomologists conduct research to develop new technologies to control or eliminate pests in infested areas and to prevent the spread of harmful pests to new areas, as well as technologies that are compatible with the environment. They also conduct re-

The work of agricultural and food scientists plays an important part in maintaining the Nation's food supply.

search or engage in oversight activities aimed at halting the spread of insect-borne disease.

Soil science. Soil scientists study the chemical, physical, biological, and mineralogical composition of soils as they relate to plant or crop growth. They also study the responses of various soil types to fertilizers, tillage practices, and crop rotation. Many soil scientists who work for the Federal Government conduct soil surveys, classifying and mapping soils. They provide information and recommendations to farmers and other landowners regarding the best use of land, plant growth, and methods to avoid or correct problems such as erosion. They may also consult with engineers and other technical personnel working on construction projects about the effects of, and solutions to, soil problems. Because soil science is closely related to environmental science, persons trained in soil science also apply their knowledge to ensure environmental quality and effective land use.

Animal science. Animal scientists work to develop better, more efficient ways of producing and processing meat, poultry, eggs, and milk. Dairy scientists, poultry scientists, animal breeders, and other scientists in related fields study the genetics, nutrition, reproduction, growth, and development of domestic farm animals. Some animal scientists inspect and grade livestock food products, purchase livestock, or work in technical sales or marketing. As extension agents or consultants, animal scientists advise agricultural producers on how to upgrade animal housing facilities properly, lower mortality rates, handle waste matter, or increase production of animal products, such as milk or eggs.

Working Conditions

Agricultural scientists involved in management or basic research tend to work regular hours in offices and laboratories. The work environment for those engaged in applied research or product development varies, depending on the discipline of agricultural science and on the type of employer. For example, food scientists in private industry may work in test kitchens while investigating new processing techniques. Animal scientists working for Federal, State, or university research stations may spend part of their time at dairies, farrowing houses, feedlots, or farm animal facilities or outdoors conducting research associated with livestock. Soil and crop scientists also spend time outdoors conducting research on farms and agricultural research stations. Entomologists work in laboratories, insectories, or agricultural research stations, and also may spend time outdoors studying or collecting insects in their natural habitat.

Employment

Agricultural and food scientists held about 18,000 jobs in 2002. In addition, several thousand persons held agricultural science faculty positions in colleges and universities. (See the statement on postsecondary teachers elsewhere in the *Handbook*.)

Almost 4 in 10 salaried agricultural and food scientists work for Federal, State, or local governments. One out of 6 worked for the Federal Government in 2002, mostly in the U.S. Department of Agriculture. Another 1 in 6 worked for State governments at State agricultural colleges or agricultural research stations. Some worked for agricultural service companies; others worked for commercial research and development laboratories, seed companies, pharmaceutical companies, wholesale distributors, and food products companies. Over 1,600 agricultural scientists were self-employed in 2002, mainly as consultants.

Training, Other Qualifications, and Advancement

Training requirements for agricultural scientists depend on their specialty and on the type of work they perform. A bachelor's degree in agricultural science is sufficient for some jobs in applied research or for assisting in basic research, but a master's or doctoral degree is required for basic research. A Ph.D. in agricultural science usually is needed for college teaching and for advancement to administrative research positions. Degrees in related sciences such as biology, chemistry, or physics or in related engineering specialties also may qualify persons for some agricultural science jobs.

All States have a land-grant college that offers agricultural science degrees. Many other colleges and universities also offer agricultural science degrees or some agricultural science courses. However, not every school offers all specialties. A typical undergraduate agricultural science curriculum includes communications, mathematics, economics, business, and physical and life sciences courses, in addition to a wide variety of technical agricultural science courses. For prospective animal scientists, these technical agricultural science courses might include animal breeding, reproductive physiology, nutrition, and meats and muscle biology. Graduate students typically specialize in a subfield of agricultural science, such as animal breeding and genetics, crop science, or horticulture science, depending on their interest and the kind of work they wish to do. For example, those interested in doing genetic and biotechnological research in the food industry need to develop a strong background in life and physical sciences, such as cell and molecular biology, microbiology, and inorganic and organic chemistry. However, students normally need not specialize at the undergraduate level. In fact, undergraduates who are broadly trained have greater flexibility when changing jobs than if they had narrowly defined their interests.

Students preparing as food scientists take courses such as food chemistry, food analysis, food microbiology, food engineering, and food processing operations. Those preparing as crop or soil scientists take courses in plant pathology, soil chemistry, entomology, plant physiology, and biochemistry, among others. Advanced degree programs include classroom and fieldwork, laboratory research, and a thesis or dissertation based on independent research.

Agricultural and food scientists should be able to work independently or as part of a team and be able to communicate clearly and concisely, both orally and in writing. Most of these scientists also need an understanding of basic business principles, and the ability to apply basic statistical techniques. Employers increasingly prefer job applicants who are able to apply computer skills to determine solutions to problems, to collect and analyze data, and to control various processes.

The American Society of Agronomy offers certification programs in crop science, agronomy, crop advising, soil science, plant pathology, and weed science. To become certified, applicants must pass designated examinations and have at least 2 years of experience with at least a bachelor's degree in agriculture or 4 years of experience with no degree. To become a certified crop advisor, however, candidates do not need a degree.

Agricultural scientists who have advanced degrees usually begin in research or teaching. With experience, they may advance to jobs such as supervisors of research programs or managers of other agriculture-related activities.

Job Outlook

Employment of agricultural and food scientists is expected to grow more slowly than the average for all occupations through 2012. This projection reflects limited growth in the Federal Government and modest growth in State and local governments. The need to replace agricultural and food scientists who retire or otherwise leave the occupation permanently will account for many more job openings than will projected growth.

Past agricultural research has resulted in the development of higher yielding crops, crops with better resistance to pests and plant pathogens, and chemically based fertilizers and pesticides. Research is still necessary, particularly as insects and diseases continue to adapt to pesticides and as soil fertility and water quality continue to need improvement, resulting in job opportunities in biotechnology. Agricultural scientists are using new avenues of research in biotechnology to develop plants and food crops that require less fertilizer, fewer pesticides and herbicides, and even less water for growth.

Biotechnological research, including studies and approaches relying on the tools of genomics, will continue to offer possibilities for the development of new food products. This research will allow agricultural and food scientists to develop techniques to detect and control food pathogens, and should lead to better understanding of other physiological responses of pathogens in food environments.

Agricultural scientists will be needed to balance increased agricultural output with protection and preservation of soil, water, and ecosystems. They will increasingly encourage the practice of "sustainable agriculture" by developing and implementing plans to manage pests, crops, soil fertility and erosion, and animal waste in ways that reduce the use of harmful chemicals and do little damage to the natural environment.

Further food research will result in more job opportunities for food scientists and technologists. This research will be stimulated by a heightened public focus on diet, health, and food safety, as well as domestic and global issues such as increasing world population, availability and cost of usable water, loss of arable land, deforestation, environmental pollution, and climate change.

Those with doctorates in agricultural and food science may face competition for jobs, due to an increase in the number of graduates and the limited numbers of research and teaching positions. Opportunities may be more numerous for those with a master's degree, particularly for graduates seeking basic research positions in a laboratory. Most of these positions, however, entail working under the guidance and direction of a Ph.D. scientist.

Graduates with a bachelor's degree should have opportunities, although not necessarily as an agricultural or food scientist. A bachelor's degree in agricultural science is useful for managerial jobs in businesses that deal with ranchers and farmers, such as feed, fertilizer, seed, and farm equipment manufacturers; retailers or wholesalers; and farm credit institutions. In some cases, persons with a 4-year degree can provide consulting services, or become a certified crop advisor, providing crop management recommendations to farmers to help them meet their objectives. Bachelor's degree holders also can work in some applied research and product development positions, but usually only in certain subfields, such as food science and technology, and the Federal Government hires bachelor's degree holders to work as soil scientists. Four-year degrees also may help persons enter occupations such as farmer, or farm or ranch manager; cooperative extension service agent; agricultural products inspector; or purchasing or sales agent for agricultural commodity or farm supply companies.

Employment of agricultural and food scientists is relatively stable during periods of economic recession. Layoffs are less likely among agricultural and food scientists than in some other occupations because food is a staple item and its demand fluctuates very little with economic activity.

Earnings

Median annual earnings of agricultural and food scientists were $48,670 in 2002. The middle 50 percent earned between $35,770 and $65,990. The lowest 10 percent earned less than $28,750, and the highest 10 percent earned more than $85,460.

The average Federal salary for employees in nonsupervisory, supervisory, and managerial positions in 2003 was $82,729 in animal science and $68,846 in agronomy.

According to the National Association of Colleges and Employers, beginning salary offers in 2003 for graduates with a bachelor's degree in animal sciences averaged $30,026 a year; plant sciences, $28,203 a year; and in other agricultural sciences, $29,971 a year.

Related Occupations

The work of agricultural scientists is closely related to that of other scientists, including biological scientists, chemists, and conservation scientists and foresters. It also is related to the work of managers of agricultural production, such as farmers, ranchers, and agricultural managers. Certain specialties of agricultural science also are related to other occupations. For example, the work of animal scientists is related to that of veterinarians, and horticulturists perform duties similar to those of landscape architects.

Sources of Additional Information

Information on careers in agricultural science is available from:

➤ American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711-1086. Internet: **http://www.agronomy.org**

➤ Food and Agricultural Careers for Tomorrow, Purdue University, 1140 Agricultural Administration Bldg., West Lafayette, IN 47907-1140.

For information on careers in food technology, write to:

➤ Institute of Food Technologists, Suite 300, 221 N. LaSalle St., Chicago IL 60601-1291. Internet: **http://www.ift.org**

Information on acquiring a job as an agricultural scientist with the Federal Government is available from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (703) 724-1850; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the Internet site **http://www.usajobs.opm.gov**.

Architects, Except Landscape and Naval

(0*NET 17-1011.00)

Significant Points

- More than 1 in 5 architects was self-employed—about three times the proportion for all professional and related occupations.
- Licensing requirements include a professional degree in architecture, a period of practical training, and passing all divisions of the Architect Registration Examination.
- Architecture graduates may face competition, especially for jobs in the most prestigious firms; opportunities will be best for those with experience working for a firm while still in school and for those with knowledge of computer-aided design and drafting technology.

Nature of the Work

People need places in which to live, work, play, learn, worship, meet, govern, shop, and eat. These places may be private or public; indoors or outdoors; or rooms, buildings, or complexes; and together, they make up neighborhoods, towns, suburbs, and cities. *Architects*—licensed professionals trained in the art and science of building design—transform these needs into concepts and then develop the concepts into images and plans of buildings that can be constructed by others.

Architects design the overall aesthetic and look of buildings and other structures, but the design of a building involves far more than its appearance. Buildings also must be functional, safe, and economical and must suit the needs of the people who use them. Architects consider all these factors when they design buildings and other structures.

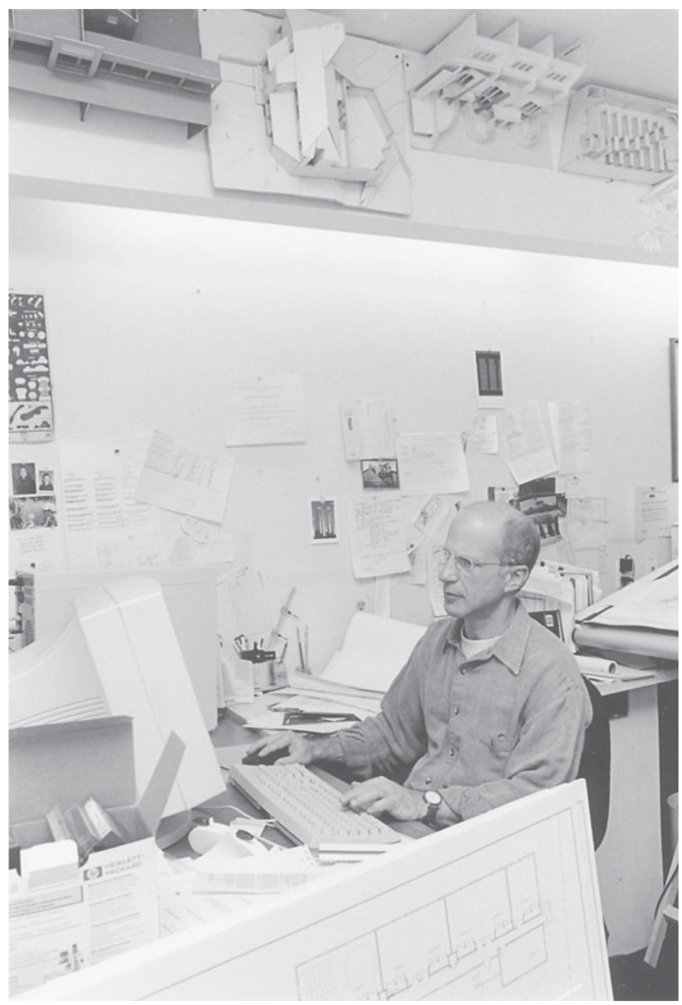
Architects provide professional services to individuals and organizations planning a construction project. They may be involved in all phases of development, from the initial discussion with the client through the entire construction process. Their duties require specific skills—designing, engineering, managing, supervising, and communicating with clients and builders. Architects spend a great deal of time explaining their ideas to clients, construction contractors, and others. Successful architects must be able to communicate their unique vision persuasively.

The architect and client discuss the objectives, requirements, and budget of a project. In some cases, architects provide various predesign services—conducting feasibility and environmental impact studies, selecting a site, or specifying the requirements the design must meet. For example, they may determine space requirements by researching the numbers and types of potential users of a building. The architect then prepares drawings and a report presenting ideas for the client to review.

After discussing and agreeing on the initial proposal, architects develop final construction plans that show the building's appearance and details for its construction. Accompanying these plans are drawings of the structural system; air-conditioning, heating, and ventilating systems; electrical systems; communications systems; plumbing; and, possibly, site and landscape plans. The plans also specify the building materials and, in some cases, the interior furnishings. In developing designs, architects follow building codes, zoning laws, fire regulations, and other ordinances, such as those requiring easy access by disabled persons. Throughout the planning stage, they make necessary changes. Although they have traditionally used pencil and paper to produce design and construction drawings, architects are increasingly turning to computer-aided design and drafting (CADD) technology for these important tasks. Continual revision of plans on the basis of client needs and budget constraints is often necessary.

Architects may also assist clients in obtaining construction bids, selecting contractors, and negotiating construction contracts. As construction proceeds, they may visit building sites to make sure that contractors follow the design, adhere to the schedule, use the specified materials, and meet work quality standards. The job is not complete until all construction is finished, required tests are conducted, and construction costs are paid. Sometimes, architects also provide postconstruction services, such as facilities management. They advise on energy efficiency measures, evaluate how well the building design adapts to the needs of occupants, and make necessary improvements.

Architects design a wide variety of buildings, such as office and apartment buildings, schools, churches, factories, hospitals, houses, and airport terminals. They also design complexes such as urban centers, college campuses, industrial parks, and



Architects update plans after receiving feedback from other professionals.

entire communities. In addition, they may advise on the selection of building sites, prepare cost analysis and land-use studies, and do long-range planning for land development.

Architects sometimes specialize in one phase of work. Some specialize in the design of one type of building—for example, hospitals, schools, or housing. Others focus on planning and predesign services or construction management and do minimal design work. They often work with engineers, urban planners, interior designers, landscape architects, and other professionals. In fact, architects spend a great deal of their time coordinating information from, and the work of, others engaged in the same project. Many architects—particularly at larger firms—use the Internet and e-mail to update designs and communicate changes efficiently. Architects also use the Internet to research product specifications and government regulations.

During the required training period leading up to licensing as architects, entry-level workers are called interns. This training period, which generally lasts 3 years, gives them practical work experience in preparation for the Architect Registration Examination (ARE). Typical duties may include preparing construction drawings on CADD, building models, or assisting in the design of one part of a project.

Working Conditions

Architects usually work in a comfortable environment. Most of their time is spent in offices consulting with clients, developing reports and drawings, and working with other architects and engineers. However, they often visit construction sites to review the progress of projects.

Architects may occasionally be under stress, working nights and weekends to meet deadlines. In 2002, more than half of all full-time architects worked more than 40 hours a week.

Employment

Architects held about 113,000 jobs in 2002. Almost 2 out of 3 jobs were in architectural, engineering, and related services—mostly in architectural firms with fewer than five workers. A small number worked for residential and nonresidential building construction firms and for government agencies responsible for housing, planning, or community development, such as the U.S. Departments of Defense and Interior, and the General Services Administration. About 1 in 5 architects was self-employed.

Training, Other Qualifications, and Advancement

All States and the District of Columbia require individuals to be licensed (registered) before they may call themselves architects or contract to provide architectural services. Nevertheless, many architecture school graduates work in the field while they are in the process of becoming licensed. However, a licensed architect is required to take legal responsibility for all work. Licensing requirements include a professional degree in architecture, a period of practical training or internship, and passage of all divisions of the ARE.

In most States, the professional degree in architecture must be from one of the 113 schools of architecture that have degree programs accredited by the National Architectural Accrediting Board (NAAB). However, State architectural registration boards set their own standards, so graduation from a non-NAAB-accredited program may meet the educational requirement for licensing in a few States. Three types of professional degrees in architecture are available through colleges and universities. The majority of all architectural degrees are from 5-year Bachelor of Architecture programs, intended for students entering university-level studies from high school or with no previous architectural training. In addition, a number of schools offer a 2-year Master of Architecture program for students with a preprofessional undergraduate degree in architecture or a related area, or a 3- or 4-year Master of Architecture program for students with a degree in another discipline.

The choice of degree depends upon each individual's preference and educational background. Prospective architecture students should consider the available options before committing to a program. For example, although the 5-year Bachelor of Architecture program offers the fastest route to the professional degree, courses are specialized, and if the student does not complete the program, transferring to program offered by another discipline may be difficult. A typical program includes courses in architectural history and theory, building design, structures, technology, construction methods, professional practice, math, physical sciences, and liberal arts. Central to most architectural programs is the design studio, where students put into practice the skills and concepts learned in the classroom. During the final semester of many programs, students devote their studio time to creating an architectural project from beginning to end, culminating in a three-dimensional model of their design.

Many schools of architecture also offer postprofessional degrees for those who already have a bachelor's or master's degree in architecture or other areas. Although graduate education beyond the professional degree is not required for practicing architects, it may be for research, teaching, and certain specialties.

High school students interested in a career in architecture should take courses in English, history, art, social studies, mathematics, physics, and computer science. Students should also visit the design studio of a school of architecture or tour the offices of a local firm. In addition, many schools of architecture offer summer programs for high school students.

Architects must be able to communicate their ideas visually to their clients. Artistic and drawing ability is helpful, but not essential, to such communication. More important are a visual orientation and the ability to conceptualize and understand spatial relationships. Good communication skills, the ability to work independently or as part of a team, and creativity are important qualities for anyone interested in becoming an architect. Computer literacy also is required for writing specifications, for two- and three-dimensional drafting, and for financial management. Knowledge of CADD is helpful and will become essential as architectural firms continue to adopt that technology. Recently, the profession recognized National CAD Standards (NCS); architecture students who master NCS may have an advantage in the job market.

All State architectural registration boards require a training period before candidates may sit for the ARE and become licensed. Most States have adopted the training standards established by the Intern Development Program, a branch of the American Institute of Architects and the National Council of Architectural Registration Boards (NCARB). These standards stipulate broad and diversified training under the supervision of a licensed architect over a 3-year period. New graduates usually begin as interns in architectural firms, where they assist in preparing architectural documents or drawings. Some States allow some of the training to occur in the offices of related professionals, such as engineers or general contractors. Architecture students who complete internships in architectural firms while still in school can count some of that time toward the required 3-year training period.

Interns may research building codes and materials or write specifications for building materials, installation criteria, the quality of finishes, and other, related details. After completing the on-the-job training period, interns are eligible to sit for the ARE. The examination tests candidates' knowledge, skills, and ability to provide the various services required in the design and construction of buildings. Nine critical areas are covered. Candidates who pass the ARE and meet all standards established by their State board are licensed to practice in that State.

Several States require continuing education to maintain a license, and many more States are expected to adopt mandatory continuing education. Requirements vary by State, but usually involve the completion of a certain number of credits every year or two through seminars, workshops, formal university classes, conferences, self-study courses, or other sources.

A growing number of architects voluntarily seek certification by the NCARB, which can facilitate an individual's becoming licensed to practice in additional States. Certification is awarded after independent verification of the candidate's educational transcripts, employment record, and professional references. Certification is the primary requirement for reciprocity of licensing among State Boards that are NCARB members.

After becoming licensed and gaining experience, architects take on increasingly responsible duties, eventually managing entire projects. In large firms, architects may advance to supervisory or managerial positions. Some architects become partners in established firms; others set up their own practices. Graduates with degrees in architecture also enter related fields, such as graphic, interior, or industrial design; urban planning; real estate development; civil engineering; and construction management.

Job Outlook

Prospective architects may face competition for entry-level positions, especially if the number of architectural degrees awarded remains at current levels or increases. Employment of architects is projected to grow about as fast as the average for all occupations through 2012, and additional job openings will stem from the need to replace architects who retire, transfer to new occupations, or leave the labor force permanently for other reasons. However, many individuals are attracted to this occupation, and the number of applicants often exceeds the number of available jobs, especially in the most prestigious firms. Prospective architects who gain career-related experience in an architectural firm while they are still in school and who know CADD technology—especially that which conforms to the new national standards—will have a distinct advantage in obtaining an intern position after graduation.

Employment of architects is strongly tied to the level of local construction, particularly nonresidential structures such as office buildings, shopping centers, schools, and healthcare facilities. Employment in nonresidential construction is expected to grow because the replacement and renovation of many industrial plants and buildings has been delayed for years and a large number of structures will have to be replaced or remodeled, particularly in urban areas where space for new buildings is becoming limited. On the other hand, technology enhancements will dampen demand for new commercial construction as nontraditional work and retail environments, such as teleconferencing, home offices, telecommuting, and electronic shopping, proliferate.

Demographic trends and changes in healthcare delivery will influence the demand for certain institutional structures and should also provide more jobs for architects in the future. A growing and aging population will drive demand for the construction of adult daycare, assisted-living, and other outpatient facilities, all of which are preferable, less costly alternatives to hospitals and nursing homes. Similarly, the construction of schools will increase to accommodate growth in the school-aged population. Additions to existing schools (especially colleges and universities), as well as overall modernization, will continue to add to demand for architects through 2012.

Demand for residential construction is also expected to continue to grow. As the baby boomers reach their peak earning years and can afford to spend more on housing, demand for larger homes with more amenities, as well as for second homes, will continue to rise. Some older, more affluent, members of the baby-boom generation will want townhouses and condominiums in conveniently located suburban and urban settings. At the same time, as the "echo boomers" (the children of the baby boomers) start to augment the younger age groups, the demand for starter homes and rental apartments also should increase.

Growth in demand for new-home construction will be tempered by consumers' preference to perform home improvements and renovations—especially in attractive, established neighborhoods—rather than construct new homes. Many starter homes will be remodeled to appeal to more affluent, space- and amenity-hungry buyers. Also, as buyers trade up, some may prefer to remodel existing homes, rather than construct new homes.

Because construction—particularly office and retail construction—is sensitive to cyclical changes in the economy, architects will face especially strong competition for jobs or clients during recessions, and layoffs may ensue. Those involved in the design of institutional buildings, such as schools, hospitals, nursing homes, and correctional facilities, will be less affected by fluctuations in the economy.

Even in times of overall good job opportunities, however, there may be areas of the country with poor opportunities. Architects who are licensed to practice in one State must meet the licensing requirements of other States before practicing elsewhere. Obtaining licensure in other States, after initially receiving licensure in one State, is known as "reciprocity" and is much easier if an architect has received certification from the NCARB.

Earnings

Median annual earnings of wage and salary architects were $56,620 in 2002. The middle 50 percent earned between $44,030 and $74,460. The lowest 10 percent earned less than $36,280, and the highest 10 percent earned more than $92,350.

Earnings of partners in established architectural firms may fluctuate because of changing business conditions. Some architects may have difficulty establishing their own practices and may go through a period when their expenses are greater than their income, requiring substantial financial resources.

Related Occupations

Architects design buildings and related structures. Construction managers, like architects, also plan and coordinate activities concerned with the construction and maintenance of buildings and facilities. Others who engage in similar work are landscape architects, civil engineers, urban and regional planners, and designers, including interior designers, commercial and industrial designers, and graphic designers.

Sources of Additional Information

Information about education and careers in architecture can be obtained from:

➤ The American Institute of Architects, 1735 New York Ave. NW., Washington, DC 20006. Internet: **http://www.aia.org**

➤ Intern Development Program, National Council of Architectural Registration Boards, Suite 1100K, 1801 K Street NW., Washington, D.C. 20006-1310. Internet: **http://www.ncarb.org**

Atmospheric Scientists

(0*NET 19-2021.00)

Significant Points

- Almost 4 in 10 atmospheric scientists work for the Federal Government, which is the largest employer of such workers.
- A bachelor's degree in meteorology, or in a closely related field with courses in meteorology, is the minimum educational requirement; a master's degree is necessary for some positions, and a Ph.D. is required for most research positions.

Nature of the Work

Atmospheric science is the study of the atmosphere—the blanket of air covering the Earth. *Atmospheric scientists*, commonly called *meteorologists*, study the atmosphere's physical characteristics, motions, and processes, and the way in which it affects the rest of our environment. The best known application of this knowledge is in forecasting the weather. Aside from predicting the weather, scientists also attempt to identify and interpret climate trends, understand past weather, and analyze today's weather. However, weather information and meteorological research also are applied in air-pollution control, agriculture, forestry, air and sea transportation, defense, and the study of possible trends in the Earth's climate, such as global warming, droughts, or ozone depletion.

Atmospheric scientists who forecast the weather, known professionally as *operational meteorologists*, are the largest group of specialists. They study information on air pressure, temperature, humidity, and wind velocity; and apply physical and mathematical relationships to make short-range and long-range weather forecasts. Their data come from weather satellites, weather radars, sensors, and weather stations in many parts of the world. Meteorologists use sophisticated computer models of the world's atmosphere to make long-term, short-term, and local-area forecasts. More accurate instruments for measuring and observing weather conditions, as well as high-speed computers to process and analyze weather data, have revolutionized weather forecasting. Using satellite data, climate theory, and sophisticated computer models of the world's atmosphere, meteorologists can more effectively interpret the results of these models to make local-area weather predictions. These forecasts inform not only the general public, but also those who need accurate weather information for both economic and safety reasons, such as the shipping, air transportation, agriculture, fishing, forestry, and utilities industries.

The use of weather balloons, launched a few times a day to measure wind, temperature, and humidity in the upper atmosphere, is currently supplemented by sophisticated atmospheric monitoring equipment that transmits data as frequently as every few minutes. Doppler radar, for example, can detect airflow patterns in violent storm systems—allowing forecasters to better predict tornadoes and other hazardous winds, and to monitor the storms' direction and intensity. Combined radar and satellite observations allow meteorologists to predict flash floods.

Some atmospheric scientists work in research. *Physical meteorologists*, for example, study the atmosphere's chemical and physical properties; the transmission of light, sound, and radio waves; and the transfer of energy in the atmosphere. They also study factors affecting the formation of clouds, rain, and snow; the dispersal of air pollutants over urban areas; and other weather phenomena, such as the mechanics of severe storms. *Synoptic meteorologists* develop new tools for weather forecasting using computers and sophisticated mathematical models of atmospheric activity. *Climatologists* study climactic variations spanning hundreds or even millions of years. They also may collect, analyze, and interpret past records of wind, rainfall, sunshine, and temperature in specific areas or regions. Their studies are used to design buildings, plan heating and cooling systems, and aid in effective land use and agricultural production. Environmental problems, such as pollution and shortages of fresh water, have widened the scope of the meteorological profession. *Environmental meteorologists* study these problems and may evaluate and report on air quality for environmental impact statements. Other research meteorologists examine the most effective ways to control or diminish air pollution.

Working Conditions

Most weather stations operate around the clock, 7 days a week. Jobs in such facilities usually involve night, weekend, and holiday work, often with rotating shifts. During weather emergencies, such as hurricanes, operational meteorologists may work overtime. Operational meteorologists also are often under pressure to meet forecast deadlines. Weather stations are found everywhere—at airports, in or near cities, and in isolated and remote areas. Some atmospheric scientists also spend time observing weather conditions and collecting data from aircraft. Weather forecasters who work for radio or television stations broadcast their reports from station studios, and may work evenings and weekends. Meteorologists in smaller weather offices often work alone; in larger ones, they work as part of a team. Meteorologists not involved in forecasting tasks work regular hours, usually in offices. Those who work for private consulting firms or for companies analyzing and monitoring emissions to improve air quality usually work with other scientists or engineers; fieldwork and travel may be common for these workers.

Employment

Atmospheric scientists held about 7,700 jobs in 2002. The Federal Government was the largest single employer of civilian meteorologists, accounting for about 2,900. The National Oceanic and Atmospheric Administration (NOAA) employed most Federal meteorologists in National Weather Service stations

Atmospheric scientists utilize sophisticated instruments and high-speed computers to predict weather and identify climate trends.

throughout the Nation; the remainder of NOAA's meteorologists worked mainly in research and development or management. The U.S. Department of Defense employed several hundred civilian meteorologists. Others worked for professional, scientific, and technical services firms, including private weather consulting services; radio and television broadcasting; air carriers; and State government.

Although several hundred people teach atmospheric science and related courses in college and university departments of meteorology or atmospheric science, physics, earth science, or geophysics, these individuals are classified as college or university faculty, rather than atmospheric scientists. (See the statement on postsecondary teachers elsewhere in the *Handbook*.)

In addition to civilian meteorologists, hundreds of Armed Forces members are involved in forecasting and other meteorological work. (See the statement on job opportunities in the Armed Forces elsewhere in the *Handbook*.)

Training, Other Qualifications, and Advancement

A bachelor's degree in meteorology or atmospheric science, or in a closely related field with courses in meteorology, usually is the minimum educational requirement for an entry-level position as an atmospheric scientist.

The preferred educational requirement for entry-level meteorologists in the Federal Government is a bachelor's degree—not necessarily in meteorology—with at least 24 semester hours of meteorology courses, including 6 hours in the analysis and prediction of weather systems, 6 hours of atmospheric dynamics and thermodynamics, 3 hours of physical meteorology, and 2 hours of remote sensing of the atmosphere or instrumentation. Other required courses include 3 semester hours of ordinary differential equations, 6 hours of college physics, and at least 9 hours of courses appropriate for a physical science major—such as statistics, chemistry, physical oceanography, physical climatology, physical hydrology, radiative transfer, aeronomy, advanced thermodynamics, advanced electricity and magnetism, light and optics, and computer science. Sometimes, a combination of education and appropriate experience may be substituted for a degree.

Although positions in operational meteorology are available for those with only a bachelor's degree, obtaining a second bachelor's degree or a master's degree enhances employment opportunities and advancement potential. A master's degree usually is necessary for conducting applied research and development, and a Ph.D. is required for most basic research positions. Students planning on a career in research and development need not necessarily major in atmospheric science or meteorology as an undergraduate. In fact, a bachelor's degree in mathematics, physics, or engineering provides excellent preparation for graduate study in atmospheric science.

Because atmospheric science is a small field, relatively few colleges and universities offer degrees in meteorology or atmospheric science, although many departments of physics, earth science, geography, and geophysics offer atmospheric science and related courses. Prospective students should make certain that courses required by the National Weather Service and other employers are offered at the college they are considering. Computer science courses, additional meteorology courses, a strong background in mathematics and physics, and good communication skills are important to prospective employers. Many programs combine the study of meteorology with another field, such as agriculture, oceanography, engineering, or physics. For example, hydrometeorology is the blending of hydrology (the science of Earth's water) and meteorology, and is the field concerned with the effect of precipitation on the hydrologic cycle and the environment. Students who wish to become broadcast meteorologists for radio or television stations should develop excellent communication skills through courses in speech, journalism, and related fields. Those interested in air quality work should take courses in chemistry and supplement their technical training with coursework in policy or government affairs. Prospective meteorologists seeking opportunities at weather consulting firms should possess knowledge of business, statistics, and economics, as an increasing emphasis is being placed on long-range seasonal forecasting to assist businesses.

Beginning atmospheric scientists often do routine data collection, computation, or analysis, and some basic forecasting. Entry-level operational meteorologists in the Federal Government usually are placed in intern positions for training and experience. During this period, they learn about the Weather Service's forecasting equipment and procedures, and rotate to different offices to learn about various weather systems. After completing the training period, they are assigned a permanent duty station. Experienced meteorologists may advance to supervisory or administrative jobs, or may handle more complex forecasting jobs. After several years of experience, some meteorologists establish their own weather consulting services.

The American Meteorological Society offers professional certification of consulting meteorologists, administered by a Board of Certified Consulting Meteorologists. Applicants must meet formal education requirements (though not necessarily have a college degree), pass an examination to demonstrate thorough meteorological knowledge, have a minimum of 5 years of experience or a combination of experience plus an advanced degree, and provide character references from fellow professionals.

Job Outlook

Employment of atmospheric scientists is projected to increase about as fast as the average for all occupations through 2012. The National Weather Service has completed an extensive modernization of its weather forecasting equipment and finished all hiring of meteorologists needed to staff the upgraded stations. The Service has no plans to increase the number of weather stations or the number of meteorologists in existing stations. Employment of meteorologists in other Federal agencies is expected to remain stable.

On the other hand, job opportunities for atmospheric scientists in private industry are expected to be better than for those in the Federal Government over the 2002-12 period. As research leads to continuing improvements in weather forecasting, demand should grow for private weather consulting firms to provide more detailed information than has formerly been available, especially to weather-sensitive industries. Farmers, commodity investors, radio and television stations, and utilities, transportation, and construction firms can greatly benefit from additional weather information more closely targeted to their needs than the general information provided by the National Weather Service. Additionally, research on seasonal and other long-range forecasting is yielding positive results, which should spur demand for more atmospheric scientists to interpret these forecasts and advise weather-sensitive industries. However, because many customers for private weather services are in industries sensitive to fluctuations in the economy, the sales and growth of private weather services depend on the health of the economy.

There will continue to be demand for atmospheric scientists to analyze and monitor the dispersion of pollutants into the air to ensure compliance with Federal environmental regulations outlined in the Clean Air Act of 1990, but related employment increases are expected to be small. Opportunities in broadcasting are rare and highly competitive, making for very few job openings.

Earnings

Median annual earnings of atmospheric scientists in 2002 were $60,200. The middle 50 percent earned between $39,970 and $76,880. The lowest 10 percent earned less than $30,220, and the highest 10 percent earned more than $92,430.

The average salary for meteorologists in nonsupervisory, supervisory, and managerial positions employed by the Federal Government was about $74,528 in 2003. Meteorologists in the Federal Government with a bachelor's degree and no experience received a starting salary of $23,442 or $29,037, depending on their college grades. Those with a master's degree could start at $35,519 or $42,976; those with the Ph.D., at $51,508. Beginning salaries for all degree levels are slightly higher in areas of the country where the prevailing local pay level is higher.

Related Occupations

Workers in other occupations concerned with the physical environment include environmental scientists and geoscientists, physicists and astronomers, mathematicians, and civil, chemical, and environmental engineers.

Sources of Additional Information

Information about careers in meteorology is available on the Internet from:

➤American Meteorological Society. Internet: **http://www.ametsoc.org/AMS. Phone: (617)-227-2425.**

Information on obtaining a meteorologist position with the Federal Government is available from the U.S. Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (703) 724-1850; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the Internet site: **http://www.usajobs.opm.gov**.

Biological Scientists

(0*NET 19-1020.01, 19-1021.01, 19-1021.02, 19-1022.00, 19-1023.00, 19-1029.99)

Significant Points

- A Ph.D. degree usually is required for independent research, but a master's degree is sufficient for some jobs in applied research or product development; a bachelor's degree is adequate for some nonresearch jobs.
- Doctoral degree holders face considerable competition for independent research positions, particularly in universities; holders of bachelor's or master's degrees in biological science can expect better opportunities in nonresearch positions.
- Biotechnological research and development will continue to drive employment growth.

Nature of the Work

Biological scientists study living organisms and their relationship to their environment. They research problems dealing with life processes. Most specialize in some area of biology such as zoology (the study of animals) or microbiology (the study of microscopic organisms). (Medical scientists, whose work is closely related to that of biological scientists, are discussed elsewhere in the *Handbook*.)

Many biological scientists work in research and development. Some conduct basic research to advance knowledge of living organisms, including viruses, bacteria, and other infectious agents. Basic biological research continues to provide the building blocks necessary to develop solutions to human health problems, and to preserve and repair the natural environment. Biological scientists mostly work independently in private industry, university, or government laboratories, often exploring new areas of research or expanding on specialized research started in graduate school. Those who are not wage and salary workers in private industry typically submit grant proposals to obtain funding for their projects. Colleges and universities, private industry, and Federal Government agencies, such as the National Institutes of Health and the National Science Foundation, contribute to the support of scientists whose research proposals are determined to be financially feasible and to have the potential to advance new ideas or processes.

Biological scientists who work in applied research or product development use knowledge provided by basic research to develop new drugs and treatments, increase crop yields, and protect and clean up the environment. They usually have less autonomy than basic researchers to choose the emphasis of their research, relying instead on market-driven directions based on the firm's products and goals. Biological scientists doing applied research and product development in private industry may be required to describe their research plans or results to nonscientists who are in a position to veto or approve their ideas, and they must understand the potential cost of their work and its impact on business. Scientists increasingly are working as part of teams, interacting with engineers, scientists of other disciplines, business managers, and technicians. Some biological scientists also work with customers or suppliers and manage budgets.

Those who conduct research usually work in laboratories and use electron microscopes, computers, thermal cyclers, or a wide variety of other equipment. Some conduct experiments using laboratory animals or greenhouse plants. This is particularly true of botanists, physiologists, and zoologists. For some biological scientists, research also is performed outside of laboratories. For example, a botanist might do research in tropical rain forests to see what plants grow there, or an ecologist might study how a forest area recovers after a fire. Some marine biologists also work outdoors, often on research vessels from which they study various marine organisms such as marine plankton or fish.

Some biological scientists work in managerial or administrative positions, usually after spending some time doing research and learning about the firm, agency, or project. They may plan and administer programs for testing foods and drugs, for example, or direct activities at zoos or botanical gardens. Some work as consultants to business firms or to government, while others test and inspect foods, drugs, and other products.

Recent advances in biotechnology and information technology are transforming the industries in which biological scientists work. In the 1980s, swift advances in basic biological knowledge related to genetics and molecules spurred growth in the field of biotechnology. Biological scientists using this technology manipulate the genetic material of animals or plants, attempting to make organisms more productive or resistant to disease. Research using biotechnology techniques, such as recombining DNA, has led to the production of important substances, including human insulin and growth hormone. Many other substances not previously available in large quantities are starting to be produced by biotechnological means; some may be useful in treating cancer and other diseases. Today, many biological scientists are involved in biotechnology. Those who work on the Human Genome project continue to isolate genes and determine their functionality. This work continues to lead to the discovery of the genes associated with specific diseases and inherited traits, such as certain types of cancer or obesity. These advances in biotechnology have opened up research opportunities in almost all areas of biology, including commercial applications in agriculture, environmental remediation, and the food and chemical industries.

Many biological scientists work in research and development, often in offices and laboratories.

Most biological scientists are further classified by the type of organism they study or by the specific activity they perform, although recent advances in the understanding of basic life processes at the molecular and cellular levels have blurred some traditional classifications.

Aquatic biologists study micro-organisms, plants, and animals living in water. *Marine biologists* study salt water organisms, and *limnologists* study fresh water organisms. Much of the work of marine biology centers on molecular biology, the study of the biochemical processes that take place inside living cells. Marine biologists sometimes are mistakenly called oceanographers, but oceanography is the study of the physical characteristics of oceans and the ocean floor. (See the statement on environmental scientists and geoscientists elsewhere in the *Handbook*.)

Biochemists study the chemical composition of living things. They analyze the complex chemical combinations and reactions involved in metabolism, reproduction, growth, and heredity. Biochemists and molecular biologists do most of their work in the field of biotechnology, which involves understanding the complex chemistry of life.

Botanists study plants and their environment. Some study all aspects of plant life, including algae, fungi, lichens, mosses, ferns, conifers, and flowering plants; others specialize in areas such as identification and classification of plants, the structure and function of plant parts, the biochemistry of plant processes, the causes and cures of plant diseases, the interaction of plants with other organisms and the environment, and the geological record of plants.

Microbiologists investigate the growth and characteristics of microscopic organisms such as bacteria, algae, or fungi. Most microbiologists specialize in environmental, food, agricultural, or industrial microbiology; virology (the study of viruses); or immunology (the study of mechanisms that fight infections). Many microbiologists use biotechnology to advance knowledge of cell reproduction and human disease.

Physiologists study life functions of plants and animals, both in the whole organism and at the cellular or molecular level, under normal and abnormal conditions. Physiologists often specialize in functions such as growth, reproduction, photosynthesis, respiration, or movement, or in the physiology of a certain area or system of the organism.

Biophysicists study the application of principles of physics, such as electrical and mechanical energy and related phenomena, to living cells and organisms.

Zoologists and wildlife biologists study animals and wildlife—their origin, behavior, diseases, and life processes. Some experiment with live animals in controlled or natural surroundings, while others dissect dead animals in order to study their structure. They also may collect and analyze biological data to determine the environmental effects of current and potential use of land and water areas. Zoologists usually are identified by the animal group studied—ornithologists (birds), mammalogists (mammals), herpetologists (reptiles), and ichthyologists (fish).

Ecologists study the relationships among organisms and between organisms and their environments, and the effects of influences such as population size, pollutants, rainfall, temperature, and altitude. Utilizing knowledge of various scientific disciplines, they may collect, study, and report data on the quality of air, food, soil, and water.

Agricultural and food scientists, who are sometimes referred to as biological scientists, are discussed elsewhere in the *Handbook*.

Working Conditions

Biological scientists usually work regular hours in offices or laboratories and usually are not exposed to unsafe or unhealthy conditions. Those who work with dangerous organisms or toxic substances in the laboratory must follow strict safety procedures to avoid contamination. Many biological scientists such as botanists, ecologists, and zoologists take field trips that involve strenuous physical activity and primitive living conditions. Biological scientists in the field may work in warm or cold climates, in all kinds of weather. In their research, they may dig, chip with a hammer, scoop with a net, and carry equipment in a backpack. They also may climb, stand, kneel, or dive.

The work of a marine biologist varies dramatically, depending on the type of work involved. Some work in a laboratory, while others work on research ships. Marine biologists who work underwater must practice safe diving while working around sharp coral reefs and hazardous marine life. Although some marine biologists obtain their specimens from the sea, many still spend a good deal of their time in laboratories and offices, conducting tests, running experiments, recording results, and compiling data.

Some biological scientists depend on grant money to support their research. They may be under pressure to meet deadlines and to conform to rigid grant-writing specifications when preparing proposals to seek new or extended funding.

Employment

Biological scientists held about 75,000 jobs in 2002. Almost half of all biological scientists were employed by Federal, State, and local governments. Federal biological scientists worked mainly for the U.S. Departments of Agriculture, Interior, and Defense, and for the National Institutes of Health. Most of the rest worked in scientific research and testing laboratories, the pharmaceutical and medicine manufacturing industry, or hospitals.

In addition, many biological scientists held biology faculty positions in colleges and universities. (See the statement on teachers—postsecondary elsewhere in the *Handbook*.)

Training, Other Qualifications, and Advancement

A Ph.D. degree usually is necessary for independent research, industrial research, and college teaching, and for advancement to administrative positions. A master's degree is sufficient for some jobs in basic research, applied research or product development, management, or inspection; it may also qualify one to work as a research technician or as a teacher in an aquarium. The bachelor's degree is adequate for some nonresearch jobs. For example, some graduates with a bachelor's degree start as biological scientists in testing and inspection, or get jobs related to biological science, such as technical sales or service representatives. In some cases, graduates with a bachelor's degree are able to work in a laboratory environment on their own projects, but this is unusual. Some may work as research assistants, while others become biological laboratory technicians or, with courses in education, high school biology teachers. (See the statements on clinical laboratory technologists and technicians; science technicians; and teachers-preschool, kindergarten, elementary, middle, and secondary elsewhere in the *Handbook*.) Many with a bachelor's degree in biology enter medical, dental, veterinary, or other health profession schools.

In addition to required courses in chemistry and biology, undergraduate biological science majors usually study allied disciplines such as mathematics, physics, and computer science.

Computer courses are essential, as employers prefer job applicants who are able to apply computer skills to modeling and simulation tasks and to operate computerized laboratory equipment. Those interested in studying the environment also should take courses in environmental studies and become familiar with current legislation and regulations. Prospective biological scientists who hope to work as marine biologists should have at least a bachelor's degree in a biological or marine science. However, students should not overspecialize in undergraduate study, as knowledge of marine biology often is acquired in graduate study. Most colleges and universities offer bachelor's degrees in biological science, and many offer advanced degrees. Curriculums for advanced degrees often emphasize a subfield such as microbiology or botany, but not all universities offer all curriculums. Larger universities frequently have separate departments specializing in different areas of biological science. For example, a program in botany might cover agronomy, horticulture, or plant pathology. Advanced degree programs include classroom and fieldwork, laboratory research, and a thesis or dissertation.

Biological scientists with a Ph.D. often take temporary postdoctoral research positions that provide specialized research experience. In private industry, some may become managers or administrators within the field of biology; others leave biology for nontechnical managerial, administrative, or sales jobs.

Biological scientists should be able to work independently or as part of a team and be able to communicate clearly and concisely, both orally and in writing. Those in private industry, especially those who aspire to management or administrative positions, should possess strong business and communication skills and be familiar with regulatory issues and marketing and management techniques. Those doing field research in remote areas must have physical stamina. Biological scientists also must have patience and self-discipline to conduct long and detailed research projects.

Job Outlook

Despite projected as fast as average job growth for biological scientists over the 2002-12 period, doctoral degree holders can expect to face competition for basic research positions. The Federal Government funds much basic research and development, including many areas of medical research that relate to biological science. Recent budget increases at the National Institutes of Health have led to large increases in Federal basic research and development expenditures, with research grants growing both in number and in dollar amount. At the same time, the number of newly trained scientists has continued to increase at least as fast as available research funds, so both new and established scientists have experienced difficulty winning and renewing research grants. Currently, about 1 in 3 grant proposals are approved for long-term research projects. If the number of advanced degrees awarded continues to grow, as seems likely based on enrollment trends, this competitive situation will persist. Additionally, applied research positions in private industry may become more difficult to obtain if increasing numbers of scientists seek jobs in private industry because of the competitive job market for independent research positions in universities and for college and university faculty.

Opportunities for those with a bachelor's or master's degree in biological science are expected to be better. The number of science-related jobs in sales, marketing, and research management, for which non-Ph.D.s usually qualify, is expected to exceed the number of independent research positions. Non-Ph.D.s also may fill positions as science or engineering technicians or health technologists and technicians. Some may become high school biology teachers.

Biological scientists enjoyed very rapid gains in employment between the mid-1980s and mid-1990s, in part reflecting increased staffing requirements in new biotechnology companies. Employment growth should slow somewhat as increases in the number of new biotechnology firms slow and existing firms merge or are absorbed into larger ones. However, much of the basic biological research done in recent years has resulted in new knowledge, including the isolation and identification of genes. Biological scientists will be needed to take this knowledge to the next stage, which is the understanding of how certain genes function within an entire organism, so that gene therapies can be developed to treat diseases. Even pharmaceutical and other firms not solely engaged in biotechnology use biotechnology techniques extensively, spurring employment increases for biological scientists. Expected expansion of research related to health issues, such as AIDS, cancer, and Alzheimer's disease, also should create more jobs for these scientists. In addition, efforts to discover new and improved ways to clean up and preserve the environment will continue to add to job growth. More biological scientists, including some botanists, will be needed to determine the environmental impact of industry and government actions and to prevent or correct environmental problems, while some will find opportunities in environmental regulatory agencies. Botanists also will use their expertise to advise lawmakers on legislation for environmental protection and for ways to save environmentally sensitive areas. There will continue to be demand for biological scientists specializing in botany, zoology, and marine biology, but opportunities will be limited because of the small size of these fields.

Biological scientists are less likely to lose their jobs during recessions than are those in many other occupations because many are employed on long-term research projects. However, an economic downturn could influence the amount of money allocated to new research and development efforts, particularly in areas of risky or innovative research. An economic downturn could also limit the possibility of extension or renewal of existing projects.

Earnings

Median annual earnings of biochemists and biophysicists were $60,390 in 2002. The middle 50 percent earned between $43,110 and $82,080. The lowest 10 percent earned less than $33,930, and the highest 10 percent earned more than $102,930. Median annual earnings of microbiologists were $51,020 in 2002. The middle 50 percent earned between $39,100 and $67,420. The lowest 10 percent earned less than $31,250, and the highest 10 percent earned more than $87,060. Median annual earnings of zoologists and wildlife biologists were $47,740 in 2002. The middle 50 percent earned between $37,100 and $58,040. The lowest 10 percent earned less than $29,260, and the highest 10 percent earned more than $71,270. Median annual earnings of biochemists and biophysicists employed in scientific research and development services were $64,390 in 2002.

According to the National Association of Colleges and Employers, beginning salary offers in 2003 averaged $29,456 a year for bachelor's degree recipients in biological and life sciences; $33,600 for master's degree recipients; and $42,244 for doctoral degree recipients.

In the Federal Government in 2003, general biological scientists in nonsupervisory, supervisory, and managerial positions earned an average salary of $66,262; microbiologists, $73,513; ecologists, $65,207; physiologists, $85,181; geneticists, $78,652; zoologists, $90,178; and botanists, $55,727.

Related Occupations

Many other occupations deal with living organisms and require a level of training similar to that of biological scientists. These include medical scientists, agricultural and food scientists, and conservation scientists and foresters, as well as health occupations such as physicians and surgeons, dentists, and veterinarians.

Sources of Additional Information

For information on careers in the biological sciences, contact:

➤ American Institute of Biological Sciences, Suite 200, 1444 I St. NW., Washington, DC 20005. Internet: **http://www.aibs.org**

For information on careers in biochemistry or biological sciences, contact:

➤ Federation of American Societies for Experimental Biology, 9650 Rockville Pike, Bethesda, MD 20814. Internet: **http://www.faseb.org**

For information on careers in microbiology, contact:

➤ American Society for Microbiology, Office of Education and Training—Career Information, 1325 Massachusetts Ave. NW., Washington, DC 20005. Internet: **http://www.asmusa.org**

Information on obtaining a biological scientist position with the Federal Government is available from the U.S. Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (703) 724-1850; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: **http://www.usajobs.opm.gov**.

Chemists and Materials Scientists

(0*NET 19-2031.00, 19-2032.00)

Significant Points

- A bachelor's degree in chemistry or a related discipline is the minimum educational requirement; however, many research jobs require a Ph.D.
- Job growth will be concentrated in pharmaceutical and medicine manufacturing companies and in scientific research and development services firms.
- Graduates with a master's degree, and particularly those with a Ph.D., will enjoy better opportunities than those with a bachelor's degree.

Nature of the Work

Everything in the environment, whether naturally occurring or of human design, is composed of chemicals. Chemists and materials scientists search for and use new knowledge about chemicals. Chemical research has led to the discovery and development of new and improved synthetic fibers, paints, adhesives, drugs, cosmetics, electronic components, lubricants, and thousands of other products. Chemists and materials scientists also develop processes that save energy and reduce pollution, such as improved oil refining and petrochemical processing methods. Research on the chemistry of living things spurs advances in medicine, agriculture, food processing, and other fields.

Materials scientists research and study the structures and chemical properties of various materials to develop new products or enhance existing ones. They also determine ways to strengthen or combine materials or develop new materials for use in a variety of products. Materials science encompasses the natural and synthetic materials used in a wide range of products and structures, from airplanes, cars, and bridges to clothing and household goods. Companies whose products are made of metals, ceramics, and rubber employ most materials scientists. Other applications of materials science include studies of superconducting materials, graphite materials, integrated-circuit chips, and fuel cells. Materials scientists, applying chemistry and physics, study all aspects of these materials. Chemistry plays an increasingly dominant role in materials science, because it provides information about the structure and composition of materials. Materials scientists often specialize in specific areas such as ceramics or metals.

Many chemists and materials scientists work in research and development (R&D). In basic research, they investigate properties, composition, and structure of matter and the laws that govern the combination of elements and reactions of substances. In applied R&D, they create new products and processes or improve existing ones, often using knowledge gained from basic research. For example, synthetic rubber and plastics resulted from research on small molecules uniting to form large ones, a process called polymerization. R&D chemists and materials scientists use computers and a wide variety of sophisticated laboratory instrumentation for modeling and simulation in their work.

The use of computers to analyze complex data has had the dramatic impact of allowing chemists and materials scientists to practice combinatorial chemistry. This technique makes and tests large quantities of chemical compounds simultaneously in order to find compounds with certain desired properties. As an integral part of drug and materials discovery, combinatorial chemistry speeds up materials design and R&D, permitting useful compounds to be developed more quickly and inexpensively than was formerly possible. Combinatorial chemistry has allowed chemists to produce thousands of compounds each year and to assist in the completion of the sequencing of human genes. Today, chemists are working with life scientists to translate this knowledge into viable new drugs.

Chemists also work in production and quality control in chemical manufacturing plants. They prepare instructions for plant workers that specify ingredients, mixing times, and temperatures for each stage in the process. They also monitor automated processes to ensure proper product yield, and test samples of raw materials or finished products to make certain that they meet industry and government standards, including the regulations governing pollution. Chemists report and document test results and analyze those results in hopes of further improving existing theories or developing new test methods.

Chemists often specialize. *Analytical chemists* determine the structure, composition, and nature of substances by examining and identifying the various elements or compounds that make up a substance. These chemists are absolutely crucial to the pharmaceutical industry because pharmaceutical companies need to know the identity of compounds that they hope to turn into drugs. Furthermore, they study the relations and interactions of the parts of compounds and develop analytical techniques. They also identify the presence and concentration of chemical pollutants in air, water, and soil. *Organic chemists* study the chemistry of the vast number of carbon compounds that make up all living things. Organic chemists who synthesize elements or simple compounds to create new compounds or substances that have different properties and applications have developed many commercial products, such as drugs, plastics, and elastomers (elastic substances similar to rubber). *Inorganic chemists* study compounds consisting mainly of elements other than carbon, such as those in electronic components. *Physical* and *theoretical chemists* study the physical characteristics of atoms and molecules and the theoretical properties of matter, and investigate how chemical reactions work. Their research may result in new and better energy sources. *Macromolecular chemists* study the behavior of atoms and molecules. *Medicinal chemists* study the structural properties of compounds intended for applications to human medicine. *Materials chemists* study and develop new materials to improve existing products or make

The use of computers allows chemists to test large quantities of chemical compounds with desired properties.

new ones. In fact, virtually all chemists are involved in this quest in one way or another. Developments in the field of chemistry that involve life sciences will expand, resulting in more interaction among biologists, engineers, and chemists. (*Biochemists*, whose work encompasses both biology and chemistry, are discussed in the *Handbook* s tatement on biological scientists.)

Working Conditions

Chemists and materials scientists usually work regular hours in offices and laboratories. R&D chemists and materials scientists spend much time in laboratories, but also work in offices when they do theoretical research or plan, record, and report on their lab research. Although some laboratories are small, others are large enough to incorporate prototype chemical manufacturing facilities as well as advanced equipment for chemists. In addition to working in a laboratory, materials scientists also work with engineers and processing specialists in industrial manufacturing facilities. After a material is sold, materials scientists often help customers tailor the material to suit their needs. Chemists do some of their work in a chemical plant or outdoors—while gathering water samples to test for pollutants, for example. Some chemists are exposed to health or safety hazards when handling certain chemicals, but there is little risk if proper procedures are followed.

Employment

Chemists and materials scientists held about 91,000 jobs in 2002. About 44 percent of all chemists and material scientists are employed in manufacturing firms—mostly in the chemical manufacturing industry, which includes firms that produce plastics and synthetic materials, drugs, soaps and cleaners, pesticides and fertilizers, paint, industrial organic chemicals, and other chemical products. About 15 percent of chemists and material scientists work in scientific research and development services; another 13 percent work in architectural, engineering, and related services. In addition, thousands of persons with a background in chemistry and materials science hold teaching positions in high schools and in colleges and universities. (See the statements on teachers—postsecondary, and teachers—preschool, kindergarten, elementary, middle, and secondary elsewhere in the *Handbook*.)

Chemists and materials scientists are employed in all parts of the country, but they are mainly concentrated in large industrial areas.

Training, Other Qualifications, and Advancement

A bachelor's degree in chemistry or a related discipline usually is the minimum educational requirement for entry-level chemist jobs. However, many research jobs require a master's degree, or more often a Ph.D. While some materials scientists hold a degree in materials science, a bachelor's degree in chemistry, physics, or electric engineering also is accepted. Similar to chemists, many R&D jobs require a Ph.D. in materials science or a related science.

Many colleges and universities offer a bachelor's degree program in chemistry; about 620 are approved by the American Chemical Society (ACS). The number of colleges that offer a degree program in materials science is small, but gradually increasing. Several hundred colleges and universities also offer advanced degree programs in chemistry; around 320 master's programs and about 190 doctoral programs are ACS-approved.

Students planning careers as chemists and materials scientists should take courses in science and mathematics, should like working with their hands building scientific apparatus and performing laboratory experiments, and should like computer modeling. Perseverance, curiosity, and the ability to concentrate on detail and to work independently are essential. Interaction among specialists in this field is increasing, especially for chemists in drug development. One type of chemist often relies on the findings of another type of chemist. For example, an organic chemist must understand findings on the identity of compounds prepared by an analytical chemist.

In addition to required courses in analytical, inorganic, organic, and physical chemistry, undergraduate chemistry majors usually study biological sciences, mathematics, and physics. Those interested in the environmental field also should take courses in environmental studies and become familiar with current legislation and regulations. Computer courses are essential, because employers prefer job applicants who are able to apply computer skills to modeling and simulation tasks and operate computerized laboratory equipment. This is increasingly important as combinatorial chemistry techniques are more widely applied. Additionally, courses in statistics are useful because both chemists and materials scientists need the ability to apply basic statistical techniques.

Because R&D chemists and materials scientists are increasingly expected to work on interdisciplinary teams, some understanding of other disciplines, including business and marketing or economics, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships, fellowships, or work-study programs in industry, also is useful. Some employers of research chemists, particularly in the pharmaceutical industry, prefer to hire individuals with several years of postdoctoral experience.

Graduate students typically specialize in a subfield of chemistry, such as analytical chemistry or polymer chemistry, depending on their interests and the kind of work they wish to do. For example, those interested in doing drug research in the pharmaceutical industry usually develop a strong background in synthetic organic chemistry. However, students normally need not specialize at the undergraduate level. In fact, undergraduates who are broadly trained have more flexibility when job hunting or changing jobs than if they had narrowly defined their interests. Most employers provide new graduates additional training or education.

In government or industry, beginning chemists with a bachelor's degree work in quality control, perform analytical testing, or assist senior chemists in R&D laboratories. Many employers prefer chemists and materials scientists with a Ph.D., or at least a master's degree, to lead basic and applied research. Nonetheless, relevant work experience is an asset. Chemists who hold a Ph.D. and have previous industrial experience may be particularly attractive to employers because such people are more likely to understand the complex regulations that apply to the pharmaceutical industry. Within materials science, a broad background in various sciences is preferred. This broad base may be obtained through degrees in physics, engineering, or chemistry. While many companies prefer hiring Ph.D.s, many materials scientists have bachelor's and master's degrees.

Job Outlook

Employment of chemists is expected to grow about as fast as the average for all occupations through 2012. Job growth will be concentrated in pharmaceutical and medicine manufacturing and in scientific research and development services firms. The chemical industry, the major employer of chemists, should face continued demand for goods such as new and better pharmaceuticals and personal care products, as well as for more specialty chemicals designed to address specific problems or applications. To meet these demands, some chemical firms will continue to devote money to research and development—through in-house teams or outside contractors—spurring employment growth of chemists. Those with at least a master's degree, and particularly those with a Ph.D., will enjoy better opportunities than those with just a bachelor's degree for most research and upper management positions. Opportunities for individuals with a bachelor's degree are expected to be more competitive. The number of science-related jobs in sales, marketing, and middle management, for which bachelor's and master's degree holders may qualify, are expected to be fewer as companies continue to streamline their operations. Some bachelor's and master's degree holders become chemical technicians or technologists or high school chemistry teachers.

Within the chemical industry, job opportunities are expected to be most plentiful in pharmaceutical and biotechnology firms. Biotechnological research, including studies of human genes, continues to offer possibilities for the development of new drugs and products to combat illnesses and diseases that have previously been unresponsive to treatments derived by traditional chemical processes. Stronger competition among drug companies and an aging population are contributing to the need for innovative and improved drugs discovered through scientific research.

Employment in the remaining segments of the chemical industry is expected to decline as companies downsize and turn to outside contractors to provide specialized services. As a result, scientific research and development services firms will experience healthy growth. To control costs, some chemical companies, including drug manufacturers, are increasingly turning to these firms to perform specialized research and other work formerly done by in-house chemists. Despite downsizing, some job openings will result from the need to replace chemists who retire or otherwise leave the labor force. Quality control will continue to be an important issue in chemical manufacturing and other industries that use chemicals in their manufacturing processes. Chemists also will be needed to develop and improve the technologies and processes used to produce chemicals for all purposes, and to monitor and measure air and water pollutants to ensure compliance with local, State, and Federal environmental regulations. Environmental research will offer many new opportunities for chemists and materials scientists. To satisfy public concerns and to comply with government regulations, the chemical industry will continue to invest billions of dollars each year in technology that reduces pollution and cleans up existing wastesites. Chemists also are needed to find ways to use less energy and to discover new sources of energy.

During periods of economic recession, layoffs of chemists may occur—especially in the industrial chemicals industry. This industry provides many of the raw materials to the auto manufacturing and construction industries, both of which are vulnerable to temporary slowdowns during recessions.

Earnings

Median annual earnings of chemists in 2002 were $52,890. The middle 50 percent earned between $39,410 and $71,710. The lowest 10 percent earned less than $30,980, and the highest 10 percent earned more than $92,170. Median annual earnings of materials scientists in 2002 were $64,590. The middle 50 percent earned between $46,280 and $86,240. The lowest 10 percent earned less than $33,480, and the highest 10 percent earned more than $107,400. Median annual earnings in the industries employing the largest numbers of chemists in 2002 were:

Federal government	$72,010
Scientific research and development services	60,400
Pharmaceutical and medicine manufacturing	53,070
Architectural, engineering, and related services	38,780

The American Chemical Society reports that the median salary of all of its members with a bachelor's degree was $32,800 a year in 2002; for those with a master's degree, it was $50,000; and for those with a Ph.D., it was $68,000. Median salaries were highest for those working in private industry; those in academia earned the least. According to an ACS survey of recent graduates, inexperienced chemistry graduates with a bachelor's degree earned a median starting salary of $31,000 in 2002; those with a master's degree earned a median salary of $45,000; and those with a Ph.D. made median earnings of $67,500. Among bachelor's degree graduates, those who had completed internships or had other work experience while in school commanded the highest starting salaries.

In 2003, chemists in nonsupervisory, supervisory, and managerial positions in the Federal Government averaged $76,857 a year.

Related Occupations

The research and analysis conducted by chemists and materials scientists is closely related to work done by agricultural and food scientists, biological scientists, medical scientists, chemical engineers, materials engineers, physicists, and science technicians.

Sources of Additional Information

General information on career opportunities and earnings for chemists is available from:

➤American Chemical Society, Education Division, 1155 16th St. NW., Washington, DC 20036. Internet: **http://www.acs.org**

For general information on materials science, contact:

➤Materials Research Society (MRS), 506 Keystone Dr., Warrendale, PA 15086-7573. Internet: **http://www.mrs.org**

Information on obtaining a position as a chemist with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (703) 724-1850; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: **http://www.usajobs.opm.gov**.

Conservation Scientists and Foresters

(0*NET 19-1031.01, 19-1031.02, 19-1031.03, 19-1032.00)

Significant Points

- Nearly two-thirds of salaried conservation scientists and foresters work for Federal, State, or local governments.
- A bachelor's degree in forestry, range management, or a related discipline is the minimum educational requirement.
- Slower-than-average job growth is projected because of limited growth in government and in forestry and logging; most employment opportunities will be in private sector consulting.

Nature of the Work

Forests and rangelands supply wood products, livestock forage, minerals, and water; serve as sites for recreational activities; and provide habitats for wildlife. Conservation scientists and foresters manage, develop, use, and help to protect these and other natural resources.

Foresters manage forested lands for a variety of purposes. Those working in private industry may manage company forest land or procure timber from private landowners. Company forests usually are managed to produce a sustainable supply of wood for company mills. Procurement foresters contact local forest owners and gain permission to take inventory of the type, amount, and location of all standing timber on the property, a process known as timber cruising. Foresters then appraise the timber's worth, negotiate its purchase, and draw up a contract for procurement. Next, they subcontract with loggers or pulpwood cutters for tree removal, aid in road layout, and maintain close contact with the subcontractor's workers and the landowner to ensure that the work meets the landowner's requirements, as well as Federal, State, and local environmental specifications. Forestry consultants often act as agents for the forest owner, performing these duties and negotiating timber sales with industrial procurement foresters.

Throughout the forest management and procurement processes, foresters consider the economics as well as the environmental impact on natural resources. To do this, they determine how to conserve wildlife habitats, creek beds, water quality, and soil stability, and how best to comply with environmental regulations. Foresters must balance the desire to conserve forested ecosystems for future generations with the need to use forest resources for recreational or economic purposes.

Through a process called regeneration, foresters also supervise the planting and growing of new trees. They choose and prepare the site, using controlled burning, bulldozers, or herbicides to clear weeds, brush, and logging debris. They advise on the type, number, and placement of trees to be planted. Foresters then monitor the seedlings to ensure healthy growth and to determine the best time for harvesting. If they detect signs of disease or harmful insects, they consult with forest pest management specialists to decide on the best course of treatment. Foresters who work for Federal and State governments manage public forests and parks and work with private landowners to protect and manage forest land outside of the public domain. They may also design campgrounds and recreation areas.

Foresters use a number of tools to perform their jobs. Clinometers measure the height, diameter tapes measure the diameter, and increment borers and bark gauges measure the growth of trees so that timber volumes can be computed and growth rates estimated. Remote sensing (aerial photographs and other imagery taken from airplanes and satellites) and Geographic Information Systems (GIS) data often are used for mapping large forest areas and for detecting widespread trends of forest and land use. Once the map is generated, the data are digitized to create a computerized inventory of information required to manage the forest land and its resources. Moreover, hand-held computers, Global Positioning Satellite (GPS), and World Wide Web-based applications are used extensively.

Range managers, also called *range conservationists*, *range ecologists*, or *range scientists*, study, manage, improve, and protect rangelands to maximize their use without damaging the environment. Rangelands cover about 1 billion acres of the United States, mostly in Western States and Alaska. They contain many natural resources, including grass and shrubs for animal grazing, wildlife habitats, water from vast watersheds, recreation facilities, and valuable mineral and energy resources. Range managers may inventory soils, plants, and animals, develop resource management plans, help to restore degraded ecosystems, or assist in managing a ranch. For example, they may help ranchers attain optimum livestock production by determining the number and kind of animals to graze, the grazing system to use, and the best season for grazing. At the same time, however, range managers maintain soil stability and vegetation for other uses such as wildlife habitats and outdoor recreation. They also plan and implement revegetation of disturbed sites.

Soil and water conservationists provide technical assistance to farmers, ranchers, forest managers, State and local agencies, and others concerned with the conservation of soil, water, and related natural resources. They develop programs for private landowners designed to make the most productive use of land without damaging it. Soil conservationists also assist landowners by visiting areas with erosion problems, finding the source of the problem, and helping landowners and managers develop management practices to combat it. Water conservationists also assist private landowners and Federal, State, and local governments by advising on a broad range of natural resource topics—specifically, issues of water quality, preserving water supplies, groundwater contamination, and management and conservation of water resources.

Conservation scientists and foresters often work outdoors, sometimes in isolated areas.

Foresters and conservation scientists often specialize in one area, such as wildlife management, urban forestry, wood technology, native species, or forest economics.

Working Conditions

Working conditions vary considerably. Although some of the work is solitary, foresters and conservation scientists also deal regularly with landowners, loggers, forestry technicians and aides, farmers, ranchers, government officials, special interest groups, and the public in general. Some foresters and conservation scientists work regular hours in offices or labs. Others may split their time between fieldwork and office work, while independent consultants and especially new, less experienced workers spend the majority of their time outdoors overseeing or participating in hands-on work.

The work can be physically demanding. Some foresters and conservation scientists work outdoors in all types of weather, sometimes in isolated areas. Other foresters may need to walk long distances through densely wooded land to carry out their work. Foresters also may work long hours fighting fires. Conservation scientists often are called to prevent erosion after a forest fire, and they provide emergency help after floods, mudslides, and tropical storms.

Employment

Conservation scientists and foresters held about 33,000 jobs in 2002. Nearly one-third of all workers were employed by the Federal Government, many in the U.S. Department of Agriculture (USDA). Foresters were concentrated in the USDA's Forest Service; soil conservationists were employed primarily in the USDA's Natural Resource Conservation Service. Most range managers worked in the U.S. Department of the Interior's Bureau of Land Management, the Natural Resource Conservation Service, or the Forest Service. Another 20 percent of conservation scientists and foresters worked for State governments, and about 10 percent worked for local governments. The remainder worked in private industry, mainly in support activities for agriculture and forestry or in wood product manufacturing. Some were self-employed as consultants for private landowners, Federal and State governments, and forestry-related businesses.

Although conservation scientists and foresters work in every State, employment of foresters is concentrated in the Western and Southeastern States, where many national and private forests and parks, and most of the lumber and pulpwood-producing forests, are located. Range managers work almost entirely in the Western States, where most of the rangeland is located. Soil conservationists, on the other hand, are employed in almost every county in the country. Besides the jobs described above, some foresters and conservation scientists held faculty positions in colleges and universities. (See the statement on teachers—postsecondary elsewhere in the *Handbook*.)

Training, Other Qualifications, and Advancement

A bachelor's degree in forestry, range management, or a related discipline is the minimum educational requirement for careers in forestry or conservation science. In the Federal Government, a combination of experience and appropriate education occasionally may substitute for a 4-year forestry degree, but job competition makes this difficult.

Sixteen States have mandatory licensing or voluntary registration requirements that a forester must meet in order to acquire the title "professional forester" and practice forestry in the State. Of those 16 States, 7 have mandatory licensing; 5 have mandatory registration, and the remaining 4 States have optional registration. Both licensing and registration requirements usually entail completing a 4-year degree in forestry and several years of forestry work experience. Candidates pursuing licensing also must pass a comprehensive written exam.

Foresters who wish to perform specialized research or teach should have an advanced degree, preferably a Ph.D.

Most land-grant colleges and universities offer bachelor's or higher degrees in forestry; about 110 of these degree programs at around 50 educational institutions are accredited by the Society of American Foresters. Curriculums stress four components: Ecology, measurement of forest resources, management of forest resources, and public policy. Students should balance general science courses such as ecology, biology, tree physiology, taxonomy, and soil formation with technical forestry courses, such as forest inventory or wildlife habitat assessment, remote sensing, land surveying, GPS technology, integrated forest resource management, silviculture, and forest protection. In addition, communications skills, mathematics, statistics, and computer science courses also are recommended. Many forestry curriculums include advanced computer applications such as GIS and resource assessment programs. Courses in resource policy and administration, specifically forest economics and business administration, supplement the student's scientific and technical knowledge. Forestry curriculums increasingly include courses on best management practices, wetlands analysis, and sustainability and regulatory issues in response to the growing focus on protecting forested lands during timber harvesting operations. Prospective foresters should have a strong grasp of Federal, State, and local policy issues and of increasingly numerous and complex environmental regulations that affect many forestry-related activities. Many colleges require students to complete a field session either in a camp operated by the college or in a cooperative work-study program with a Federal or State agency or private industry. All schools encourage students to take summer jobs that provide experience in forestry or conservation work.

A bachelor's degree in range management or range science is the usual minimum educational requirement for range managers; graduate degrees usually are required for teaching and research positions. More than 30 colleges and universities offer degrees in range management that are accredited by the Society of Range Management. A number of other schools offer degree programs in range science or in a closely related discipline with a range management or range science option. Specialized range management courses combine plant, animal, and soil sciences with principles of ecology and resource management. Desirable electives include economics, statistics, forestry, hydrology, agronomy, wildlife, animal husbandry, computer science, and recreation. Selection of a minor in range management, such as wildlife ecology, watershed management, animal science, or agricultural economics, can often enhance qualifications for certain types of employment. The Society for Range Management offers certification as a professional rangeland manager (CPRM). Candidates seeking certification must have at least a bachelor's degree in range science or a closely related field, have a minimum of 5 years of full-time work experience, and pass a comprehensive written exam.

Very few colleges and universities offer degrees in soil conservation. Most soil conservationists have degrees in environmental studies, agronomy, general agriculture, hydrology, or crop or soil science; a few have degrees in related fields such as wildlife biology, forestry, and range management. Programs of study usually include 30 semester hours in natural resources or agriculture, including at least 3 hours in soil science.

In addition to meeting the demands of forestry and conservation research and analysis, foresters and conservation scientists generally must enjoy working outdoors, be physically hardy, and be willing to move to where the jobs are. They also must work well with people and have good communication skills.

Recent forestry and range management graduates usually work under the supervision of experienced foresters or range managers. After gaining experience, they may advance to more responsible positions. In the Federal Government, most entry-level foresters work in forest resource management. An experienced Federal forester may supervise a ranger district, and may advance to forest supervisor, to regional forester, or to a top administrative position in the national headquarters. In private industry, foresters start by learning the practical and administrative aspects of the business and acquiring comprehensive technical training. They are then introduced to contract writing, timber harvesting, and decisionmaking. Some foresters work their way up to top managerial positions within their companies. Foresters in management usually leave the fieldwork behind, spending more of their time in an office, working with teams to develop management plans and supervising others. After gaining several years of experience, some foresters may become consulting foresters, working alone or with one or several partners. They contract with State or local governments, private landowners, private industry, or other forestry consulting groups.

Soil conservationists usually begin working within one county or conservation district and, with experience, may advance to the area, State, regional, or national level. Also, soil conservationists can transfer to related occupations, such as farm or ranch management advisor or land appraiser.

Job Outlook

Employment of conservation scientists and foresters is expected to grow more slowly than the average for all occupations through 2012. Growth should be strongest in private sector consulting firms and in scientific research and development services. Demand will be spurred by a continuing emphasis on environmental protection, responsible land management, and water-related issues. Job opportunities for conservation scientists will arise because government regulations, such as those regarding the management of storm water and coastlines, have created demand for persons knowledgeable about runoff and erosion on farms and in cities and suburbs. Soil and water quality experts will be needed as States design initiatives to improve water resources by preventing pollution by agricultural producers and industrial plants.

Fewer opportunities for conservation scientists and foresters are expected in Federal and State Government, mostly due to budgetary constraints and the trend among governments toward contracting functions out to private consulting firms. Also, Federal land management agencies, such as the USDA Forest Service, have de-emphasized their timber programs and increasingly focused on wildlife, recreation, and sustaining ecosystems, thereby spurring demand for other life and social scientists rather than for foresters. However, departures of foresters who retire or leave the Government for other reasons will result in some job openings between 2002 and 2012. A small number of new jobs will result from the need for range and soil conservationists to provide technical assistance to owners of grazing land through the Natural Resource Conservation Service.

Reductions in timber harvesting on public lands, most of which are located in the Northwest and California, also will dampen job growth for private industry foresters in these regions. Opportunities will be better for foresters in the Southeast, where much forested land is privately owned. Salaried foresters working for private industry—such as paper companies, sawmills, and pulpwood mills—and consulting foresters will be needed to provide technical assistance and management plans to landowners.

Scientific research and development services have increased their hiring of conservation scientists and foresters in recent years in response to demand for professionals to prepare environmental impact statements and erosion and sediment control plans, monitor water quality near logging sites, and advise on tree harvesting practices required by Federal, State, or local regulations. Hiring in these firms should continue during the 2002-12 period, although at a slower rate than over the last 10 years.

Earnings

Median annual earnings of conservation scientists in 2002 were $50,340. The middle 50 percent earned between $39,300 and $61,440. The lowest 10 percent earned less than $30,630, and the highest 10 percent earned more than $70,770.

Median annual earnings of foresters in 2002 were $46,730. The middle 50 percent earned between $36,330 and $56,890. The lowest 10 percent earned less than $29,690, and the highest 10 percent earned more than $69,600.

In 2003, most bachelor's degree graduates entering the Federal Government as foresters, range managers, or soil conservationists started at $23,442 or $29,037, depending on academic achievement. Those with a master's degree could start at $35,519 or $42,976. Holders of doctorates could start at $51,508. Beginning salaries were slightly higher in selected areas where the prevailing local pay level was higher. In 2003, the average Federal salary for foresters in nonsupervisory, supervisory, and managerial positions was $59,233; for soil conservationists, $57,084; and for rangeland managers, $53,657.

According to the National Association of Colleges and Employers, graduates with a bachelor's degree in conservation and renewable natural resources received an average starting salary offer of $29,715 in 2003.

In private industry, starting salaries for students with a bachelor's degree were comparable with starting salaries in the Federal Government, but starting salaries in State and local governments were usually lower.

Conservation scientists and foresters who work for Federal, State, and local governments and large private firms generally receive more generous benefits than do those working for smaller firms.

Related Occupations

Conservation scientists and foresters manage, develop, and protect natural resources. Other workers with similar responsibilities include environmental engineers; agricultural and food scientists; biological scientists; environmental scientists and geoscientists; and farmers, ranchers, and agricultural managers.

Sources of Additional Information

For information about the forestry profession and lists of schools offering education in forestry, send a self-addressed, stamped business envelope to:

➤ Society of American Foresters, 5400 Grosvenor Lane, Bethesda, MD 20814, or visit the society's Web site: **http://www.safnet.org**

For information about career opportunities in forestry in the Federal Government, contact:

➤ Chief, U.S. Forest Service, U.S. Department of Agriculture, P.O. Box 96090, Washington, DC 20090-6090. Internet: **http://www.fs.fed.us**

Information about a career as a range manager, as well as a list of schools offering training, is available from:

➤ Society for Range Management, 445 Union Blvd., Suite 230, Lakewood, CO 80228-1259. Internet: **http://www.rangelands.org/ScriptContent/Index.cfm**

Drafters

(0*NET 17-3011.01, 17-3011.02, 17-3012.01, 17-3012.02, 17-3013.00)

Significant Points

- The type and quality of postsecondary drafting programs vary considerably; prospective students should be careful in selecting a program.
- Opportunities should be best for individuals with at least 2 years of postsecondary training in drafting and considerable skill and experience using computer-aided design and drafting (CADD) systems.
- Demand for particular drafting specialties varies geographically, depending on the needs of local industry.

Nature of the Work

Drafters prepare technical drawings and plans used by production and construction workers to build everything from manufactured products, such as toys, toasters, industrial machinery, and spacecraft, to structures, such as houses, office buildings, and oil and gas pipelines. Their drawings provide visual guidelines, show the technical details of the products and structures, and specify dimensions, materials, and procedures. Drafters fill in technical details, using drawings, rough sketches, specifications, codes, and calculations previously made by engineers, surveyors, architects, or scientists. For example, they use their knowledge of standardized building techniques to draw in the details of a structure. Some drafters use their knowledge of engineering and manufacturing theory and standards to draw the parts of a machine in order to determine design elements, such as the numbers and kinds of fasteners needed to assemble the machine. Drafters use technical handbooks, tables, calculators, and computers to complete their work.

Traditionally, drafters sat at drawing boards and used pencils, pens, compasses, protractors, triangles, and other drafting devices to prepare a drawing manually. Most drafters now use computer-aided design and drafting (CADD) systems to prepare drawings. Consequently, some drafters are referred to as *CADD operators*. CADD systems employ computer workstations to create a drawing on a video screen. The drawings are stored electronically to facilitate revisions and create duplications easily. These systems also permit drafters to quickly prepare variations of a design. Although drafters use CADD extensively, it is only a tool: Persons who produce technical drawings with CADD still function as drafters and need the knowledge of traditional drafters, in addition to CADD skills. Despite the near-universal use of CADD systems, manual drafting and sketching still is used in certain applications.

Drafting work has many specialties, and titles may denote a particular discipline of design or drafting.

Aeronautical drafters prepare engineering drawings detailing plans and specifications used in the manufacture of aircraft, missiles, and related parts.

Architectural drafters draw architectural and structural features of buildings and other structures. These workers may specialize in a type of structure, such as residential or commercial, or in a kind of material used, such as reinforced concrete, masonry, steel, or timber.

Civil drafters prepare drawings and topographical and relief maps used in major construction or civil engineering projects, such as highways, bridges, pipelines, flood control projects, and water and sewage systems.

Electrical drafters prepare wiring and layout diagrams used by workers who erect, install, and repair electrical equipment and wiring in communication centers, powerplants, electrical distribution systems, and buildings.

Electronics drafters draw wiring diagrams, circuit board assembly diagrams, schematics, and layout drawings used in the manufacture, installation, and repair of electronic devices and components.

Mechanical drafters prepare detail and assembly drawings of a wide variety of machinery and mechanical devices, indicating dimensions, fastening methods, and other requirements.

Process piping or *pipeline drafters* prepare drawings used in the layout, construction, and operation of oil and gas fields, refineries, chemical plants, and process piping systems.

Working Conditions

Most drafters work a standard 40-hour week; only a small number work part time. Drafters usually work in comfortable offices furnished to accommodate their tasks. They may sit at adjustable drawing boards or drafting tables when doing manual drawings, although most drafters work at computer terminals much of the time. Because they spend long periods in front of computer terminals doing detailed work, drafters may be susceptible to eyestrain, back discomfort, and hand and wrist problems.

Employment

Drafters held about 216,000 jobs in 2002. Architectural and civil drafters held about half of all jobs for drafters, mechanical drafters held about a third of all jobs, and the rest of all jobs were held by electrical and electronics drafters.

Almost half of all jobs for drafters were in architectural, engineering, and related services firms that design construction projects or do other engineering work on a contract basis for other industries. More than a quarter of jobs were in manufacturing industries, such as machinery manufacturing, including metalworking and other general machinery; fabricated metal products manufacturing, including architectural and structural metals; computer and electronic products manufacturing, in-

Most drafters now use computer-aided design drafting (CADD) systems to prepare drawings.

cluding navigational, measuring, electromedical, and control instruments; and transportation equipment manufacturing, including aerospace products and parts manufacturing, as well as ship and boat building. Most of the rest were employed in construction, government, wholesale trade, utilities, and employment services. Only a small number were self-employed in 2002.

Training, Other Qualifications, and Advancement

Employers prefer applicants who have completed postsecondary school training in drafting, which is offered by technical institutes, community colleges, and some 4-year colleges and universities. Employers are most interested in applicants with well-developed drafting and mechanical-drawing skills; knowledge of drafting standards, mathematics, science, and engineering technology; and a solid background in computer-aided design and drafting techniques. In addition, communication and problem-solving skills are important.

Training and course work differ somewhat within the drafting specialties. The initial training for each specialty is similar. All incorporate math and communication skills, for example, but course work relating to the specialty varies. In an electronics drafting program, for example, students learn how to depict electronic components and circuits in drawings.

Many types of publicly and privately operated schools provide some form of training in drafting. The kind and quality of programs vary considerably; therefore, prospective students should be careful in selecting a program. They should contact prospective employers regarding their preferences and ask schools to provide information about the kinds of jobs that are obtained by the school's graduates, the types and conditions of the instructional facilities and equipment, and the faculty's qualifications.

Technical institutes offer intensive technical training, but less general education than do junior and community colleges. Certificates or diplomas based on the completion of a certain number of course hours may be awarded. Many technical institutes offer 2-year associate degree programs, which are similar to, or part of, the programs offered by community colleges or State university systems. Their programs vary considerably in both length and type of courses offered. Some area vocational-technical schools are postsecondary public institutions that serve local students and emphasize the type of training preferred by local employers. Many offer introductory drafting instruction. Most require a high school diploma or its equivalent for admission. Other technical institutes are run by private, often for-profit, organizations, sometimes called proprietary schools.

Community colleges offer curricula similar to those in technical institutes, but include more courses on theory and liberal arts. Often, there is little or no difference between technical institute and community college programs. However, courses taken at community colleges are more likely than those given at technical institutes to be accepted for credit at 4-year colleges. After completing a 2-year associate degree program, graduates may obtain jobs as drafters or continue their education in a related field at 4-year colleges. Most 4-year colleges usually do not offer training in drafting, but college courses in engineering, architecture, and mathematics are useful for obtaining a job as a drafter.

Technical training obtained in the Armed Forces also can be applied in civilian drafting jobs. Some additional training may be necessary, depending on the technical area or military specialty.

The American Design Drafting Association (ADDA) has established a certification program for drafters. Although employers usually do not require drafters to be certified, certification demonstrates an understanding of nationally recognized practices and standards of knowledge. Individuals who wish to become certified must pass the Drafter Certification Test, which is administered periodically at ADDA-authorized sites. Applicants are tested on their knowledge and understanding of basic drafting concepts, such as geometric construction, working drawings, and architectural terms and standards.

Individuals planning careers in drafting should take courses in mathematics, science, computer technology, design, and computer graphics, as well as any high school drafting courses available. Mechanical ability and visual aptitude also are important. Prospective drafters should be able to draw well and perform detailed work accurately and neatly. Artistic ability is helpful in some specialized fields, as is knowledge of manufacturing and construction methods. In addition, prospective drafters should have good interpersonal skills, because they work closely with engineers, surveyors, architects, other professionals, and, sometimes, customers.

Entry-level or junior drafters usually do routine work under close supervision. After gaining experience, they may become intermediate-level drafters and progress to more difficult work with less supervision. At the intermediate level, they may need to exercise more judgment and perform calculations when preparing and modifying drawings. Drafters may eventually advance to senior drafter, designer, or supervisor. Many employers pay for continuing education, and, with appropriate college degrees, drafters may go on to become engineering technicians, engineers, or architects.

Job Outlook

Employment of drafters is expected to grow more slowly than the average for all occupations through 2012. Industrial growth and increasingly complex design problems associated with new products and manufacturing processes will increase the demand for drafting services. Further, drafters are beginning to break out of the traditional drafting role and increasingly do work traditionally performed by engineers and architects, thus also increasing demand for drafters. However, the greater use of CADD equipment by drafters, as well as by architects and engineers, should limit demand for lesser skilled drafters, resulting in slower-than-average overall employment growth. Most job openings are expected to arise from the need to replace drafters who transfer to other occupations, leave the labor force, or retire.

Opportunities should be best for individuals with at least 2 years of postsecondary training in a drafting program that provides strong technical skills, as well as considerable experience with CADD systems. CADD has increased the complexity of drafting applications while enhancing the productivity of drafters. It also has enhanced the nature of drafting by creating more possibilities for design and drafting. As technology continues to advance, employers will look for drafters with a strong background in fundamental drafting principles, a higher level of technical sophistication, and an ability to apply their knowledge to a broader range of responsibilities.

Demand for particular drafting specialties varies throughout the country because employment usually is contingent upon the needs of local industry. Employment of drafters remains highly concentrated in industries that are sensitive to cyclical changes in the economy, such as manufacturing and architectural and engineering services. During recessions, drafters may be laid off. However, a growing number of drafters should continue to find employment on a temporary or contract basis as more companies turn to the employment services industry to meet their changing needs.

Earnings

Earnings for drafters vary by specialty and level of responsibility. Median annual earnings of architectural and civil drafters were $37,330 in 2002. The middle 50 percent earned between $30,170 and $45,500. The lowest 10 percent earned less than $24,570, and the highest 10 percent earned more than $56,260. Median annual earnings for architectural and civil drafters in architectural, engineering, and related services were $36,780.

Median annual earnings of mechanical drafters were $40,730 in 2002. The middle 50 percent earned between $32,100 and $51,950. The lowest 10 percent earned less than $25,950, and the highest 10 percent earned more than $64,780. Median annual earnings for mechanical drafters in architectural, engineering, and related services were $41,170.

Median annual earnings of electrical and electronics drafters were $41,090 in 2002. The middle 50 percent earned between $32,060 and $53,440. The lowest 10 percent earned less than $25,710, and the highest 10 percent earned more than $68,000. In architectural, engineering, and related services, median annual earnings for electrical and electronics drafters were $39,760.

Related Occupations

Other workers who prepare or analyze detailed drawings and make precise calculations and measurements include architects, except landscape and naval; landscape architects; designers; engineers; engineering technicians; science technicians; and surveyors, cartographers, photogrammetrists, and surveying technicians.

Sources of Additional Information

Information on schools offering programs in drafting and related fields is available from:

➤ Accrediting Commission of Career Schools and Colleges of Technology, 2101 Wilson Blvd., Suite 302, Arlington, VA 22201. Internet: **http://www.accsct.org**

Information about certification is available from:

➤ American Design Drafting Association, 105 E. Main St., Newbern, TN 38059. Internet: **http://www.adda.org**

Engineering and Natural Sciences Managers

(0*NET 11-9041.00, 11-9121.00)

Significant Points

- Most engineering and natural sciences managers have previous experience as engineers, scientists, or mathematicians.
- Projected employment growth for engineering and natural sciences managers should be closely related to those for the engineers and scientists they supervise and the industries in which they are found.
- Opportunities will be best for workers with advanced technical knowledge and strong communication and business management skills.

Nature of the Work

Engineering and natural sciences managers plan, coordinate, and direct research, design, and production activities. They may supervise engineers, scientists, and technicians, along with support personnel. These managers use advanced technical knowledge of engineering and science to oversee a variety of activities. They determine scientific and technical goals within broad outlines provided by top executives, who are discussed elsewhere in the *Handbook*. These goals may include improving manufacturing processes, advancing scientific research, or developing new products. Managers make detailed plans to accomplish these goals—for example, they may develop the overall concepts of a new product or identify technical problems preventing the completion of a project.

To perform effectively, they also must possess knowledge of administrative procedures, such as budgeting, hiring, and supervision. These managers propose budgets for projects and programs and determine staff, training, and equipment needs. They hire and assign scientists, engineers, and support personnel to carry out specific parts of each project. They also supervise the work of these employees, review their output, and establish administrative procedures and policies—including environmental standards, for example.

In addition, these managers use communication skills extensively. They spend a great deal of time coordinating the activities of their unit with those of other units or organizations. They confer with higher levels of management; with financial, production, marketing, and other managers; and with contractors and equipment and materials suppliers.

Engineering managers supervise people who design and develop machinery, products, systems, and processes; or direct and coordinate production, operations, quality assurance, testing, or maintenance in industrial plants. Many are plant engineers, who direct and coordinate the design, installation, operation, and maintenance of equipment and machinery in industrial plants. Others manage research and development teams that produce new products and processes or improve existing ones.

Natural sciences managers oversee the work of life and physical scientists, including agricultural scientists, chemists, biologists, geologists, medical scientists, and physicists. These managers direct research and development projects and coordinate activities such as testing, quality control, and production. They may work on basic research projects or on commercial activities. Science managers sometimes conduct their own research in addition to managing the work of others.

Working Conditions

Engineering and natural sciences managers spend most of their time in an office. Some managers, however, also may work in laboratories, where they may be exposed to the same conditions as research scientists, or in industrial plants, where they may be exposed to the same conditions as production workers. Most managers work at least 40 hours a week and may work much longer on occasion to meet project deadlines. Some may experience considerable pressure to meet technical or scientific goals on a short deadline or within a tight budget.

Employment

Engineering and natural sciences managers held about 257,000 jobs in 2002. About 26 percent worked in professional, scientific, and technical services industries, primarily for firms providing architectural, engineering, and related services; computer systems design and related services; and scientific research and development services. Manufacturing industries employed 35 percent of engineering and natural sciences managers. Manufacturing industries with the largest employment include those producing computer and electronic equipment, machinery, transportation equipment, including aerospace products and parts, and chemicals, including pharmaceuticals. Other large employers include government agencies and telecommunications and utilities companies.

Training, Other Qualifications, and Advancement

Strong technical knowledge is essential for engineering and natural sciences managers, who must understand and guide the work of their subordinates and explain the work in nontechnical terms to senior management and potential customers. Therefore, these management positions usually require work experience and formal education similar to those of engineers, scientists, or mathematicians.

Most engineering managers begin their careers as engineers, after completing a bachelor's degree in the field. To advance to higher level positions, engineers generally must assume management responsibility. To fill management positions, employers seek engineers who possess administrative and communications skills in addition to technical knowledge in their specialty. Many engineers gain these skills by obtaining a master's degree in engineering management or a master's degree in business administration (MBA). Employers often pay for such training. In large firms, some courses required in these degree programs may be offered on site. Engineers who prefer to manage in technical areas should get a master's

Engineering and natural sciences managers provide guidance to employees and oversee day-to-day operations of the organization.

degree in engineering management, while those interested in nontechnical management should get an MBA.

Many science managers begin their careers as scientists, such as chemists, biologists, geologists, or mathematicians. Most scientists or mathematicians engaged in basic research have a Ph.D.; some in applied research and other activities may have a bachelor's or master's degree. Science managers must be specialists in the work they supervise. In addition, employers prefer managers with good communication and administrative skills. Graduate programs allow scientists to augment their undergraduate training with instruction in other fields, such as management or computer technology. Given the rapid pace of scientific developments, science managers must continuously upgrade their knowledge.

Engineering and natural sciences managers may advance to progressively higher leadership positions within their discipline. Some may become managers in nontechnical areas such as marketing, human resources, or sales. In high technology firms, managers in nontechnical areas often must possess the same specialized knowledge as do managers in technical areas. For example, employers in an engineering firm may prefer to hire experienced engineers as sales workers because the complex services offered by the firm can be marketed only by someone with specialized engineering knowledge. Such sales workers could eventually advance to jobs as sales managers.

Job Outlook

Employment of engineering and natural sciences managers is expected to have average growth through the year 2012—in line with projected employment growth in engineering and most sciences. However, many additional jobs will result from the need to replace managers who retire or move into other occupations. Opportunities for obtaining a management position will be best for workers with advanced technical knowledge and strong communication skills. In addition, business management skills are important because engineering and natural sciences managers are involved in their firm's financial, production, and marketing activities.

Projected employment growth for engineering and natural sciences managers should be closely related to the growth of the occupations they supervise and the industries in which they are found. For example, opportunities for managers should be better in rapidly growing areas of engineering—such as electrical, computer, and biomedical engineering—than in more slowly growing areas of engineering or physical science, such as aerospace and petroleum engineering. (See the statements on engineers and on life and physical scientists, elsewhere in the *Handbook*.) In addition, many employers are finding it more efficient to contract engineering and science management services to outside companies and consultants, creating good opportunities for managers in management services and management, scientific, and technical consulting firms.

Earnings

Earnings for engineering and natural sciences managers vary by specialty and level of responsibility. Median annual earnings of engineering managers were $90,930 in 2002. The middle 50 percent earned between $72,480 and $114,050. The lowest 10 percent earned less than $57,840, and the highest 10 percent earned more than $141,380. Median annual earnings in the industries employing the largest numbers of engineering managers in 2002 were:

Navigational, measuring, electromedical, and control instruments manufacturing	$101,290
Management of companies and enterprises	98,000
Aerospace product and parts manufacturing	97,420
Federal Government	90,030
Architectural, engineering, and related services	89,520

Median annual earnings of natural sciences managers were $82,250 in 2002. The middle 50 percent earned between $60,000 and $111,070. The lowest 10 percent earned less than $45,640, and the highest 10 percent earned more than $144,590. Median annual earnings in the industries employing the largest numbers of natural sciences managers in 2002 were:

Scientific research and development services	$101,690
Federal Government	77,020

A survey of manufacturing firms, conducted by Abbot, Langer & Associates, found that engineering department managers and superintendents earned a median annual income of $89,271 in 2003, while research and development managers earned $86,412.

In addition, engineering and natural sciences managers, especially those at higher levels, often receive more benefits—such as expense accounts, stock option plans, and bonuses—than do nonmanagerial workers in their organizations.

Related Occupations

The work of engineering and natural sciences managers is closely related to that of engineers; mathematicians; and physical and life scientists, including agricultural and food scientists, biological and medical scientists, conservation scientists and foresters, atmospheric scientists, chemists and materials scientists, environmental scientists and geoscientists, and physicists and astronomers. It also is related to the work of other managers, especially top executives.

Sources of Additional Information

For information about a career as an engineering and natural sciences manager, contact the sources of additional information for engineers, life scientists, and physical scientists that are listed at the end of statements on these occupations elsewhere in the *Handbook*.

Engineering Technicians

(0*NET 17-3021.00, 17-3022.00, 17-3023.01, 17-3023.02, 17-3023.03, 17-3024.00, 17-3025.00, 17-3026.00, 17-3027.00)

Significant Points

- Electrical and electronic engineering technicians make up 42 percent of all engineering technicians.
- Because the type and quality of training programs vary considerably, prospective students should carefully investigate training programs before enrolling.
- Opportunities will be best for individuals with an associate degree or extensive job training in engineering technology.

Nature of the Work

Engineering technicians use the principles and theories of science, engineering, and mathematics to solve technical problems in research and development, manufacturing, sales, construction, inspection, and maintenance. Their work is more limited in scope and more practically oriented than that of scientists and engineers. Many engineering technicians assist engineers and scientists, especially in research and development. Others work in quality control—inspecting products and processes, conducting tests, or collecting data. In manufacturing, they may assist in product design, development, or production. Although many workers who repair or maintain various types of electrical, electronic, or mechanical equipment are called technicians, these workers are covered in the *Handbook* section on installation, maintenance, and repair occupations.

Engineering technicians who work in research and development build or set up equipment, prepare and conduct experiments, collect data, calculate or record results, and help engineers or scientists in other ways, such as making prototype versions of newly designed equipment. They also assist in design work, often using computer-aided design (CAD) equipment.

Most engineering technicians specialize in certain areas, learning skills and working in the same disciplines as engineers. Occupational titles, therefore, tend to reflect those of engineers.

Aerospace engineering and operations technicians install, construct, maintain, and test systems used to test, launch, or track aircraft and space vehicles. They may calibrate test equipment and determine causes of equipment malfunctions. Using computer and communications systems, aerospace engineering and operations technicians often record and interpret test data.

Chemical engineering technicians usually are employed in industries producing pharmaceuticals, chemicals, and petroleum products, among others. They work in laboratories as well as processing plants. They help to develop new chemical products and processes, test processing equipment and instrumentation, gather data, and monitor quality.

Civil engineering technicians help civil engineers to plan and build highways, buildings, bridges, dams, wastewater treatment systems, and other structures, and to do related research. Some estimate construction costs and specify materials to be used, and some may even prepare drawings or perform land-surveying duties. Others may set up and monitor instruments used to study traffic conditions. (Cost estimators; drafters; and surveyors, cartographers, photogrammetrists, and surveying technicians are covered elsewhere in the *Handbook*.)

Electrical and electronics engineering technicians help to design, develop, test, and manufacture electrical and electronic equipment such as communication equipment, radar, industrial and medical measuring or control devices, navigational equipment, and computers. They may work in product evaluation and testing, using measuring and diagnostic devices to adjust, test, and repair equipment. (Workers whose jobs are limited to repairing electrical and electronic equipment, who often are referred to as electronics technicians, are included with electrical and electronics installers and repairers elsewhere in the *Handbook*.)

Electrical and electronic engineering technology also is applied to a wide variety of systems such as communication and process controls. *Electromechanical engineering technicians* combine fundamental principles of mechanical engineering technology with knowledge of electrical and electronic circuits to design, develop, test, and manufacture electrical and computer-controlled mechanical systems.

Environmental engineering technicians work closely with environmental engineers and scientists in developing methods and devices used in the prevention, control, or correction of environmental hazards. They inspect and maintain equipment affecting air pollution and recycling. Some inspect water and wastewater treatment systems to ensure that pollution control requirements are met.

Industrial engineering technicians study the efficient use of personnel, materials, and machines in factories, stores, repair shops, and offices. They prepare layouts of machinery and equipment, plan the flow of work, make statistical studies, and analyze production costs.

Mechanical engineering technicians help engineers to design, develop, test, and manufacture industrial machinery, consumer products, and other equipment. They may assist in product tests—by setting up instrumentation for auto crash tests, for example. They may make sketches and rough layouts, record data, make computations, analyze results, and write reports. When planning production, mechanical engineering technicians prepare layouts and drawings of the assembly process and of parts to be manufactured. They estimate labor costs, equipment life, and plant space. Some test and inspect machines and equipment or work with engineers to eliminate production problems.

Many engineering technicians assist engineers and scientists, especially in research and development.

Working Conditions

Most engineering technicians work at least 40 hours a week in laboratories, offices, or manufacturing or industrial plants, or on construction sites. Some may be exposed to hazards from equipment, chemicals, or toxic materials.

Employment

Engineering technicians held 478,000 jobs in 2002. 204,000 of these were electrical and electronics engineering technicians, as indicated by the following tabulation.

Electrical and electronic engineering technicians	204,000
Civil engineering technicians	92,000
Industrial engineering technicians	62,000
Mechanical engineering technicians	55,000
Electro-mechanical technicians	31,000
Environmental engineering technicians	19,000
Aerospace engineering and operations technicians	15,000

About 39 percent of all engineering technicians worked in manufacturing, mainly in the computer and electronic equipment, transportation equipment, and machinery manufacturing industries. Another 20 percent worked in professional, scientific, and technical service industries, mostly in engineering or business services companies that do engineering work on contract for government, manufacturing firms, or other organizations.

In 2002, the Federal Government employed 11,000 engineering technicians. State governments employed 34,000, and local governments employed 24,000.

Training, Other Qualifications, and Advancement

Although it may be possible to qualify for certain engineering technician jobs without formal training, most employers prefer to hire someone with at least a 2-year associate degree in engineering technology. Training is available at technical institutes, community colleges, extension divisions of colleges and universities, and public and private vocational-technical schools, and in the Armed Forces. Persons with college courses in science, engineering, and mathematics may qualify for some positions but may need additional specialized training and experience. Although employers usually do not require engineering technicians to be certified, such certification may provide jobseekers a competitive advantage.

Prospective engineering technicians should take as many high school science and math courses as possible to prepare for postsecondary programs in engineering technology. Most 2-year associate degree programs accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC/ABET) require, at a minimum, college algebra and trigonometry, and one or two basic science courses. Depending on the specialty, more math or science may be required.

The type of technical courses required also depends on the specialty. For example, prospective mechanical engineering technicians may take courses in fluid mechanics, thermodynamics, and mechanical design; electrical engineering technicians may need classes in electric circuits, microprocessors, and digital electronics; and those preparing to work in environmental engineering technology need courses in environmental regulations and safe handling of hazardous materials.

Because many engineering technicians assist in design work, creativity is desirable. Because these workers often are part of a team of engineers and other technicians, good communication skills and the ability to work well with others also are important.

Engineering technicians usually begin by performing routine duties under the close supervision of an experienced technician, technologist, engineer, or scientist. As they gain experience, they are given more difficult assignments with only general supervision. Some engineering technicians eventually become supervisors.

Many publicly and privately operated schools provide technical training; the type and quality of training varies considerably. Therefore, prospective students should be careful in selecting a program. They should contact prospective employers regarding their preferences and ask schools to provide information about the kinds of jobs obtained by graduates, instructional facilities and equipment, and faculty qualifications. Graduates of ABET-accredited programs usually are recognized to have achieved an acceptable level of competence in the mathematics, science, and technical courses required for this occupation.

Technical institutes offer intensive technical training through application and practice, but less theory and general education than do community colleges. Many offer 2-year associate degree programs, and are similar to or part of a community college or State university system. Other technical institutes are run by private, often for-profit organizations, sometimes called proprietary schools. Their programs vary considerably in length and types of courses offered, although some are 2-year associate degree programs.

Community colleges offer curriculums that are similar to those in technical institutes, but that may include more theory and liberal arts. There may be little or no difference between programs at technical institutes and community colleges, as both offer associate degrees. After completing the 2-year program, some graduates get jobs as engineering technicians, while others continue their education at 4-year colleges. However, there is a difference between an associate degree in pre-engineering and one in engineering technology. Students who enroll in a 2-year pre-engineering program may find it very difficult to find work as an engineering technician should they decide not to enter a 4-year engineering program, because pre-engineering programs usually focus less on hands-on applications and more on academic preparatory work. Conversely, graduates of 2-year engineering technology programs may not receive credit for some of the courses they have taken if they choose to transfer to a 4-year engineering program. Colleges with these 4-year programs usually do not offer engineering technician training, but college courses in science, engineering, and mathematics are useful for obtaining a job as an engineering technician. Many 4-year colleges offer bachelor's degrees in engineering technology, but graduates of these programs often are hired to work as technologists or applied engineers, not technicians.

Area vocational-technical schools, another source of technical training, include postsecondary public institutions that serve local students and emphasize training needed by local employers. Most require a high school diploma or its equivalent for admission.

Other training in technical areas may be obtained in the Armed Forces. Many military technical training programs are highly regarded by employers. However, skills acquired in military programs are often narrowly focused, so they may not be useful in civilian industry, which often requires broader training. Therefore, some additional training may be needed, depending on the acquired skills and the kind of job.

The National Institute for Certification in Engineering Technologies (NICET) has established a voluntary certification program for engineering technicians. Certification is available at various levels, each level combining a written examination in 1 of about 30 specialties with a certain amount of job-related experience, a supervisory evaluation, and a recommendation.

Job Outlook

Opportunities will be best for individuals with an associate degree or extensive job training in engineering technology. As technology becomes more sophisticated, employers will continue to look for technicians who are skilled in new technology and require a minimum of additional job training. An increase in the number of jobs related to public health and safety should create job opportunities for engineering technicians with the appropriate certification.

Overall employment of engineering technicians is expected to increase about as fast as the average for all occupations through 2012. Competitive pressures will force companies to improve and update manufacturing facilities and product designs, resulting in more jobs for engineering technicians. However, the growing use of advanced technologies, such as computer simulation and computer-aided design and drafting will continue to increase productivity and limit job growth. In addition to growth, many job openings will stem from the need to replace technicians who retire or leave the labor force.

As is the case for engineers, employment of engineering technicians is influenced by local and national economic conditions. As a result, the employment outlook varies with industry and specialization. Growth in the largest specialty—electrical and electronics engineering technicians—is expected to be about as fast as the average, and there will also be many jobs created by the need to replace technicians who retire or leave the labor force. Employment of environmental engineering technicians is expected to grow faster than average, partly due to increased demand for environmental protection and partly due to recognition of environmental engineering technicians as a separate occupation.

Earnings

Median annual earnings of engineering technicians by specialty is shown in the following tabulation.

Aerospace engineering and operations technicians	$51,650
Electrical and electronic engineering technicians	42,950
Industrial engineering technicians	41,910
Mechanical engineering technicians	41,280
Electro-mechanical technicians	38,120
Civil engineering technicians	37,720
Environmental engineering technicians	36,850

Median annual earnings of electrical and electronics engineering technicians were $42,950 in 2002. The middle 50 percent earned between $33,760 and $53,200. The lowest 10 percent earned less than $26,770, and the highest 10 percent earned more than $64,070. Median annual earnings in the industries employing the largest numbers of electrical and electronics engineering technicians in 2002 are shown below.

Federal government	$58,520
Wired telecommunications carriers	49,610
Architectural, engineering, and related services	43,670
Semiconductor and other electronic component manufacturing	40,110
Navigational, measuring, electromedical, and control instruments manufacturing	39,760

Median annual earnings of civil engineering technicians were $37,720 in 2002. The middle 50 percent earned between $29,030 and $47,260. The lowest 10 percent earned less than $23,080, and the highest 10 percent earned more than $56,910. Median annual earnings in the industries employing the largest numbers of civil engineering technicians in 2002 are shown below.

Local government	42,120
Architectural, engineering, and related services	36,930
State government	34,800

In 2002, the average annual salary for aerospace engineering and operations technicians in the aerospace products and parts manufacturing industry was $54,530, and the average annual salary for environmental engineering technicians in the architectural, engineering, and related services industry was $32,690. The average annual salary for industrial engineering technicians in the semiconductor and other electronic component manufacturing industry was $38,230. In the architectural, engineering, and related services industry, the average annual salary for mechanical engineering technicians was $42,090.

Related Occupations

Engineering technicians apply scientific and engineering principles usually acquired in postsecondary programs below the baccalaureate level. Similar occupations include science technicians; drafters; surveyors, cartographers, photogrammetrists, and surveying technicians; and broadcast and sound engineering technicians and radio operators.

Sources of Additional Information

High school students interested in obtaining information about careers in engineering technology should visit the JETS Web site: **http://www.jets.org**.

➤ JETS-Guidance, 1420 King St., Suite 405, Alexandria, VA 22314-2794.

Information on ABET-accredited engineering technology programs is available from:

➤ Accreditation Board for Engineering and Technology, Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202. Internet: **http://www.abet.org**

Information on certification of engineering technicians as well as job and career information is available from:

➤ National Institute for Certification in Engineering Technologies (NICET), 1420 King St., Alexandria, VA 22314-2794. Internet: **http://www.nicet.org**

Engineers

(0*NET 17-2011.00, 17-2021.00, 17-2031.00, 17-2041.00, 17-2051.00, 17-2061.00, 17-2071.00, 17-2072.00, 17-2081.00, 17-2111.01, 17-2111.02, 17-2111.03, 17-2112.00, 17-2121.01, 17-2121.02, 17-2131.00, 17-2141.00, 17-2151.00, 17-2161.00, 17-2171.00, 17-2199.99)

Significant Points

- Overall, job opportunities in engineering are expected to be good, but will vary by specialty.
- A bachelor's degree is required for most entry-level jobs.
- Starting salaries are significantly higher than those of college graduates in other fields.
- Continuing education is critical to keep abreast of the latest technology.

Nature of the Work

Engineers apply the theories and principles of science and mathematics to research and develop economical solutions to technical problems. Their work is the link between perceived social needs and commercial applications. Engineers design products, machinery to build those products, plants in which those products are made, and the systems that ensure the quality of the products and the efficiency of the workforce and manufacturing process. Engineers design, plan, and supervise the construction of buildings, highways, and transit systems. They develop and implement improved ways to extract, process, and use raw materials, such as petroleum and natural gas. They develop new materials that both improve the performance of products and take advantage of advances in technology. They harness the power of the sun, the Earth, atoms, and electricity for use in supplying the Nation's power needs, and create millions of products using power. They analyze the impact of the products they develop or the systems they design on the environment and on people using them. Engineering knowledge is applied to improving many things, including the quality of healthcare, the safety of food products, and the operation of financial systems.

Engineers consider many factors when developing a new product. For example, in developing an industrial robot, engineers determine precisely what function the robot needs to perform; design and test the robot's components; fit the components together in an integrated plan; and evaluate the design's overall effectiveness, cost, reliability, and safety. This process applies to many different products, such as chemicals, computers, gas turbines, helicopters, and toys.

In addition to design and development, many engineers work in testing, production, or maintenance. These engineers supervise production in factories, determine the causes of breakdowns, and test manufactured products to maintain quality. They also estimate the time and cost to complete projects. Some move into engineering management or into sales. In sales, an engineering background enables them to discuss technical aspects and assist in product planning, installation, and use. (See the statements on engineering and natural sciences managers, and sales engineers, elsewhere in the *Handbook*.)

Most engineers specialize. More than 25 major specialties are recognized by professional societies, and the major branches have numerous subdivisions. Some examples include structural and transportation engineering, which are subdivisions of civil engineering; and ceramic, metallurgical, and polymer engineering, which are subdivisions of materials engineering. Engineers also may specialize in one industry, such as motor vehicles, or in one field of technology, such as turbines or semiconductor materials.

This statement, which contains an overall discussion of engineering, is followed by separate statements on 14 branches of engineering: Aerospace; agricultural; biomedical; chemical; civil; computer hardware; electrical and electronics, except computer; environmental; industrial, including health and safety; materials; mechanical; mining and geological, including mining safety; nuclear; and petroleum engineering. (Computer software engineers are discussed elsewhere in the *Handbook*.) Some branches of engineering not covered in detail in the *Handbook*, but for which there are established college programs, include architectural engineering—the design of a building's internal support structure; and marine engineering—the design and installation of ship machinery and propulsion systems.

Engineers in each branch have a base of knowledge and training that can be applied in many fields. Electronics engineers, for example, work in the medical, computer, communications, and missile guidance fields. Because there are many separate problems to solve in a large engineering project, engineers in one field often work closely with specialists in other scientific, engineering, and business occupations.

Engineers use computers to produce and analyze designs; to simulate and test how a machine, structure, or system operates; and to generate specifications for parts. Using the Internet or related communications systems, engineers can collaborate on designs with other engineers around the country or even abroad. Many engineers also use computers to monitor product quality and control process efficiency. They spend a great deal of time writing reports and consulting with other engineers, as complex projects often require an interdisciplinary team of engineers. Supervisory engineers are responsible for major components or entire projects.

Working Conditions

Most engineers work in office buildings, laboratories, or industrial plants. Others may spend time outdoors at construction sites and oil and gas exploration and production sites, where they monitor or direct operations or solve onsite problems. Some engineers travel extensively to plants or worksites.

Many engineers work a standard 40-hour week. At times, deadlines or design standards may bring extra pressure to a job, sometimes requiring engineers to work longer hours.

Employment

In 2002 engineers held 1.5 million jobs. The following tabulation shows the distribution of employment by engineering specialty.

Specialty	*Employment*	*Percent*
Total, all engineers	1,478,000	100
Electrical and electronics	292,000	19.8
Civil	228,000	15.4
Mechanical	215,000	14.5
Industrial, including health and safety	194,000	13.1
Aerospace	78,000	5.3
Computer hardware	74,000	5.0
Environmental	47,000	3.2
Chemical	33,000	2.2
Materials	24,000	1.6
Nuclear	16,000	1.1
Petroleum	14,000	0.9
Biomedical	7,600	0.5
Mining and geological, including mining safety	5,200	0.4
Marine engineers and naval architects	4,900	0.3
Agricultural	2,900	0.2
All other engineers	243,000	16.4

Almost 4 in 10 of all engineering jobs were found in manufacturing industries, such as transportation and equipment manufacturing and computer and electronic product manufacturing. About 354,000 wage and salary jobs were in the professional, scientific, and technical service industry, primarily in architectural, engineering, and related services and in scientific research and development services, where firms designed construction projects or did other engineering work on a contractual basis. Engineers also worked in the construction and transportation, telecommunications, and utilities industries.

Federal, State, and local governments employed about 192,000 engineers in 2002. About 88,000 of these were in the Federal Government, mainly in the U.S. Departments of Defense, Transportation, Agriculture, Interior, and Energy, and in the National Aeronautics and Space Administration. Most engineers in State and local government agencies worked in highway and public works departments. In 2002, about 55,000 engineers were self-employed, many as consultants.

Engineers are employed in every State, in small and large cities, and in rural areas. Some branches of engineering are concentrated in particular industries and geographic areas, as discussed later in this chapter.

Training, Other Qualifications, and Advancement

A bachelor's degree in engineering is required for almost all entry-level engineering jobs. College graduates with a degree in a physical science or mathematics occasionally may qualify for some engineering jobs, especially in specialties in high demand. Most engineering degrees are granted in electrical, electronics, mechanical, or civil engineering. However, engineers trained in one branch may work in related branches. For example, many aerospace engineers have training in mechanical engineering. This flexibility allows employers to meet staffing needs in new technologies and specialties in which engineers may be in short supply. It also allows engineers to shift to fields with better employment prospects or to those that more closely match their interests.

Most engineering programs involve a concentration of study in an engineering specialty, along with courses in both mathematics and science. Most programs include a design course, sometimes accompanied by a computer or laboratory class or both.

In addition to the standard engineering degree, many colleges offer 2- or 4-year degree programs in engineering technology. These programs, which usually include various hands-on laboratory classes that focus on current issues, prepare students for practical design and production work, rather than for jobs that require more theoretical and scientific knowledge. Graduates of 4-year technology programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. Engineering technology graduates, however, are not qualified to register as professional engineers under the same terms as graduates with degrees in engineering. Some employers regard technology program graduates as having skills between those of a technician and an engineer.

Graduate training is essential for engineering faculty positions and many research and development programs, but is not required for the majority of entry-level engineering jobs. Many engineers obtain graduate degrees in engineering or business administration to learn new technology and broaden their education. Many high-level executives in government and industry began their careers as engineers.

About 340 colleges and universities offer bachelor's degree programs in engineering that are accredited by the Accreditation Board for Engineering and Technology (ABET), and about 240 colleges offer accredited bachelor's degree programs in engineering technology. ABET accreditation is based on an examination of an engineering program's student achievement, program improvement, faculty, curricular content, facilities, and institutional commitment. Although most institutions offer programs in the major branches of engineering, only a few offer programs in the smaller specialties. Also, programs of the same title may vary in content. For example, some programs emphasize industrial practices, preparing students for a job in industry, whereas others are more theoretical and are designed to prepare students for graduate work. Therefore, students should investigate curricula and check accreditations carefully before selecting a college.

Admissions requirements for undergraduate engineering schools include a solid background in mathematics (algebra, geometry, trigonometry, and calculus) and science (biology, chemistry, and physics), and courses in English, social studies, humanities, and computer and information technology. Bachelor's degree programs in engineering typically are designed to last 4 years, but many students find that it takes between 4 and 5 years to complete their studies. In a typical 4-year college curriculum, the first 2 years are spent studying mathematics, basic sciences, introductory engineering, humanities, and social sciences. In the last 2 years, most courses are in engineering, usually with a concentration in one branch. For example, the last 2 years of an aerospace program might include courses in fluid mechanics, heat transfer, applied aerodynamics, analytical mechanics, flight vehicle design, trajectory dynamics, and aerospace propulsion systems. Some programs offer a general engineering curriculum; students then specialize in graduate school or on the job.

Some engineering schools and 2-year colleges have agreements whereby the 2-year college provides the initial engineering education, and the engineering school automatically admits students for their last 2 years. In addition, a few engineering schools have arrangements whereby a student spends 3 years in a liberal arts college studying pre-engineering subjects and 2 years in an engineering school studying core subjects, and then receives a bachelor's degree from each school. Some colleges and universities offer 5-year master's degree programs. Some 5-year or even 6-year cooperative plans combine classroom study and practical work, permitting students to gain valuable experience and to finance part of their education.

All 50 States and the District of Columbia require licensure for engineers who offer their services directly to the public. Engineers who are licensed are called Professional Engineers (PE). This licensure generally requires a degree from an ABET-accredited engineering program, 4 years of relevant work experience, and successful completion of a State examination. Recent graduates can start the licensing process by taking the examination in two stages. The initial Fundamentals of Engineering (FE) examination can be taken upon graduation. Engineers who pass this examination commonly are called Engineers in Training (EIT) or Engineer Interns (EI). After acquiring suitable work experience, EITs can take the second examination, the Principles and Practice of Engineering exam. Several States have imposed mandatory continuing education requirements for relicensure. Most States recognize licensure from other States provided that the manner in which the initial license was obtained meets or exceeds their licensure requirements. Many civil, electrical, mechanical, and chemical engineers are licensed PEs.

Engineers should be creative, inquisitive, analytical, and detail-oriented. They should be able to work as part of a team and to communicate well, both orally and in writing. Communication abilities are important because engineers often interact with specialists in a wide range of fields outside engineering.

Beginning engineering graduates usually work under the supervision of experienced engineers and, in large companies, also may receive formal classroom or seminar-type training. As new engineers gain knowledge and experience, they are assigned more difficult projects with greater independence to develop designs, solve problems, and make decisions. Engineers may advance to become technical specialists or to supervise a staff or team of engineers and technicians. Some may eventually become engineering managers or enter other managerial or sales jobs. (See the statements under management and business and financial operations occupations, and sales and related occupations, elsewhere in the *Handbook*.)

Job Outlook

Overall engineering employment is expected to increase more slowly than the average for all occupations over the 2002-12 period. Engineers tend to be concentrated in slow-growing manufacturing industries, a factor which tends to hold down their employment growth. Also, many employers are increasing their use of engineering services performed in other countries. Despite this, overall job opportunities in engineering are expected to be good because the number of engineering graduates should be in rough balance with the number of job openings over this period. Expected changes in employment and, thus, job opportunities vary by specialty. Projections range from a decline in employment of mining and geological engineers, petroleum engineers, and nuclear engineers to much faster than average growth among environmental engineers.

Competitive pressures and advancing technology will force companies to improve and update product designs and to optimize their manufacturing processes. Employers will rely on engineers to further increase productivity, as investment in plant and equipment increases to expand output of goods and services. New computer and communications systems have improved the design process, enabling engineers to produce and analyze various product designs much more rapidly than in the past and to collaborate on designs with other engineers throughout the world. Despite these widespread applications, computer technology is not expected to limit employment opportunities. Finally, additional engineers will be needed to improve or build new roads, bridges, water and pollution control systems, and other public facilities.

There is a large number of well-trained, often English-speaking engineers available in many countries who are willing to work at much lower salaries than U.S. engineers. The rise of the Internet and other electronic communications systems has made it relatively easy for much of the engineering work previously done by engineers in this country to be done by engineers in other countries, a factor that will tend to hold down employment growth.

Compared with most other workers, a smaller proportion of engineers leave their jobs each year. Nevertheless, many job openings will arise from replacement needs, reflecting the large size of this profession. Numerous job openings will be created by engineers who transfer to management, sales, or other professional occupations; additional openings will arise as engineers retire or leave the labor force for other reasons.

Many engineers work on long-term research and development projects or in other activities that continue even during economic slowdowns. In industries such as electronics and aerospace, however, large cutbacks in defense expenditures and government research and development funds in the past, as well as the trend toward contracting out engineering work to engineering services firms, both domestic and foreign, have resulted in significant layoffs of engineers.

It is important for engineers, like those working in other technical occupations, to continue their education throughout their careers because much of their value to their employer depends on their knowledge of the latest technology. Although the pace of technological change varies by engineering specialty and industry, advances in technology have significantly affected every engineering discipline. Engineers in high-technology areas, such as advanced electronics or information technology, may find that technical knowledge can become outdated rapidly. Even those who continue their education are vulnerable to layoffs if the particular technology or product in which they have specialized becomes obsolete. By keeping current in their field, engineers are able to deliver the best solutions and greatest value to their employers. Engineers who have not kept current in their field may find themselves passed over for promotions or vulnerable to layoffs, should they occur. On the other hand, it often is these high-technology areas that offer the greatest challenges, the most interesting work, and the highest salaries. Therefore, the choice of engineering specialty and employer involves an assessment not only of the potential rewards but also of the risk of technological obsolescence.

Related Occupations

Engineers apply the principles of physical science and mathematics in their work. Other workers who use scientific and mathematical principles include architects, except landscape and naval; engineering and natural sciences managers; computer and information systems managers; mathematicians; drafters; engineering technicians; sales engineers; science technicians; and physical and life scientists, including agricultural and food scientists, biological scientists, conservation scientists and foresters, atmospheric scientists, chemists and materials scientists, environmental scientists and geoscientists, and physicists and astronomers.

Sources of Additional Information

High school students interested in obtaining information about careers in engineering should visit the JETS Web site: **http://www.jets.org**.

➤ JETS-Guidance, 1420 King St., Suite 405, Alexandria, VA 22314-2794.

Information on ABET-accredited engineering programs is available from:

➤ The Accreditation Board for Engineering and Technology, Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202-4012. Internet: **http://www.abet.org**

Those interested in information on the Professional Engineer licensure should contact:

➤ The National Society of Professional Engineers, 1420 King St., Alexandria, VA 22314-2794. Internet: **http://www.nspe.org**

➤ National Council of Examiners for Engineers and Surveying, P.O. Box 1686, Clemson, SC 29633-1686. Internet: **http://www.ncees.org**

Information on general engineering education and career resources is available from:

➤ American Society for Engineering Education, 1818 N St. NW., Suite 600, Washington, DC 20036-2479. Internet: **http://www.asee.org**

Information on obtaining an engineering position with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (703) 724-1850; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site **http://www.usajobs.opm.gov**

Non-high school students wanting more detailed information on an engineering specialty should contact societies representing the individual branches of engineering. Each can provide information about careers in the particular branch. The individual statements that follow also provide other detailed information on aerospace; agricultural; biomedical; chemical; civil; computer hardware; electrical and electronics, except computer; environmental; industrial, including health and safety; materials; mechanical; mining and geological, including mining safety; nuclear; and petroleum engineering.

Aerospace Engineers

(0*NET 17-2011.00)

Nature of the Work

Aerospace engineers create extraordinary machines, from airplanes that weigh over a half a million pounds to spacecraft that travel over 17,000 miles an hour. They design, develop, and test aircraft, spacecraft, and missiles and supervise the manufacture of these products. Aerospace engineers who work with aircraft are called *aeronautical engineers*, and those working specifically with spacecraft are *astronautical engineers*.

Aerospace engineers develop new technologies for use in aviation, defense systems, and space exploration, often specializing in areas such as structural design, guidance, navigation and control, instrumentation and communication, or production methods. They often use computer-aided design (CAD) software, robotics, and lasers and advanced electronic optics. They also may specialize in a particular type of aerospace product, such as commercial transports, military fighter jets, helicopters, spacecraft, or missiles and rockets. Aerospace engineers may be experts in aerodynamics, thermodynamics, celestial mechanics, propulsion, acoustics, or guidance and control systems.

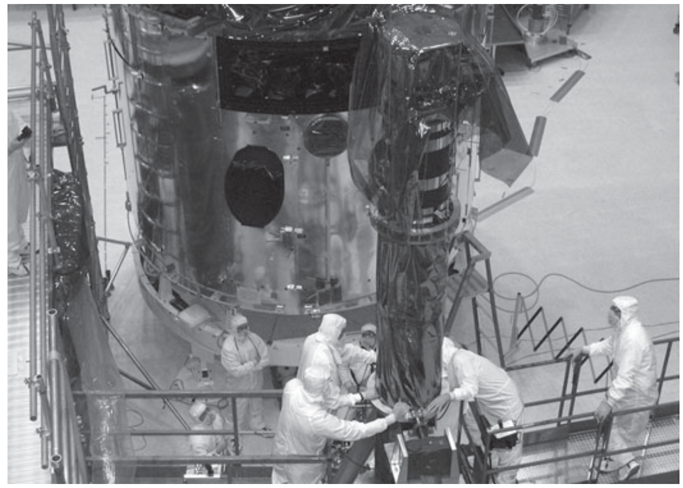
Aerospace engineers typically are employed in the aerospace product and parts industry, although their skills are becoming increasingly valuable in other fields. For example, in the motor vehicles manufacturing industry, aerospace engineers design vehicles that have lower air resistance and, thus, increased fuel efficiency.

Employment

Aerospace engineers held about 78,000 jobs in 2002. Most worked in the aerospace product and parts manufacturing industries. Federal Government agencies, primarily the U.S. Department of Defense and the National Aeronautics and Space Administration, provided 10 percent of jobs. Architectural, engineering and related services, scientific research and development services, and navigational, measuring, electromedical, and control instruments manufacturing industry firms accounted for most of the remaining jobs.

Job Outlook

Employment of aerospace engineers is expected to decline over the projection period. Foreign competition and the slowdown in air travel will limit the number of new jobs for aerospace engineers related to the design and production of commercial aircraft over the projection period. Despite the expected decline in employment, favorable opportunities are expected for aerospace engineers through 2012 because the number of degrees granted in aerospace engineering has declined greatly over the last decade due to the perceived lack of opportunities in this occupation. The decline in degree production has reached the point that the number trained in aerospace engineering may not be adequate to replace the large numbers of aerospace engineers who are expected to leave the occupation, especially due to retirement, over the 2002-12 period. Some employment opportunities also will occur in industries not typically associated with aerospace, such as motor vehicle manufacturing.



Aerospace engineers prepare a space vehicle for launch.

Earnings

Median annual earnings of aerospace engineers were $72,750 in 2002. The middle 50 percent earned between $59,520 and $88,310. The lowest 10 percent earned less than $49,640, and the highest 10 percent earned more than $105,060. Median annual earnings in the industries employing the largest numbers of aerospace engineers in 2002 were:

Federal government	$81,830
Architectural, engineering, and related services	74,890
Aerospace product and parts manufacturing	70,920

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in aerospace engineering received starting salary offers averaging $48,028 a year, master's degree candidates were offered $61,162, and Ph.D. candidates were offered $68,406.

Sources of Additional Information

For further information about careers in the aerospace industry, contact:

➤ Aerospace Industries Association, 1250 Eye St. NW., Suite 1200, Washington, DC 20005-3924. Internet: **http://www.aia-aerospace.org**

➤ American Institute of Aeronautics and Astronautics, Inc., 1801 Alexander Bell Dr., Suite 500, Reston, VA 20191-4344. Internet: **http://www.aiaa.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Agricultural Engineers

(0*NET 17-2021.00)

Agricultural engineers apply knowledge of engineering technology and biological science to agriculture.

Nature of the Work

Agricultural engineers apply knowledge of engineering technology and biological science to agriculture. (See biological scientists and agricultural and food scientists elsewhere in the *Handbook*.) They design agricultural machinery and equipment and agricultural structures. Some specialties include power systems and machinery design; structures and environment; and food and bioprocess engineering. They develop ways to conserve soil and water and to improve the processing of agricultural products. Agricultural engineers work in research and development, production, sales, or management.

Employment

About one third of the 2,900 agricultural engineers employed in 2002 worked for professional, scientific, and technical services, supplying consultant services to farmers and farm-related industries. Others worked in a wide variety of industries, including crops and livestock as well as manufacturing and government.

Job Outlook

Employment of agricultural engineers is expected to increase about as fast as the average for all occupations through 2012. The growing interest in worldwide standardization of agricultural equipment should result in increased employment of agricultural engineers. Job opportunities also should result from the increasing demand for agricultural products, the continued efforts for more efficient agricultural production, and the increasing emphasis on the conservation of resources. In addition to those resulting from employment growth, job openings will be created by the need to replace agricultural engineers who transfer to other occupations or leave the labor force.

Earnings

Median annual earnings of agricultural engineers were $50,700 in 2002. The middle 50 percent earned between $40,320 and $70,100. The lowest 10 percent earned less than $35,590, and the highest 10 percent earned more than $87,220.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in agricultural engineering received starting offers averaging $42,987 a year, and master's degree candidates, on average, were offered $54,000.

Sources of Additional Information

Information on a career as an agricultural engineer can be obtained from:

➤ American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659. Internet: **http://www.asae.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Biomedical Engineers

(0*NET 17-2031.00)

Nature of the Work

By combining biology and medicine with engineering, biomedical engineers develop devices and procedures that solve medical and health-related problems. Many do research, along with life scientists, chemists, and medical scientists, to develop and evaluate systems and products for use in the fields of biology and health, such as artificial organs, prostheses (artificial devices that replace missing body parts), instrumentation, medical information systems, and health management and care delivery systems. (See biological scientists, medical scientists, and chemists and materials scientists elsewhere in the *Handbook*.) Biomedical engineers design devices used in various medical procedures, such as the computers used to analyze blood or the laser systems used in corrective eye surgery. They develop artificial organs, imaging systems such as magnetic resonance, ultrasound, and x-ray, and devices for automating insulin injections or controlling body functions. Most engineers in this specialty require a sound background in one of the basic engineering specialties, such as mechanical or electronics engineering, in addition to specialized biomedical training. Some specialties within biomedical engineering include biomaterials, biomechanics, medical imaging, rehabilitation engineering, and orthopedic engineering.

Unlike many other engineering specialties, a graduate degree is recommended or required for many entry-level jobs.

Employment

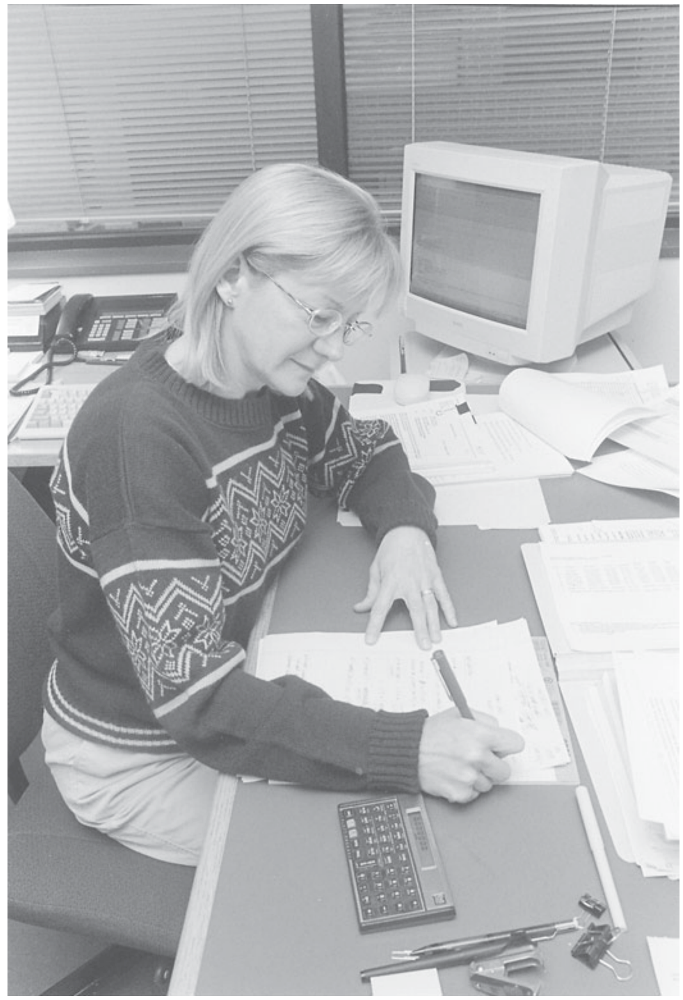
Biomedical engineers held about 7,600 jobs in 2002. Manufacturing industries employed 38 percent of all biomedical engineers, primarily in the pharmaceutical and medicine manufacturing and medical instruments and supplies industries. Many others worked for hospitals. Some also worked for government agencies or as independent consultants.

Job Outlook

Employment of biomedical engineers is expected to increase faster than the average for all occupations through 2012. The aging of the population and the focus on health issues will increase the demand for better medical devices and equipment designed by biomedical engineers. For example, computer-assisted surgery and molecular, cellular, and tissue engineering are being more heavily researched and are developing rapidly. In addition, the rehabilitation and orthopedic engineering specialties are growing quickly, increasing the need for biomedical engineers. Along with the demand for more sophisticated medical equipment and procedures is an increased concern for cost efficiency and effectiveness that also will boost demand for biomedical engineers. However, because of the growing interest in this field, the number of degrees granted in biomedical engineering has increased greatly, leading to the potential for competition for jobs.

Earnings

Median annual earnings of biomedical engineers were $60,410 in 2002. The middle 50 percent earned between $58,320 and $88,830. The lowest 10 percent earned less than $48,450, and the highest 10 percent earned more than $107,520.



Many biomedical engineers conduct research to develop and evaluate systems and products for use in the fields of biology and health.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in biomedical engineering received starting offers averaging $39,126 a year, and master's degree candidates, on average, were offered $61,000.

Sources of Additional Information

For further information about biomedical engineering careers, contact:

➤ Biomedical Engineering Society, 8401 Corporate Dr., Suite 225, Landover, MD 20785-2224. Internet: **http://www.bmes.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Chemical Engineers

(0*NET 17-2041.00)

Nature of the Work

Chemical engineers build a bridge between science and manufacturing, applying the principles of chemistry and engineering to solve problems involving the production or use of chemicals. They design equipment and develop processes for large-scale chemical manufacturing, plan and test methods of manufacturing products and treating byproducts, and supervise production. Chemical engineers also work in a variety of manufacturing industries other than chemical manufacturing, such as those producing electronics, photographic equipment, clothing, and pulp and paper. They also work in the healthcare, biotechnology, and business services industries.

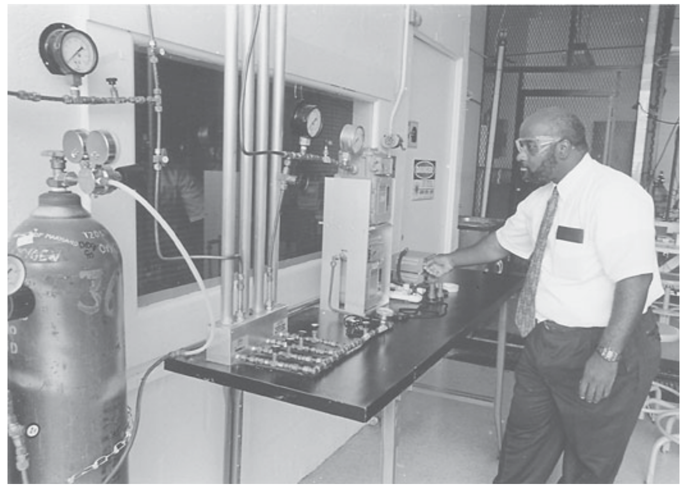
The knowledge and duties of chemical engineers overlap many fields. Chemical engineers apply principles of chemistry, physics, mathematics, and mechanical and electrical engineering. (See chemists and materials scientists; physicists and astronomers; mechanical engineers; electrical and electronics engineers, except computer; and mathematicians elsewhere in the *Handbook*.) They frequently specialize in a particular chemical process such as oxidation or polymerization. Others specialize in a particular field, such as materials science, or the development of specific products such as fertilizers and pesticides, automotive plastics, or chlorine bleach. They must be aware of all aspects of chemicals manufacturing and how it affects the environment, the safety of workers, and customers. Because chemical engineers use computer technology to optimize all phases of research and production, they need to understand how to apply computer skills to chemical process analysis, automated control systems, and statistical quality control.

Employment

Chemical engineers held about 33,000 jobs in 2002. Manufacturing industries employed 55 percent of all chemical engineers, primarily in the chemicals, electronics, petroleum refining, paper, and related industries. Most others worked for professional, scientific, or technical services firms that design chemical plants or perform research and development or other services, mainly for chemical companies.

Job Outlook

Little or no growth in employment of chemical engineers is expected though 2012. Although overall employment in the chemical manufacturing industry is expected to decline, chemical companies will continue to research and develop new chemicals and more efficient processes to increase output of existing chemicals. Among manufacturing industries, pharmaceuticals may provide the best opportunities for jobseekers. Many of the jobs for chemical engineers, however, will be in nonmanufacturing industries, especially services industries such as research and testing services. Even though no new jobs due to growth are expected to be created, many openings will result from the need to replace chemical engineers who transfer to other occupations or leave the labor force.



In addition to working in the chemical industry, chemical engineers are employed in a variety of other manufacturing industries and professional, scienitfic, and technical services firms.

Earnings

Median annual earnings of chemical engineers were $72,490 in 2002. The middle 50 percent earned between $58,320 and $88,830. The lowest 10 percent earned less than $48,450, and the highest 10 percent earned more than $107,520.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in chemical engineering received starting offers averaging $52,384 a year, master's degree candidates averaged $57,857, and Ph.D. candidates averaged $70,729.

Sources of Additional Information

Information on careers, employment, education, training, conferences, and publications on chemical engineering is available from:

➤ American Institute of Chemical Engineers, 3 Park Ave., New York, NY 10016-5901. Internet: **http://www.aiche.org**

Additional information on careers in chemical engineering is available from:

➤ American Chemical Society, Department of Career Services, 1155 16th St. NW., Washington, DC 20036. Internet: **http://www.chemistry.org/portal/Chemistry**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Civil Engineers

(0*NET 17-2051.00)

Nature of the Work

Civil engineers design and supervise the construction of roads, buildings, airports, tunnels, dams, bridges, and water supply and sewage systems. Civil engineering, considered one of the oldest engineering disciplines, encompasses many specialties. The major specialties within civil engineering are structural, water resources, environmental, construction, transportation, and geotechnical engineering.

Many civil engineers hold supervisory or administrative positions, from supervisor of a construction site to city engineer. Others may work in design, construction, research, and teaching.

Employment

Civil engineers held about 228,000 jobs in 2002. More than 4 in 10 were employed by firms providing architectural, engineering, and related services, primarily developing designs for new construction projects. Almost one-third of the jobs were in Federal, State, and local government agencies. The construction industry accounted for most of the remaining employment. About 15,000 civil engineers were self-employed, many as consultants.

Civil engineers usually work near major industrial and commercial centers, often at construction sites. Some projects are situated in remote areas or in foreign countries. In some jobs, civil engineers move from place to place to work on different projects.

Job Outlook

Employment of civil engineers is expected to increase more slowly than the average for all occupations through 2012. Spurred by general population growth and an increased emphasis on infrastructure and security, more civil engineers will be needed to design and construct safe and higher capacity transportation, water supply, and pollution control systems, and large buildings and building complexes. They also will be needed to repair or replace existing roads, bridges, and other public structures. In addition to those arising from job growth, openings will result from the need to replace civil engineers who transfer to other occupations or leave the labor force.

Because construction and related industries—including those providing design services—employ many civil engineers, employment opportunities will vary by geographic area and may decrease during economic slowdowns, when construction often is curtailed.

Earnings

Median annual earnings of civil engineers were $60,070 in 2002. The middle 50 percent earned between $48,360 and $74,700. The lowest 10 percent earned less than $39,960, and the highest 10 percent earned more than $91,010. Median annual earnings in the industries employing the largest numbers of civil engineers in 2002 were:

Some civil engineers do research on building materials.

Federal government	$67,410
Local government	62,210
Architectural, engineering, and related services	59,060
State government	58,350
Nonresidential building construction	54,190

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in civil engineering received starting offers averaging $41,669 a year; master's degree candidates received an average offer of $47,245, and Ph.D. candidates were offered $69,079, on average, as an initial salary.

Sources of Additional Information

General information about civil engineers, as well as career, education, and related information, can be obtained from:

➤ American Society of Civil Engineers, 1801 Alexander Bell Dr., Reston, VA 20191-4400. Internet: **http://www.asce.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Computer Hardware Engineers

(0*NET 17-2061.00)

Nature of the Work

Computer hardware engineers research, design, develop, and test computer hardware and supervise its manufacture and installation. Hardware refers to computer chips, circuit boards, computer systems, and related equipment such as keyboards, modems, and printers. (Computer software engineers—often simply called computer engineers—design and develop the software systems that control computers. These workers are covered elsewhere in the *Handbook*.) The work of computer hardware engineers is very similar to that of electronics engineers, but, unlike electronics engineers, computer hardware engineers work exclusively with computers and computer-related equipment. (See electrical and electronics engineers elsewhere in the *Handbook*.) In addition to design and development duties, computer hardware engineers may supervise the manufacture and installation of computers and computer-related equipment. The rapid advances in computer technology are largely a result of the research, development, and design efforts of computer hardware engineers. To keep up with technological advances, these engineers must continually update their knowledge.

Employment

The number of computer hardware engineers is relatively small compared with the number of computer-related workers who work with software or computer applications. Computer hardware engineers held about 74,000 jobs in 2002. Almost 40 percent worked in computer and electronic product manufacturing. Almost one-quarter worked in professional, scientific, and technical services firms, many of which provided services to the computer industry. Many of the rest were employed in the telecommunications.

Job Outlook

Computer hardware engineers may face competition for jobs because the number of degrees granted in this field has increased rapidly and because employment is expected to grow more slowly than average. Although the use of information technology continues to expand rapidly, the manufacture of computer hardware is expected to be adversely affected by intense foreign competition. Also, this industry is expected to continue to experience very high levels of productivity growth, which will even affect computer hardware engineers. The utilization of foreign computer hardware engineering services also will serve to limit growth. In addition to job openings arising from employment growth, other vacancies will result from the need to replace workers who move into managerial positions, transfer to other occupations, or leave the labor force.

Earnings

Median annual earnings of computer hardware engineers were $72,150 in 2002. The middle 50 percent earned between $56,490 and $91,730. The lowest 10 percent earned less than $46,190, and the highest 10 percent earned more than $114,880. Median annual earnings in the industries employing the largest numbers of computer hardware engineers in 2002 were:

The work of computer hardware engineers is similar to that of electronics engineers, but, unlike electronics engineers, computer hardware engineers work exclusively with computers and computer-related equipment.

Semiconductor and other electronic component manufacturing	$76,600
Computer and peripheral equipment manufacturing	75,300
Computer systems designs and related services	74,320

According to the National Association of Colleges and Employers, starting salary offers in 2003 for bachelor's degree candidates in computer engineering averaged $51,343 a year; master's degree candidates averaged $64,200.

Sources of Additional Information

For further information on careers, education, certification, publications, and conferences related to computer hardware engineers, contact:

➤ IEEE Computer Society, 1730 Massachusetts Ave. NW., Washington, DC 20036-1992. Internet: **http://www.computer.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Electrical and Electronics Engineers

(0*NET 17-2071.00, 17-2072.00)

Nature of the Work

From the global positioning system that can continuously provide the location of a vehicle to giant electric power generators, electrical and electronics engineers are responsible for a wide range of technologies. Electrical and electronics engineers design, develop, test, and supervise the manufacture of electrical and electronic equipment. Some of this equipment includes broadcast and communications systems; electric motors, machinery controls, lighting, and wiring in buildings, automobiles, aircraft, and radar and navigation systems; and power generating, controlling, and transmission devices used by electric utilities. Many electrical and electronics engineers also work in areas closely related to computers. However, engineers whose work is related exclusively to computer hardware are considered computer hardware engineers, another engineering specialty covered elsewhere in the *Handbook.*

Electrical and electronics engineers specialize in different areas such as power generation, transmission, and distribution; communications; and electrical equipment manufacturing, or a specialty within one of these areas—industrial robot control systems or aviation electronics, for example. Electrical and electronics engineers design new products, write performance requirements, and develop maintenance schedules. They also test equipment, solve operating problems, and estimate the time and cost of engineering projects.

Employment

Electrical and electronics engineers held about 292,000 jobs in 2002, making up the largest branch of engineering. Most jobs were in professional, scientific, and technical services firms, government agencies, and manufacturers of computer and electronic products and machinery. Wholesale trade, communications, and utilities firms accounted for most of the remaining jobs.

Job Outlook

Electrical and electronics engineering graduates should have favorable employment opportunities. The number of job openings resulting from employment growth and the need to replace electrical engineers who transfer to other occupations or leave the labor force is expected to be in rough balance with the supply of graduates.

Employment of electrical and electronics engineers is expected to increase more slowly than the average for all occupations through 2012. Although rising demand for electrical and electronic goods, including advanced communications equipment, defense-related electronic equipment, and consumer electronics products should increase, foreign competition for electronic products and increasing use of engineering services performed in other countries will act to limit employment growth Job growth is expected to be fastest in services industries—particularly consulting firms that provide electronic engineering expertise.

Continuing education is important for electrical and electronics engineers. Engineers who fail to keep up with the rapid changes in technology risk becoming more susceptible to layoffs or, at a minimum, more likely to be passed over for advancement.

Earnings

Median annual earnings of electrical engineers were $68,180 in 2002. The middle 50 percent earned between $54,550 and $84,670. The lowest 10 percent earned less than $44,780, and the highest 10 percent earned more than $100,980. Median annual earnings in the industries employing the largest numbers of electrical engineers in 2002 were:

Scientific research and development services	$77,410
Semiconductor and other electronic component manufacturing	72,670
Electric power generation, transmission, and distribution	71,640
Navigational, measuring, electromedical, and control instruments manufacturing	70,430
Architectural, engineering, and related services	66,980

Median annual earnings of electronics engineers, except computer, were $69,930 in 2002. The middle 50 percent earned between $55,930 and $85,980. The lowest 10 percent earned less than $46,310, and the highest 10 percent earned more than $103,860. Median annual earnings in the industries employing the largest numbers of electronics engineers in 2002 were:

Federal government	$78,830
Architectural, engineering, and related services	72,850
Navigational, measuring, electromedical, and control instruments manufacturing	70,950
Semiconductor and other electronic component manufacturing	70,800
Wired telecommunications carriers	62,670

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in electrical/electronics and communications engineering received starting offers averaging $49,794 a year; master's degree candidates averaged $64,556; and Ph.D. candidates averaged $74,283.

Sources of Additional Information

Information on careers and employment, education, publications, and conferences related to electrical and electronics engineers is available from:

➤ Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331. Internet: **http://www.ieee.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Electrical and electronics engineering graduates should have favorable employment opportunities.

Environmental Engineers

(0*NET 17-2081.00)

Nature of the Work

Using the principles of biology and chemistry, environmental engineers develop solutions to environmental problems. They are involved in water and air pollution control, recycling, waste disposal, and public health issues. Environmental engineers conduct hazardous-waste management studies in which they evaluate the significance of the hazard, offer analysis on treatment and containment, and develop regulations to prevent mishaps. They design municipal water supply and industrial wastewater treatment systems. They conduct research on proposed environmental projects, analyze scientific data, and perform quality control checks.

Environmental engineers are concerned with local and worldwide environmental issues. They study and attempt to minimize the effects of acid rain, global warming, automobile emissions, and ozone depletion. They also are involved in the protection of wildlife.

Many environmental engineers work as consultants, helping their clients to comply with regulations and to clean up hazardous sites.

Employment

Environmental engineers held about 47,000 jobs in 2002. Almost half worked in professional, scientific, and technical services and about 15,000 were employed in Federal, State, and local government agencies. Most of the rest worked in various manufacturing industries.

Job Outlook

Environmental engineering graduates should have favorable job opportunities. Employment of environmental engineers is expected to increase much faster than the average for all occupations through 2012. Much of the expected growth will be due to the emergence of this occupation as a widely recognized engineering specialty rather than as an area that other engineering specialties, such as civil engineers, specialize in. More environmental engineers will be needed to comply with environmental regulations and to develop methods of cleaning up existing hazards. A shift in emphasis toward preventing problems rather than controlling those that already exist, as well as increasing public health concerns, also will spur demand for environmental engineers. However, political factors determine the job outlook for environmental engineers more than that for other engineers. Looser environmental regulations would reduce job opportunities; stricter regulations would enhance opportunities.

Even though employment of environmental engineers should be less affected by economic conditions than that of most other types of engineers, a significant economic downturn could reduce the emphasis on environmental protection, reducing employment opportunities. Environmental engineers need to keep abreast of a range of environmental issues to ensure their steady employment because their area of focus may change frequently—for example, from hazardous waste cleanup to the prevention of water pollution.

Earnings

Median annual earnings of environmental engineers were $61,410 in 2002. The middle 50 percent earned between $47,650 and $77,360. The lowest 10 percent earned less than $38,640, and the highest 10 percent earned more than $91,510. Median annual earnings in the industries employing the largest numbers of environmental engineers in 2002 were:

Architectural, engineering, and related services	$58,620
Management, scientific, and technical consulting services	57,800
State government	54,160

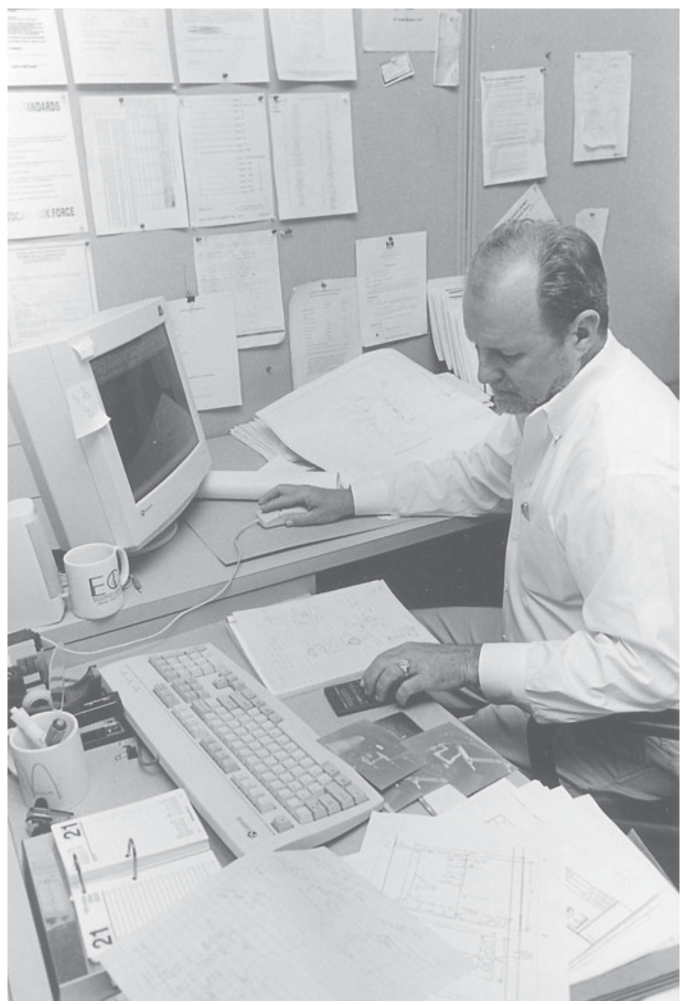
According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in environmental/environmental health engineering received starting offers averaging $44,702 a year.

Sources of Additional Information

Further information about environmental engineering careers, training, and certification can be obtained from:

➤ American Academy of Environmental Engineers, 130 Holiday Court, Suite 100, Annapolis, MD 21401. Internet: **http://www.aaee.net**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.



Many environmental engineers work as consultants, helping their clients to comply with regulations and to clean up hazardous sites.

Industrial Engineers, Including Health and Safety

(0*NET 17-2111.01, 17-2111.02, 17-2111.03, 17-2112.00)

Nature of the Work

Industrial engineers determine the most effective ways to use the basic factors of production—people, machines, materials, information, and energy—to make a product or to provide a service. They are the bridge between management goals and operational performance. They are more concerned with increasing productivity through the management of people, methods of business organization, and technology than are engineers in other specialties, who generally work more with products or processes. Although most industrial engineers work in manufacturing industries, they may also work in consulting services, healthcare, and communications.

To solve organizational, production, and related problems most efficiently, industrial engineers carefully study the product and its requirements, use mathematical methods such as operations research to meet those requirements, and design manufacturing and information systems. They develop management control systems to aid in financial planning and cost analysis and design production planning and control systems to coordinate activities and ensure product quality. They also design or improve systems for the physical distribution of goods and services. Industrial engineers determine which plant location has the best combination of raw materials availability, transportation facilities, and costs. Industrial engineers use computers for simulations and to control various activities and devices, such as assembly lines and robots. They also develop wage and salary administration systems and job evaluation programs. Many industrial engineers move into management positions because the work is closely related.

The work of health and safety engineers is similar to that of industrial engineers in that it deals with the entire production process. Health and safety engineers promote worksite or product safety and health by applying knowledge of industrial processes, as well as mechanical, chemical, and psychological principles. They must be able to anticipate, recognize, and evaluate hazardous conditions as well as develop hazard control methods. They also must be familiar with the application of health and safety regulations.

Employment

Industrial engineers, including health and safety, held about 194,000 jobs in 2002. Six in 10 of these jobs were in manufacturing industries, and an additional 1 in 10 worked in professional, scientific, and technical services firms, many of whom provide consulting services to manufacturing firms. Because their skills can be used in almost any type of organization, industrial engineers are more widely distributed among industries than are other engineers.

Job Outlook

Overall employment of industrial engineers, including health and safety, is projected to increase as fast as the average for all occupations through 2012. In addition, many openings will be created by the need to replace industrial engineers who transfer to other occupations or leave the labor force. Employment of industrial engineers is expected to increase as fast as the average while that of health and safety engineers is expected to grow more slowly than average.

Because the main function of industrial and health and safety engineers is to make a higher quality product as efficiently and as safely as possible, their services should be in demand in the manufacturing sector as firms seek to reduce costs and increase productivity. The concern for health and safety within work environments should increase the need for health and safety engineers.

Earnings

Median annual earnings of industrial engineers were $62,150 in 2002. The middle 50 percent earned between $50,160 and $75,440. The lowest 10 percent earned less than $40,380, and the highest 10 percent earned more than $90,420. Median annual earnings in the manufacturing industries employing the largest numbers of industrial engineers in 2002 were:

Semiconductor and other electronic component manufacturing	$67,460
Navigational, measuring, electromedical, and control i nstruments manufacturing	65,470
Architectural, engineering, and related services	64,020
Aerospace products and parts manufacturing	63,630
Motor vehicle parts manufacturing	62,610

Median annual earnings of health and safety engineers were $58,010 in 2002. The middle 50 percent earned between $46,580 and $71,980. The lowest 10 percent earned less than $37,230, and the highest 10 percent earned more than $87,250.

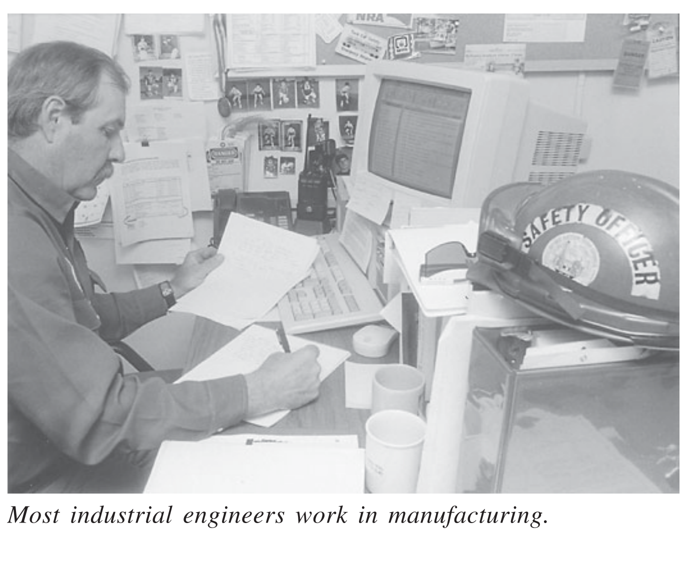
According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in industrial/manufacturing engineering received starting offers averaging about $47,051 a year and master's degree candidates averaged $54,565 a year.

Sources of Additional Information

For further information about industrial engineering careers, education, and training, contact:

➤ Institute of Industrial Engineers, 3577 Parkway Lane, Suite 200, Norcross, GA 30092. Internet: **http://www.iienet.org**

Information on careers, education, accreditation and certification, and salaries of safety engineers is available from:



Most industrial engineers work in manufacturing.

➤ American Society of Safety Engineers, 1800 E Oakton St., Des Plaines, IL 60018. Internet: **http://www.asse.org**

Information on certification, accreditation, careers, and safety-related degree programs for safety professionals, including safety engineers, is available from:

➤ Board of Certified Safety Professionals, 208 Burwash Ave., Savoy, Il 61874. Internet: **http://www.bcsp.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Materials Engineers

(0*NET 17-2131.00)

Nature of the Work

Materials engineers are involved in the extraction, development, processing, and testing of the materials used to create a diversity of products, from computer chips and television screens to golf clubs and snow skis. They work with metals, ceramics, plastics, semiconductors, and combinations of materials called composites to create new materials that meet certain mechanical, electrical, and chemical requirements. They also are involved in selecting materials for new applications.

There are numerous new developments within materials engineering that make it possible to manipulate and use materials in various ways. For example, materials engineers have developed the ability to create and then study materials at an atomic level using advanced processes to replicate the characteristics of materials and their components with computers.

Most metallurgical engineers work in 1 of the 3 main branches of metallurgy—extractive or chemical, physical, and process. Extractive metallurgists are concerned with removing metals from ores and refining and alloying them to produce suitable inputs for a number of industrial processes. Physical metallurgists study the nature, structure, and physical properties of metals and their alloys to find the best methods of processing basic materials into final products. Process metallurgists develop and improve metalworking processes such as casting, forging, rolling, and drawing. Most materials engineers specialize in a particular material. For example, metallurgical engineers specialize in metals, while ceramic engineers develop ceramic materials and the processes for making ceramic materials into useful products. Ceramics include all nonmetallic, inorganic materials that generally require high temperatures in their processing. Ceramic engineers work on products as diverse as glassware, automobile and aircraft engine components, fiberoptic communication lines, tile, and electric insulators.

Employment

Materials engineers held about 24,000 jobs in 2002. Because materials are building blocks for other goods, materials engineers are widely distributed among manufacturing industries. In fact, 68 percent of materials engineers worked in manufacturing industries, primarily computer and electronic products, transportation equipment, fabricated metal products, primary metal production, and machinery manufacturing. They also worked in services industries such as professional, scientific, and technical services. Most remaining materials engineers worked for Federal and State governments.

Job Outlook

Employment of materials engineers is expected to grow more slowly than the average for all occupations through 2012. Although many of the manufacturing industries in which materials engineers are concentrated are expected to experience declines in employment, more materials engineers will be needed to develop new materials for electronics, biotechnology, and plastics products. As manufacturing firms contract for their materials engineering needs, employment growth is expected in professional, scientific, and technical services industries. In addition to those arising from employment growth, job openings will result from the need to replace materials engineers who transfer to other occupations or leave the labor force.

Because materials are building blocks for other goods, materials engineers are widely distributed among manufacturing industries.

Earnings

Median annual earnings of materials engineers were $62,590 in 2002. The middle 50 percent earned between $49,810 and $77,500. The lowest 10 percent earned less than $39,360, and the highest 10 percent earned more than $92,690.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in materials engineering received starting offers averaging $44,680 a year.

Sources of Additional Information

For information on careers, education, accreditation, and other topics related to materials engineers, contact:

➤ The Minerals, Metals, & Materials Society, 184 Thorn Hill Rd., Warrendale, PA 15086. Internet: **http://www.tms.org**

➤ ASM International, 9639 Kinsman Rd., Materials Park, OH 44073-0002. Internet: **http://www.asm-intl.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Mechanical Engineers

(0*NET 17-2141.00)

Nature of the Work

Mechanical engineers research, develop, design, manufacture, and test tools, engines, machines, and other mechanical devices. They work on power-producing machines such as electric generators, internal combustion engines, and steam and gas turbines. They also develop power-using machines such as refrigeration and air-conditioning equipment, machine tools, material handling systems, elevators and escalators, industrial production equipment, and robots used in manufacturing. Mechanical engineers also design tools that other engineers need for their work. The field of nanotechnology, which involves the creation of high-performance materials and components by integrating atoms and molecules, is introducing entirely new principles to the design process.

Computers assist mechanical engineers by accurately and efficiently performing computations, and by permitting the modeling and simulation of new designs as well as facilitating changes to existing designs. Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) are used for design data processing and for turning the design into a product.

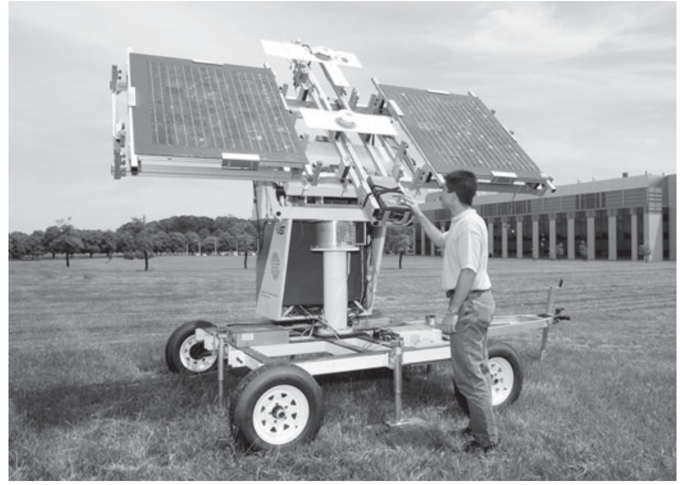
Mechanical engineers work in many industries, and their work varies by industry and function. Some specialize in energy systems; applied mechanics; automotive design; manufacturing; materials; plant engineering and maintenance; pressure vessels and piping; and heating, refrigeration, and air-conditioning systems. Mechanical engineering is one of the broadest engineering disciplines. Mechanical engineers may work in production operations in manufacturing or agriculture, maintenance, or technical sales; many are administrators or managers.

Employment

Mechanical engineers held about 215,000 jobs in 2002. More than half of the jobs were in manufacturing—mostly in machinery, transportation equipment, computer and electronic products, and fabricated metal products manufacturing industries. Architectural, engineering, and related services, and the Federal Government provided many of the remaining jobs.

Job Outlook

Employment of mechanical engineers is projected to grow more slowly than the average for all occupations though 2012. Although overall employment in manufacturing industries—where employment of mechanical engineers is concentrated—is expected to decrease slightly, employment of mechanical engineers in manufacturing should increase more rapidly as the demand for improved machinery and machine tools grows and as industrial machinery and processes become increasingly complex. Also, emerging technologies in biotechnology, materials science, and nanotechnology will create new job opportunities for mechanical engineers. Additional opportunities for mechanical engineers will arise because a degree in mechanical engineering often can be applied in other engineering specialties. In addition to job openings arising from growth, many openings should result from the need to replace workers who transfer to other occupations or leave the labor force.



Some mechanical engineers specialize in developing new energy systems.

Earnings

Median annual earnings of mechanical engineers were $62,880 in 2002. The middle 50 percent earned between $50,800 and $78,040. The lowest 10 percent earned less than $41,490, and the highest 10 percent earned more than $93,430. Median annual earnings in the industries employing the largest numbers of mechanical engineers in 2002 were:

Federal government	$72,500
Architectural, engineering, and related services	65,610
Navigational, measuring, electromedical, and control instruments manufacturing	65,430
Aerospace products and parts manufacturing	65,160
Other general puropse machinery manufacturing	55,850

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in mechanical engineering received starting offers averaging $48,585 a year, master's degree candidates had offers averaging $54,565, and Ph.D. candidates were initially offered $69,904.

Sources of Additional Information

General information about mechanical engineers as well as information on careers, education, and training is available from:

➤ The American Society of Mechanical Engineers, 3 Park Ave., New York, NY 10016. Internet: **http://www.asme.org**

Information about heating, refrigeration, and air-conditioning engineering, a mechanical engineering specialty, is available from:

➤ American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE., Atlanta, GA 30329. Internet: **http://www.ashrae.org**

Information about automotive engineering, a mechanical engineering specialty, is available from:

➤ Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096-0001. Internet: **http://www.sae.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Mining and Geological Engineers, Including Mining Safety Engineers

(0*NET 17-2151.00)

Nature of the Work

Mining and geological engineers find, extract, and prepare coal, metals, and minerals for use by manufacturing industries and utilities. They design open pit and underground mines, often using computers; supervise the construction of mine shafts and tunnels in underground operations; and devise methods for transporting minerals to processing plants. Mining engineers are responsible for the safe, economical, and environmentally sound operation of mines. Some mining engineers work with geologists and metallurgical engineers to locate and appraise new ore deposits. Others develop new mining equipment or direct mineral processing operations to separate minerals from the dirt, rock, and other materials with which they are mixed. Mining engineers frequently specialize in the mining of one mineral or metal, such as coal or gold. With increased emphasis on protecting the environment, many mining engineers work to solve problems related to land reclamation and water and air pollution.

Mining safety engineers use their knowledge of mine design and practices to ensure the safety of workers and to comply with State and Federal safety regulations. They inspect walls and roof surfaces, test air samples, and examine mining equipment for compliance with safety practices.

Employment

Mining and geological engineers, including mining safety engineers, held about 5,200 jobs in 2002. While about 4 out of 10 mining engineers worked in the mining industry, over one-third worked in professional, scientific, and technical services firms, mostly providing consulting and other services to the mining industry. Most of the rest worked in State or Federal government.

Mining engineers often are employed at the location of natural deposits, often near small communities, and sometimes outside the United States. Those in research and development, management, consulting, or sales, however, often are located in metropolitan areas.

Job Outlook

Despite a projected decline in employment, very good employment opportunities are expected in this small occupation. A significant number of mining engineers currently employed are approaching retirement age, which should create some job openings over the 2002-12 period. In addition, relatively few schools offer mining engineering programs, and the small number of graduates is not expected to increase.

Favorable job opportunities also may be available worldwide as mining operations around the world recruit graduates of U.S. mining engineering programs. As a result, some graduates should expect to travel frequently, or even live abroad.

Employment of mining and geological engineers, including mining safety engineers, is projected to decline through 2012. Most of the industries in which mining engineers are concentrated—such as coal, metal, and copper mining—are expected to experience declines in employment.

Earnings

Median annual earnings of mining and geological engineers, including mining safety engineers, were $61,770 in 2002. The middle 50 percent earned between $48,250 and $77,160. The lowest 10 percent earned less than $36,720, and the highest 10 percent earned more than $93,660.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in mining and mineral engineering (including geological) received starting offers averaging $44,326 a year.

Mining engineers frequently specialize in the mining of one mineral or metal, such as coal or gold.

Sources of Additional Information

For more information on careers, education, accreditation, and related topics for mining engineers, contact:

➤ The Society for Mining, Metallurgy, and Exploration, Inc., 8307 Shaffer Parkway, P.O. Box 277002, Littleton, CO 80127. Internet: **http://www.smenet.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Nuclear Engineers

(0*NET 17-2161.00)

Nature of the Work

Nuclear engineers research and develop the processes, instruments, and systems used to derive benefits from nuclear energy and radiation. They design, develop, monitor, and operate nuclear plants used to generate power. They may work on the nuclear fuel cycle—the production, handling, and use of nuclear fuel and the safe disposal of waste produced by the generation of nuclear energy—or on the production of fusion energy. Some specialize in the development of nuclear power sources for spacecraft; others find industrial and medical uses for radioactive materials, such as equipment to diagnose and treat medical problems.

Employment

Nuclear engineers held about 16,000 jobs in 2002. Almost half were employed in utilities, one-quarter in professional, scientific, and technical services firms, and 14 percent in the Federal Government. Many Federally employed nuclear engineers were civilian employees of the U.S. Navy, and most of the rest worked for the U.S. Department of Energy.

Job Outlook

Good opportunities should exist for nuclear engineers because the small number of nuclear engineering graduates is likely to be in rough balance with the number of job openings. Because this is a small occupation, projected job growth will generate few openings; consequently, most openings will result from the need to replace nuclear engineers who transfer to other occupations or leave the labor force.

Little or no growth in employment of nuclear engineers is expected through 2012. Due to public concerns over the cost and safety of nuclear power, no commercial nuclear powerplants have been built in the United States for many years. Nevertheless, nuclear engineers will be needed to operate existing plants. In addition, nuclear engineers may be needed to research and develop future nuclear power sources. They also will be needed to work in defense-related areas, to develop nuclear medical technology, and to improve and enforce waste management and safety standards.

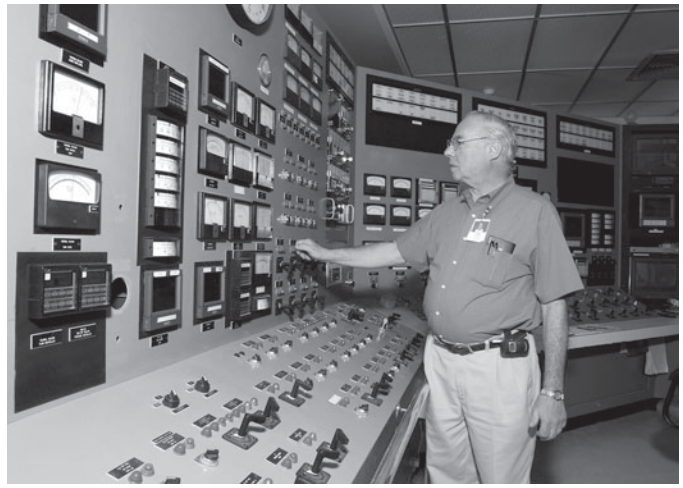
Earnings

Median annual earnings of nuclear engineers were $81,350 in 2002. The middle 50 percent earned between $67,970 and $92,930. The lowest 10 percent earned less than $58,350, and the highest 10 percent earned more than $111,260. In the Federal Government, nuclear engineers in supervisory, nonsupervisory, and management positions earned an average of $73,769 a year in 2003.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in nuclear engineering received starting offers averaging $50,104 a year.

Sources of Additional Information

Information on careers and related topics for nuclear engineers is available from:



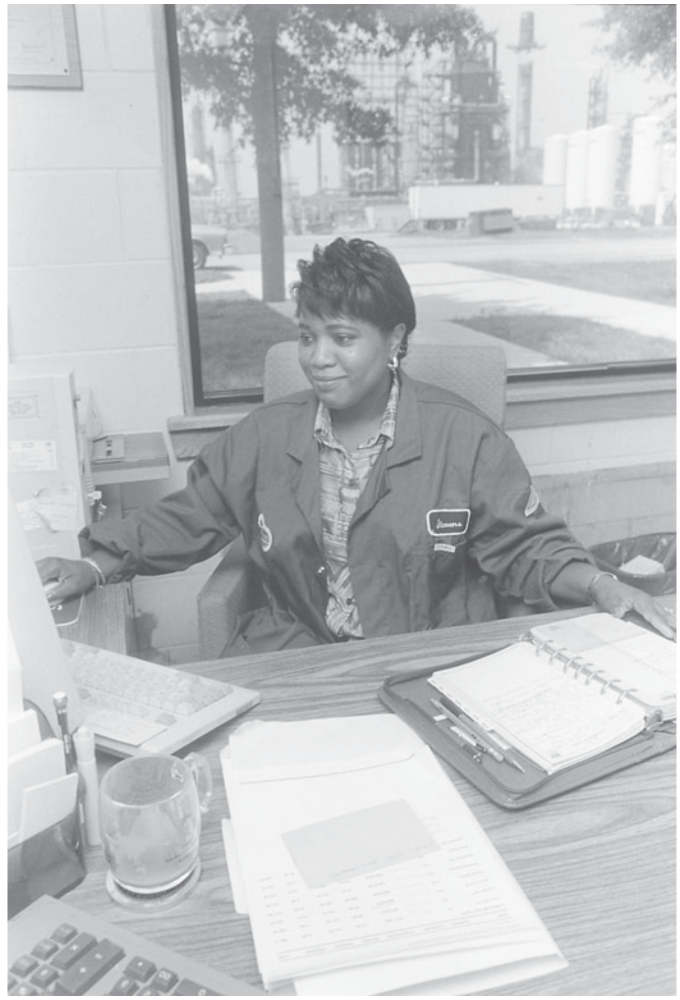
Almost half of all nuclear engineers work in utilities.

➤ American Nuclear Society, 555 North Kensington Ave., LaGrange Park, IL 60526. Internet: **http://www.ans.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Petroleum Engineers

(0*NET 17-2171.00)



Even though employment is expected to decline, favorable opportunities are expected for petroleum engineers because the number of job openings is likely to exceed the relatively small number of graduates.

Nature of the Work

Petroleum engineers search the world for reservoirs containing oil or natural gas. Once these resources are discovered, petroleum engineers work with geologists and other specialists to understand the geologic formation and properties of the rock containing the reservoir, determine the drilling methods to be used, and monitor drilling and production operations. They design equipment and processes to achieve the maximum profitable recovery of oil and gas. Petroleum engineers rely heavily on computer models to simulate reservoir performance using different recovery techniques. They also use computer models for simulations of the effects of various drilling options.

Because only a small proportion of oil and gas in a reservoir will flow out under natural forces, petroleum engineers develop and use various enhanced recovery methods. These include injecting water, chemicals, gases, or steam into an oil reservoir to force out more of the oil, and computer-controlled drilling or fracturing to connect a larger area of a reservoir to a single well. Because even the best techniques in use today recover only a portion of the oil and gas in a reservoir, petroleum engineers research and develop technology and methods to increase recovery and lower the cost of drilling and production operations.

Employment

Petroleum engineers held about 14,000 jobs in 2002, mostly in oil and gas extraction, professional, scientific and technical services, and petroleum refining. Employers include major oil companies and hundreds of smaller, independent oil exploration, production, and service companies.

Most petroleum engineers work where oil and gas are found. Large numbers are employed in Texas, Louisiana, Oklahoma, Alaska, and California, including offshore sites. Many American petroleum engineers also work overseas in oil-producing countries.

Job Outlook

Employment of petroleum engineers is expected to decline through 2012 because most of the potential petroleum-producing areas in the United States already have been explored. Even so, favorable opportunities are expected for petroleum engineers because the number of job openings is likely to exceed the relatively small number of graduates. All job openings should result from the need to replace petroleum engineers who transfer to other occupations or leave the labor force.

Petroleum engineers work around the world and, in fact, the best employment opportunities may be in other countries. Many foreign employers seek U.S.-trained petroleum engineers, and many U.S. employers maintain overseas branches where petroleum engineers work.

Earnings

Median annual earnings of petroleum engineers were $83,370 in 2002. The middle 50 percent earned between $63,390 and $105,920. The lowest 10 percent earned less than $49,010, and the highest 10 percent earned more than $127,950.

According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in petroleum engineering received starting offers averaging $55,987 year.

Sources of Additional Information

For further information on careers, education, and salaries for petroleum engineers, contact:

➤ Society of Petroleum Engineers, P.O. Box 833836, Richardson, TX 75083-3836. Internet: **http://www.spe.org**

See the introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.

Environmental Scientists and Geoscientists

(0*NET 19-2041.00, 19-2042.01, 19-2043.00)

Significant Points

- Work at remote field sites is common.
- Federal, State, and local governments employ nearly one-half of all environmental scientists and geoscientists.
- A bachelor's degree is adequate for a few entry-level jobs, but a master's degree is usually the minimum educational requirement; a Ph.D. degree is required for most high-level research positions.
- Employment of geoscientists is expected to grow as fast as average, while environmental scientists and hydrologists will experience faster than average growth.

Nature of the Work

Environmental scientists and geoscientists use their knowledge of the physical makeup and history of the Earth to protect the environment; locate water, mineral, and energy resources; predict future geologic hazards; and offer advice on construction and land-use projects.

Environmental scientists conduct research to identify and abate or eliminate sources of pollutants that affect people, wildlife, and their environments. These workers analyze and report measurements and observations of air, water, soil, and other sources and make recommendations on how best to clean and preserve the environment. Understanding the issues involved in protecting the environment—degradation, conservation, recycling, and replenishment—is central to the work of environmental scientists, who often use their skills and knowledge to design and monitor waste disposal sites, preserve water supplies, and reclaim contaminated land and water to comply with Federal environmental regulations.

Many environmental scientists do work and have training that is similar to other physical or life scientists, but is applied to environmental areas. Many specialize in some specific area, such as environmental ecology and conservation, environmental chemistry, environmental biology, or fisheries science. Most environmental scientists are further classified by the specific activity they perform (although recent advances in the understanding of basic life processes within the ecosystem have blurred some traditional classifications). For example, *environmental ecologists* study the relationships between organisms and their environments and the effects of influences such as population size, pollutants, rainfall, temperature, and altitude. Utilizing their knowledge of various scientific disciplines, they may collect, study, and report data on air, food, soil, and water. *Ecological modelers* study ecosystems, the control of environmental pollution, and the management of resources. These environmental scientists may use mathematical modeling, systems analysis, thermodynamics, and computer techniques. *Environmental chemists* may study the toxicity of various chemicals—how those chemicals affect plants, animals, and people. *Geochemists* study the nature and distribution of chemical elements in ground water and Earth materials.

Some environmental scientists work in managerial positions, usually after spending some time performing research or learning about environmental laws and regulations. Many work as consultants to business firms or to government agencies, helping them comply with environmental policy, particularly with regard to ground-water contamination and flood control. Environmental scientists who determine policy may help identify how human behavior can be modified in the future to avoid such problems as ground-water contamination and depletion of the ozone layer.

Geoscientists study the composition, structure, and other physical aspects of the Earth. With the use of sophisticated instruments and by analyzing the composition of the earth and water, geoscientists study the Earth's geologic past and present. Many geoscientists are involved in searching for oil and gas, while others work closely with environmental scientists in preserving and cleaning up the environment.

Geoscientists usually study, and are subsequently classified into, one of several closely related fields of geoscience. *Geologists* study the composition, processes, and history of the Earth. They try to find out how rocks were formed and what has happened to them since their formation. They also study the evolution of life by analyzing plant and animal fossils. *Geophysicists* use the principles of physics, mathematics, and chemistry to

Some environmental scientists and geoscientists spend the majority of their time in an office, but many others divide their time between fieldwork and laboratory work.

study not only the Earth's surface, but also its internal composition; ground and surface waters; atmosphere; oceans; and magnetic, electrical, and gravitational forces.

Oceanographers use their knowledge of geology and geophysics, in addition to biology and chemistry, to study the world's oceans and coastal waters. They study the motion and circulation of the ocean waters; the physical and chemical properties of the oceans; and how these properties affect coastal areas, climate, and weather. Oceanographers are further broken down according to their areas of expertise. For example, *physical oceanographers* study the ocean tides, waves, currents, temperatures, density, and salinity. They examine the interaction of various forms of energy, such as light, radar, sound, heat, and wind, with the sea, in addition to investigating the relationship between the sea, weather, and climate. *Chemical oceanographers* study the distribution of chemical compounds and chemical interactions that occur in the ocean and on the sea floor. They may investigate how pollution affects the chemistry of the ocean. *Geological and geophysical oceanographers* study the topographic features and the physical makeup of the ocean floor. Their knowledge can help companies find oil and gas off coastal waters. (*Biological oceanographers*, often called marine biologists, study the distribution and migration patterns of the many diverse forms of sea life in the ocean, but because they are considered biological scientists, they are not covered in this statement on environmental scientists and geoscientists. See instead the statement on biological scientists elsewhere in the *Handbook*.)

Geoscientists can spend a large part of their time in the field, identifying and examining rocks, studying information collected by remote sensing instruments in satellites, conducting geological surveys, constructing field maps, and using instruments to measure the Earth's gravity and magnetic field. For example, they often perform seismic studies, which involve bouncing energy waves off buried rock layers, to search for oil and gas or to understand the structure of subsurface rock layers. Seismic signals generated by an earthquake are used to determine the earthquake's location and intensity. In laboratories, geologists and geophysicists examine the chemical and physical properties of specimens. They study fossil remains of animal and plant life or experiment with the flow of water and oil through rocks.

Numerous specialties that further differentiate the type of work geoscientists do fall under the two major disciplines of geology and geophysics. For example, *petroleum geologists* explore for oil and gas deposits by studying and mapping the subsurface of the ocean or land. They use sophisticated geophysical instrumentation and computers to interpret geological information. *Engineering geologists* apply geologic principles to the fields of civil and environmental engineering, offering advice on major construction projects and assisting in environmental remediation and natural hazard reduction projects. *Mineralogists* analyze and classify minerals and precious stones according to their composition and structure. They study the environment surrounding rocks in order to find new mineral resources. *Paleontologists* study fossils found in geological formations to trace the evolution of plant and animal life and the geologic history of the Earth. *Stratigraphers* examine the formation and layering of rocks to understand the environment in which they were formed. *Volcanologists* investigate volcanoes and volcanic phenomena to try to predict the potential for future eruptions and possible hazards to human health and welfare. *Hydrologists* study the quantity, distribution, circulation, and physical properties of underground and surface waters. They examine the form and intensity of precipitation, its rate of infiltration into the soil, its movement through the earth, and its return to the ocean and atmosphere. The work hydrologists do is particularly important in environmental preservation, remediation, and flood control.

Geophysicists specialize in areas such as geodesy, seismology, or magnetic geophysics. *Geodesists* study the Earth's size, shape, gravitational field, tides, polar motion, and rotation. *Seismologists* interpret data from seismographs and other geophysical instruments to detect earthquakes and locate earthquake-related faults. *Geomagnetists* measure the Earth's magnetic field and use measurements taken over the past few centuries to devise theoretical models that explain the Earth's origin. *Paleomagnetists* interpret fossil magnetization in rocks and sediments from the continents and oceans to record the spreading of the sea floor, the wandering of the continents, and the many reversals of polarity that the Earth's magnetic field has undergone through time. Other geophysicists study atmospheric sciences and space physics. (See the statements on atmospheric scientists, and physicists and astronomers, elsewhere in the *Handbook*.)

Working Conditions

Some environmental scientists and geoscientists spend the majority of their time in an office, but many others divide their time between fieldwork and office or laboratory work. Many environmental scientists, such as environmental ecologists, environmental chemists, and hydrologists, often take field trips that involve physical activity. Environmental scientists in the field may work in warm or cold climates, in all kinds of weather. In their research, they may dig or chip with a hammer, scoop with a net, and carry equipment in a backpack. Oceanographers may spend considerable time at sea on academic research ships. Fieldwork often requires working long hours. Geologists frequently travel to remote field sites by helicopter or four-wheel-drive vehicles and cover large areas on foot. An increasing number of exploration geologists and geophysicists work in foreign countries, sometimes in remote areas and under difficult conditions. Travel often is required to meet with prospective clients or investors.

Environmental scientists and geoscientists in research positions with the Federal Government or in colleges and universities frequently are required to design programs and write grant proposals in order to continue their data collection and research. Environmental scientists and geoscientists in consulting jobs face similar pressures to market their skills and write proposals so that they will have steady work.

Employment

Environmental scientists and geoscientists held about 101,000 jobs in 2002. Environmental scientists accounted for 65,000 of the total; geoscientists, 28,000; and hydrologists, 8,000. Many more individuals held environmental science and geoscience faculty positions in colleges and universities, but they are classified as college and university faculty. (See the statement on teachers-postsecondary elsewhere in the *Handbook*.)

About 47 percent of environmental scientists were employed in State and local governments, 14 percent in architectural, engineering and related services, 13 percent in management, scientific, and technical consulting services, and 9 percent in the Federal Government. About 1,900 were self-employed.

Among geoscientists, 30 percent were employed in architectural, engineering, and related services, and 15 percent worked for oil and gas extraction companies. In 2002, the Federal Government employed about 3,000 geoscientists, including geologists, geophysicists, and oceanographers, mostly within the U.S. Department of the Interior for the U.S. Geological Survey (USGS) and within the U.S. Department of Defense. Another 3,400 worked for State agencies, such as State geological surveys and State departments of conservation. Nearly 3 percent of geoscientists were self-employed, most as consultants to industry or government.

Approximately 32 percent of hydrologists worked in the Federal Government in 2002, another 21 percent in architectural, engineering, and related services, 17 percent worked in management, scientific, and technical consulting services, and 16 percent for State governments.

Training, Other Qualifications, and Advancement

A bachelor's degree is adequate for a few entry-level positions, but environmental scientists and geoscientists increasingly need a master's degree in a natural science. A master's degree also is the minimum educational requirement for most entry-level research positions in private industry, Federal agencies, and State geological surveys. A doctoral degree is necessary for most high-level research positions.

Many environmental scientists earn degrees in life science, chemistry, geology, geophysics, atmospheric science, or physics and then, either through further education or through their research interests and work experience, apply their education to environmental areas. Others earn a degree in environmental science. A bachelor's degree in environmental science offers an interdisciplinary approach to the natural sciences, with an emphasis on biology, chemistry, and geology. In addition, undergraduate environmental science majors should focus on data analysis and physical geography, particularly if they are interested in studying pollution abatement, water resources, or ecosystem protection, restoration, or management. Those students interested in working in the environmental or regulatory fields, either in environmental consulting firms or for Federal or State governments, should take courses in hydrology, hazardous waste management, environmental legislation, chemistry, fluid mechanics, and geologic logging. An understanding of environmental regulations and government permit issues also is valuable for those planning to work in mining and oil and gas extraction. Hydrologists and environmental scientists should have some knowledge of the potential liabilities associated with some environmental work. Students interested in the field of hydrology should take courses in the physical sciences, geophysics, chemistry, engineering science, soils, mathematics, aquatic biology, atmospheric science, meteorology, geology, oceanography, or the management or conservation of water resources. In some cases, graduates with a bachelor's degree in a hydrologic science are qualified for positions in environmental consulting and planning regarding water quality or waste-water treatment. Curricula for advanced degrees often emphasize the natural sciences, but not all universities offer all curricula.

Traditional geoscience courses emphasizing classical geologic methods and topics (such as mineralogy, petrology, paleontology, stratigraphy, and structural geology) are important for all geoscientists. Persons studying physics, chemistry, biology, mathematics, engineering, or computer science may also qualify for some geoscience positions if their course work includes study in geology or natural sciences.

Computer skills are essential for prospective environmental scientists and geoscientists; students who have some experience with computer modeling, data analysis and integration, digital mapping, remote sensing, and geographic information systems will be the most prepared entering the job market. A knowledge of the Global Information System (GIS) and Global Positioning System (GPS)—a locator system that uses satellites—also is very helpful. Some employers seek applicants with field experience, so a summer internship may be beneficial to prospective geoscientists.

Environmental scientists and geoscientists must have excellent interpersonal skills, because they usually work as part of a team with other scientists, engineers, and technicians. Strong oral and written communication skills also are important, because writing technical reports and research proposals, as well as communicating research results to others, are important aspects of the work. Because many jobs require foreign travel, knowledge of a second language is becoming an important attribute to employers. Geoscientists must be inquisitive, be able to think logically, and have an open mind. Those involved in fieldwork must have physical stamina.

Environmental scientists and geoscientists often begin their careers in field exploration or as research assistants or technicians in laboratories or offices. They are given more difficult assignments as they gain experience. Eventually, they may be promoted to project leader, program manager, or some other management and research position.

Job Outlook

Overall employment of environmental scientists and geoscientists is expected to grow about as fast as the average for all occupations through 2012. Driving job growth will be public policy, which will force companies and organizations to comply with environmental laws and regulations, particularly those regarding ground-water contamination, clean air, and flood control.

Projected employment growth varies by occupational specialty. Environmental scientists and hydrologists are expected to grow faster than average. A general heightened awareness regarding the need to monitor the quality of the environment, to interpret the impact of human actions on terrestrial and aquatic ecosystems, and to develop strategies for ecosystem restoration are all increasingly important issues that will drive demand for environmental scientists. Issues related to water conservation, deteriorating coastal environments, and rising sea levels also will stimulate employment growth of these workers. As the population increases and moves to more environmentally sensitive locations, environmental scientists and hydrologists will be needed to assess building sites for potential geologic hazards, to mitigate the effects of natural hazards such as floods, tornadoes, and earthquakes, and to address issues related to pollution control and waste disposal. Hydrologists and environmental scientists also will be needed to conduct research on hazardous-waste sites in order to determine the impact of hazardous pollutants on soil and ground water so that engineers can design remediation systems. Demand is growing for environmental scientists who understand both the science and engineering aspects of waste remediation.

In contrast to employment of environmental scientists and hydrologists, that of geoscientists is expected to grow about as fast as the average for all occupations. In the past, employment of geologists and some other geoscientists has been cyclical and largely affected by the price of oil and gas. When prices were low, oil and gas producers curtailed exploration activities and laid off geologists. When prices were higher, companies had the funds and incentive to renew exploration efforts and hire geoscientists in large numbers. In recent years, a growing worldwide demand for oil and gas and for new exploration and recovery techniques—particularly in deep water and previously inaccessible sites—has returned a modicum of stability to the petroleum industry. Growth in this area, though, will be limited due to increasing efficiencies in finding oil and gas. Geoscientists who speak a foreign language and who are willing to work abroad should enjoy the best opportunities. An expected increase in highway building and other infrastructure projects will be a source of jobs for engineering geologists. The need to replace geoscientists who retire also will result in job openings over the next decade.

Earnings

Median annual earnings of environmental scientists were $47,600 in 2002. The middle 50 percent earned between $36,820 and $62,400. The lowest 10 percent earned less than $29,920, and the highest 10 percent earned more than $78,200.

Median annual earnings of geoscientists were $67,470 in 2002. The middle 50 percent earned between $48,370 and $102,120; the lowest 10 percent, less than $36,580 and the highest 10 percent more than $133,310.

Median annual earnings of hydrologists were $56,530 in 2002, with the middle 50 percent earning between $44,080 and $70,160, the lowest 10 percent less than $36,790, and the highest 10 percent more than $86,620.

Median annual earnings in the industries employing the largest number of environmental scientists in 2002 were as follows:

Federal Government	$66,190
Management, scientific, and technical consulting services	45,560
Local government	45,270
Architectural, engineering, and related services	44,590
State government	44,580

According to the National Association of Colleges and Employers, beginning salary offers in 2003 for graduates with bachelor's degrees in geology and related sciences averaged about $32,828 a year; graduates with a master's degree averaged $47,981, and graduates with a doctoral degree averaged $61,050.

In 2003, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was $76,389 for geologists, $86,809 for geophysicists, $70,525 for hydrologists, and $79,023 for oceanographers.

The petroleum, mineral, and mining industries are vulnerable to recessions and to changes in oil and gas prices, among other factors, and usually release workers when exploration and drilling slow down. Consequently, they offer higher salaries, but less job security, than do other industries.

Related Occupations

Many geoscientists work in the petroleum and natural gas industry, an industry that also employs many other workers in the scientific and technical aspects of petroleum and natural gas exploration and extraction. Among these other workers are engineering technicians, science technicians, petroleum engineers, surveyors, cartographers, photogrammetrists, and surveying technicians. Also, some physicists, chemists, and atmospheric scientists—as well as mathematicians, computer systems analysts, database administrators, and computer scientists—perform related work both in petroleum and natural gas exploration and extraction and in environment-related activities.

Sources of Additional Information

Information on training and career opportunities for geologists is available from either of the following organizations:

➤American Geological Institute, 4220 King St., Alexandria, VA 22302-1502. Internet: **http://www.agiweb.org**

➤American Association of Petroleum Geologists, P.O. Box 979, Tulsa, OK 74101. Internet: **http://www.aapg.org**

A packet of free career information and a list of education and training programs in oceanography and related fields, priced at $6.00, is available from

➤Marine Technology Society, 5565 Sterrett Place, Suite 108, Columbia, MD 21004. Telephone: (410) 884-5330. Internet: **http://www.mtsociety.org**

Information on applying for a job as a geologist, a geophysicist, a hydrologist, or an oceanographer with the Federal Government may be obtained through a telephone-based system from the Office of Personnel Management. Consult your telephone directory under "U.S. Government" for a local number, or call (703) 724-1850 or Federal Relay Service (800) 877-8339. This number is not toll free, and charges may accrue. Information also is available from the Internet site **http://www.usajobs.opm.gov**.

Landscape Architects

(0*NET 17-1012.00)

Significant Points

- Almost 23 percent are self-employed—more than 3 times the proportion for all professionals.
- A bachelor's degree in landscape architecture is the minimum requirement for entry-level jobs; many employers prefer to hire landscape architects who also have completed at least one internship.
- A growing demand for incorporating natural elements into man-made environments, along with the need to meet a wide array of environmental restrictions, will increase the demand for landscape architects.

Nature of the Work

Everyone enjoys attractively designed residential areas, public parks and playgrounds, college campuses, shopping centers, golf courses, parkways, and industrial parks. Landscape architects design these areas so that they are not only functional, but also beautiful, and compatible with the natural environment. They plan the location of buildings, roads, and walkways, and the arrangement of flowers, shrubs, and trees.

Landscape architects work for many types of organizations—from real estate development firms starting new projects to municipalities constructing airports or parks—and they often are involved with the development of a site from its conception. Working with architects, surveyors, and engineers, landscape architects help determine the best arrangement of roads and buildings. They also collaborate with environmental scientists, foresters, and other professionals to find the best way to conserve or restore natural resources. Once these decisions are made, landscape architects create detailed plans indicating new topography, vegetation, walkways, and other landscaping details, such as fountains and decorative features.

In planning a site, landscape architects first consider the nature and purpose of the project and the funds available. They analyze the natural elements of the site, such as the climate, soil, slope of the land, drainage, and vegetation; observe where sunlight falls on the site at different times of the day and examine the site from various angles; and assess the effect of existing buildings, roads, walkways, and utilities on the project.

After studying and analyzing the site, landscape architects prepare a preliminary design. To account for the needs of the client as well as the conditions at the site, they frequently make changes before a final design is approved. They also take into account any local, State, or Federal regulations, such as those protecting wetlands or historic resources. In preparing designs, computer-aided design (CAD) has become an essential tool for most landscape architects. Many landscape architects also use video simulation to help clients envision the proposed ideas and plans. For larger scale site planning, landscape architects also use geographic information systems technology, a computer mapping system.

Throughout all phases of the planning and design, landscape architects consult with other professionals involved in the project. Once the design is complete, they prepare a proposal for the client. They produce detailed plans of the site, including written reports, sketches, models, photographs, land-use studies, and cost estimates, and submit them for approval by the client and by regulatory agencies. When the plans are approved, landscape architects prepare working drawings showing all existing and proposed features. They also outline in detail the methods of construction and draw up a list of necessary materials. Although many landscape architects monitor the installation of their design, the developer's project general contractor or a landscape contractor usually directs the actual construction and installation of plantings.

Some landscape architects work on a variety of projects. Others specialize in a particular area, such as residential development, street and highway beautification, waterfront improvement projects, parks and playgrounds, or shopping centers. Still others work in regional planning and resource management; feasibility, environmental impact, and cost studies; or site construction. Increasingly, landscape architects are becoming involved with projects in environmental remediation, such as preservation and restoration of wetlands. Historic landscape preservation and restoration is another important area where landscape architects are increasingly playing an important role.

Most landscape architects do at least some residential work, but relatively few limit their practice to individual homeowners. Residential landscape design projects usually are too small to provide suitable income compared with larger commercial or multiunit residential projects. Some nurseries offer residential landscape design services, but these services often are performed by lesser qualified landscape designers, or others with training and experience in related areas.

Landscape architects who work for government agencies do site and landscape design for government buildings, parks, and other public lands, as well as park and recreation planning in national parks and forests. In addition, they prepare environmental impact statements and studies on environmental issues such as public land-use planning. Some restore degraded land, such as mines or landfills. Other architects use their skills in traffic-calming, the "art" of slowing traffic down through use of traffic design, enhancement of the physical environment, and greater attention to aesthetics.

Working Conditions

Landscape architects spend most of their time in offices creating plans and designs, preparing models and cost estimates, doing research, or attending meetings with clients and other professionals involved in a design or planning project. The remainder of their time is spent at the site. During the design and planning stage, landscape architects visit and analyze the

Landscape architects often visit the worksite to check that plans are implemented properly.

site to verify that the design can be incorporated into the landscape. After the plans and specifications are completed, they may spend additional time at the site observing or supervising the construction. Those who work in large national or regional firms may spend considerably more time out of the office traveling to sites away from the local area.

Salaried employees in both government and landscape architectural firms usually work regular hours; however, they may work overtime to meet a project deadline. Hours of self-employed landscape architects vary depending on the demands of the projects on which they are working.

Employment

Landscape architects held about 23,000 jobs in 2002. About 4 out of 10 workers were employed in firms that provide architectural, engineering, and related services. The Federal Government also employs these workers, primarily in the U.S. Departments of Agriculture, Defense, and Interior. Almost 1 of every 4 landscape architects was self-employed.

Employment of landscape architects is concentrated in urban and suburban areas throughout the country; some landscape architects work in rural areas, particularly those employed by the Federal Government to plan and design parks and recreation areas.

Training, Other Qualifications, and Advancement

A bachelor's or master's degree in landscape architecture usually is necessary for entry into the profession. The bachelor's degree in landscape architecture takes 4 or 5 years to complete. There also are two types of accredited master's degree programs. The most common type of master's degree is a 3-year first professional degree program designed for students with an undergraduate degree in another discipline. The second type of master's degree is a 2-year second professional degree program for students who have a bachelor's degree in landscape architecture and who wish to teach or specialize in some aspect of landscape architecture, such as regional planning or golf course design.

In 2002, 58 colleges and universities offered 75 undergraduate and graduate programs in landscape architecture that were accredited by the Landscape Architecture Accreditation Board of the American Society of Landscape Architects. College courses required in these programs usually include technical subjects such as surveying, landscape design and construction, landscape ecology, site design, and urban and regional planning. Other courses include history of landscape architecture, plant and soil science, geology, professional practice, and general management. Many landscape architecture programs also are adding courses that address environmental issues, a growing concern of landscape architects. The design studio is another important aspect of many landscape architecture curriculums. Whenever possible, students are assigned real projects, providing them with valuable hands-on experience. While working on these projects, students become more proficient in the use of computer-aided design, geographic information systems, and video simulation.

In 2002, 46 States required landscape architects to be licensed or registered. Licensing is based on the Landscape Architect Registration Examination (L.A.R.E.), sponsored by the Council of Landscape Architectural Registration Boards and administered over a 3-day period. Admission to the exam usually requires a degree from an accredited school plus 1 to 4 years of work experience under the supervision of a registered landscape architect, although standards vary from State to State. Currently, 15 States require the passage of a State examination in addition to the L.A.R.E. to satisfy registration requirements. State examinations, which usually are 1 hour in length and completed at the end of the L.A.R.E., focus on laws, environmental regulations, plants, soils, climate, and any other characteristics unique to the State.

Because State requirements for licensure are not uniform, landscape architects may not find it easy to transfer their registration from one State to another. However, those who meet the national standards of graduating from an accredited program, serving 3 years of internship under the supervision of a registered landscape architect, and passing the L.A.R.E. can satisfy requirements in most States. Through this means, a landscape architect can obtain certification from the Council of Landscape Architectural Registration Boards, and so gain reciprocity (the right to work) in other States.

In the Federal Government, candidates for entry positions should have a bachelor's or master's degree in landscape architecture. The Federal Government does not require its landscape architects to be licensed.

Persons planning a career in landscape architecture should appreciate nature, enjoy working with their hands, and possess strong analytical skills. Creative vision and artistic talent also are desirable qualities. Good oral communication skills are essential; landscape architects must be able to convey their ideas to other professionals and clients and to make presentations before large groups. Strong writing skills also are valuable, as is knowledge of computer applications of all kinds, including word processing, desktop publishing, and spreadsheets. Landscape architects use these tools to develop presentations, proposals, reports, and land impact studies for clients, colleagues, and superiors. The ability to draft and design using CAD software is essential. Many employers recommend that prospective landscape architects complete at least one summer internship with a landscape architecture firm in order to gain an understanding of the day-to-day operations of a small business, including how to win clients, generate fees, and work within a budget.

In States where licensure is required, new hires may be called "apprentices" or "intern landscape architects" until they become licensed. Their duties vary depending on the type and size of the employing firm. They may do project research or prepare working drawings, construction documents, or base maps of the area to be landscaped. Some are allowed to participate in the actual design of a project. However, interns must perform all work under the supervision of a licensed landscape architect. Additionally, all drawings and specifications must be signed and sealed by the licensed landscape architect, who takes legal responsibility for the work. After gaining experience and becoming licensed, landscape architects usually can carry a design through all stages of development. After several years, they may become project managers, taking on the responsibility for meeting schedules and budgets, in addition to overseeing the project design. Later, they may become associates or partners of a firm, with a proprietary interest in the business.

Many landscape architects are self-employed because start-up costs, after an initial investment in CAD software, are relatively low. Self-discipline, business acumen, and good marketing skills are important qualities for those who choose to open their own business. Even with these qualities, however, some may struggle while building a client base.

Those with landscape architecture training also qualify for jobs closely related to landscape architecture, and may, after gaining some experience, become construction supervisors, land or environmental planners, or landscape consultants.

Job Outlook

Employment of landscape architects is expected to increase faster than the average for all occupations through the year 2012. Their expertise will be highly sought after in the planning and development of new residential, commercial, and other types of construction, to meet the needs of a growing population. With land costs rising and the public demanding more beautiful spaces, the importance of good site planning and landscape design grows. Also, new construction is increasingly contingent upon compliance with environmental regulations, land use zoning, and water restrictions, spurring demand for landscape architects to help plan sites and integrate man-made structures with the natural environment in the least disruptive way. Landscape architects also will be increasingly involved in preserving and restoring wetlands and other environmentally sensitive sites. However, opportunities will vary from year to year, and by geographic region, depending on local economic conditions. During a recession, when real estate sales and construction slow down, landscape architects may face layoffs and greater competition for jobs. The need to replace landscape architects who retire or leave the labor force will produce some additional job openings.

Continuation of the Transportation Equity Act for the Twenty-First Century is expected to spur employment for landscape architects, particularly within State and local governments. This Act, known as TEA-21, provides funds for surface transportation and transit programs, such as interstate highway construction and maintenance and environment-friendly pedestrian and bicycle trails. Budget tightening in the Federal Government might restrict hiring in the U.S. Forest Service and the National Park Service, agencies that traditionally employ the most landscape architects in the Federal Government. Instead, such agencies may increasingly contract out for landscape architecture services, providing additional employment opportunities in private landscape architecture firms.

In addition to the work related to new development and construction, landscape architects are expected to be involved in historic preservation, land reclamation, and refurbishment of existing sites. They are also doing more residential design work as households spend more on landscaping than in the past. Because landscape architects can work on many different types of projects, they may have an easier time than other design professionals finding employment when traditional construction slows down.

New graduates can expect to face competition for jobs in the largest and most prestigious landscape architecture firms, but should face good job opportunities overall as demand increases, while the number of graduates of landscape architecture holds steady or goes up slightly. Opportunities will be best for landscape architects who develop strong technical skills—such as computer design—and communication skills, as well as knowledge of environmental codes and regulations. Those with additional training or experience in urban planning increase their opportunities for employment in landscape architecture firms that specialize in site planning as well as landscape design. Many employers prefer to hire entry-level landscape architects who have internship experience, which significantly reduces the amount of on-the-job training required.

Earnings

In 2002, median annual earnings for landscape architects were $47,400. The middle 50 percent earned between $36,140 and $62,470. The lowest 10 percent earned less than $28,730 and the highest 10 percent earned over $79,620. Architectural, engineering, and related services employed more landscape architects than any other group of industries, and there the median annual earnings were $46,980 in 2002.

In 2003, the average annual salary for all landscape architects in the Federal Government in nonsupervisory, supervisory, and managerial positions was $68,959.

Because many landscape architects work for small firms or are self-employed, benefits tend to be less generous than those provided to workers in large organizations.

Related Occupations

Landscape architects use their knowledge of design, construction, land-use planning, and environmental issues to develop a landscape project. Others whose work requires similar skills are architects, except landscape and naval; surveyors, cartographers, photogrammetrists, and surveying technicians; civil engineers; and urban and regional planners. Landscape architects also must know how to grow and use plants in the landscape. Some conservation scientists and foresters and biological and medical scientists study plants in general and do related work, while environmental scientists and geoscientists work in the area of environmental remediation.

Sources of Additional Information

Additional information, including a list of colleges and universities offering accredited programs in landscape architecture, is available from:

➤ American Society of Landscape Architects, Career Information, 636 Eye St. NW., Washington, DC 20001-3736. Internet: **http://www.asla.org**

General information on registration or licensing requirements is available from:

➤ Council of Landscape Architectural Registration Boards, 144 Church Street NW., Suite 201, Vienna, VA 22180-4550. Internet: **http://www.clarb.org**

Medical Scientists

(0*NET 19-1041.00, 19-1042.00)

Significant Points

- Epidemiologists typically require a master's degree in public health or, in some cases, a medical degree; other medical scientists need a Ph.D. degree in a biological science.
- Competition is expected for most positions.
- Most medical scientists work in research and development.

Nature of the Work

Medical scientists research human diseases in order to improve human health. Most medical scientists work in research and development. Some conduct basic research to advance knowledge of living organisms, including viruses, bacteria, and other infectious agents. Past research has resulted in the development of vaccines, medicines, and treatments for many diseases. Basic medical research continues to provide the building blocks necessary to develop solutions to human health problems. Medical scientists also engage in clinical investigation, technical writing, drug application review, patent examination, or related activities.

Medical scientists study biological systems to understand the causes of disease and other health problems and to develop treatments. They try to identify changes in a cell or chromosomes that signal the development of medical problems, such as different types of cancer. For example, a medical scientist involved in cancer research may formulate a combination of drugs that will lessen the effects of the disease. Medical scientists who are also physicians can administer these drugs to patients in clinical trials, monitor their reactions, and observe the results. Those who are not physicians normally collaborate with a physician who deals directly with patients. Medical scientists examine the results of clinical trials and, if necessary, adjust the dosage levels to reduce negative side effects or to try to induce even better results. In addition to developing treatments for health problems, medical scientists attempt to discover ways to prevent health problems, such as affirming the link between smoking and lung cancer, or between alcoholism and liver disease.

Many medical scientists work independently in private industry, university, or government laboratories, often exploring new areas of research or expanding on specialized research that they started in graduate school. Medical scientists working in colleges and universities, hospitals, and nonprofit medical research organizations typically submit grant proposals to obtain funding for their projects. Colleges and universities, private industry, and Federal Government agencies, such as the National Institutes of Health and the National Science Foundation, contribute to the support of scientists whose research proposals are determined to be financially feasible and have the potential to advance new ideas or processes.

Medical scientists who work in applied research or product development use knowledge provided by basic research to develop new drugs and medical treatments. They usually have less autonomy than basic researchers to choose the emphasis of their research, relying instead on market-driven directions based on the firm's products and goals. Medical scientists doing applied research and product development in private industry may be required to express their research plans or results to nonscientists who are in a position to veto or approve their ideas, and they must understand the impact of their work on business. Scientists increasingly work as part of teams, interacting with engineers, scientists of other disciplines, business managers, and technicians.

Medical scientists who conduct research usually work in laboratories and use electron microscopes, computers, thermal cyclers, or a wide variety of other equipment. Some may work directly with individual patients or larger groups as they administer drugs and monitor and observe the patients during clinical trials. Medical scientists who are also physicians may administer gene therapy to human patients, draw blood, excise tissue, or perform other invasive procedures.

Some medical scientists work in managerial, consulting, or administrative positions, usually after spending some time doing research and learning about the firm, agency, or project. In the 1980s, swift advances in basic medical knowledge related to genetics and molecules spurred growth in the field of biotechnology. Medical scientists using this technology manipulate the genetic material of animals, attempting to make organisms more productive or resistant to disease. Research using biotechnology techniques, such as recombining DNA, has led to the discovery of important drugs, including human insulin and growth hormone. Many other substances not previously available in large quantities are now produced by biotechnological means; some may be useful in treating diseases such as Parkinson's or Alzheimer's. Today, many medical scientists are involved in the science of genetic engineering—isolating, identifying, and sequencing human genes and then determining their functionality. This work continues to lead to the discovery of the genes associated with specific diseases and inherited traits, such as certain types of cancer or obesity. These advances in biotechnology have opened up research opportunities in almost all areas of medical science.

Some medical scientists specialize in epidemiology. This branch of medical science investigates and describes the determinants of disease, disability, and other health outcomes and develops the means for prevention and control. Epidemiologists may study many different diseases such as tuberculosis, influenza, or cholera, often focusing on epidemics.

Epidemiologists can be separated into two groups, research and clinical. Research epidemiologists conduct basic and advanced research on infectious diseases that affect the entire body,

Most medical scientists conduct basic research to advance knowledge of living organisms.

such as AIDS or typhus—attempting to eradicate or control these diseases. Others may focus only on localized infections of the brain, lungs, or digestive tract, for example. Research epidemiologists work at colleges and universities, schools of public health, medical schools, and research and development services firms. For example, Government agencies such as the Department of Defense may contract with a research firm's epidemiologists to evaluate the incidence of malaria in certain parts of the world. While some perform consulting services, other research epidemiologists may work as college and university faculty.

Clinical epidemiologists work primarily in consulting roles at hospitals, informing the medical staff of infectious outbreaks and providing containment solutions. These clinical epidemiologists sometimes are referred to as infection control professionals. Consequently, many epidemiologists in this specific area often are physicians. Epidemiologists who are not physicians often collaborate with physicians to find ways to contain diseases and outbreaks. In addition to traditional duties of studying and controlling diseases, clinical epidemiologists also may be required to develop standards and guidelines for the treatment and control of communicable diseases. Some clinical epidemiologists may work in outpatient settings.

Working Conditions

Medical scientists typically work regular hours in offices or laboratories and usually are not exposed to unsafe or unhealthy conditions. Those who work with dangerous organisms or toxic substances in the laboratory must follow strict safety procedures to avoid contamination. Medical scientists also spend time working in clinics and hospitals administering drugs and treatments to patients in clinical trials. On occasion, epidemiologists may be required to work evenings and weekends to attend meetings and hearings for medical investigations.

Some medical scientists depend on grant money to support their research. They may be under pressure to meet deadlines and to conform to rigid grant-writing specifications when preparing proposals to seek new or extended funding.

Employment

Medical scientists, including epidemiologists, held about 62,000 jobs in 2002. Medical scientists accounted for 58,000 of the total; epidemiologists, 3,900. In addition, many medical scientists held faculty positions in colleges and universities, but they are classified as college or university faculty. (See teachers—postsecondary elsewhere in the *Handbook*.)

Almost 30 percent of medical scientists were employed in scientific research and development services firms, another 24 percent worked in Government, 14 percent in pharmaceutical and medicine manufacturing, 13 percent in private hospitals, and most of the remainder worked in private educational services and ambulatory health care services. About 1,000 were self-employed.

Among epidemiologists, nearly 45 percent were employed in Government, another 20 percent worked in management, scientific, and technical consulting services firms, 14 percent in private hospitals, and 12 percent in scientific research and development services firms.

Training, Other Qualifications, and Advancement

A Ph.D. degree in a biological science is the minimum education required for most prospective medical scientists, except epidemiologists, because the work of medical scientists is almost entirely research oriented. A Ph.D. degree qualifies one to do research on basic life processes or on particular medical problems or diseases, and to analyze and interpret the results of experiments on patients. Some medical scientists obtain a medical degree instead of a Ph.D., but may not be licensed physicians because they have not taken the State licensing examination or completed a residency program, typically because they prefer research to clinical practice. Medical scientists who administer drug or gene therapy to human patients, or who otherwise interact medically with patients—drawing blood, excising tissue, or performing other invasive procedures—must be licensed physicians. To be licensed, physicians must graduate from an accredited medical school, pass a licensing examination, and complete 1 to 7 years of graduate medical education. (See physicians and surgeons elsewhere in the *Handbook*.) It is particularly helpful for medical scientists to earn both Ph.D. and medical degrees.

Students planning careers as medical scientists should have a bachelor's degree in a biological science. In addition to required courses in chemistry and biology, undergraduates should study allied disciplines such as mathematics, physics, and computer science, or courses in their field of interest. Once they have completed undergraduate studies, they can then select a specialty area for their advanced degree, such as cytology, genomics, or pathology. In addition to formal education, medical scientists usually spend several years in a postdoctoral position before they apply for permanent jobs. Postdoctoral work provides valuable laboratory experience, including experience in specific processes and techniques such as gene splicing, which is transferable to other research projects. In some institutions, the postdoctoral position can lead to a permanent job.

Medical scientists should be able to work independently or as part of a team and be able to communicate clearly and concisely, both orally and in writing. Those in private industry, especially those who aspire to consulting and administrative positions, should possess strong communication skills so they can provide instruction and advice to physicians and other healthcare professionals.

The minimum educational requirement for epidemiology is a master's degree from a school of public health. Some jobs require a Ph.D. or medical degree, depending on the work performed. Epidemiologists who work in hospitals and healthcare centers often must have a medical degree with specific training in infectious diseases. Currently, 134 infectious disease training programs exist in 42 States. Some employees in research epidemiology positions are required to be licensed physicians, as they are required to administer drugs in clinical trials.

Epidemiologists who perform laboratory tests often require the knowledge and expertise of a licensed physician in order to administer drugs to patients in clinical trials. Epidemiologists who are not physicians frequently work closely with one.

Very few students select epidemiology for undergraduate study. Undergraduates, nonetheless, should study biological sciences and should have a solid background in chemistry, mathematics, and computer science. Once a student is prepared for graduate studies, he or she can choose a specialty within epidemiology. For example, those interested in studying environmental epidemiology should focus on environmental coursework, such as water pollution, air pollution, or pesticide use. The core work of environmental studies includes toxicology and molecular biology, and students may continue with advanced coursework in environmental or occupational epidemiology. Some epidemiologists are registered nurses and medical technologists seeking advancement.

Job Outlook

Employment of medical scientists is expected to grow faster than the average for all occupations through 2012. Despite projected rapid job growth for medical scientists, doctoral degree holders can expect to face considerable competition for basic research positions. The Federal Government funds much basic research and development, including many areas of medical research. Recent budget increases at the National Institutes of Health have led to large increases in Federal basic research and development expenditures, with the number of grants awarded to researchers growing in number and dollar amount. At the same time, the number of newly trained medical scientists has continued to increase at least as fast as employment opportunities, so both new and established scientists have experienced greater difficulty winning and renewing research grants. If the number of advanced degrees awarded continues to grow unabated, as expected, this competitive situation is likely to persist.

Medical scientists enjoyed rapid gains in employment between the mid-1980s and mid-1990s, in part reflecting increased staffing requirements in new biotechnology companies. Employment growth should slow somewhat as increases in the number of new biotechnology firms slow and existing firms merge or are absorbed into larger ones. However, much of the basic medical research done in recent years has resulted in new knowledge, including the isolation and identification of new genes. Medical scientists will be needed to take this knowledge to the next stage, which is understanding how certain genes function within an entire organism, so that gene therapies can be developed to treat diseases. Even pharmaceutical and other firms not solely engaged in biotechnology are expected to increasingly use biotechnology techniques, thus creating employment for medical scientists.

Expected expansion in research related to health issues such as AIDS, cancer, and Alzheimer's disease also should result in employment growth. Although medical scientists greatly contributed to developing many vaccines and antibiotics, more medical research will be required to better understand these and other epidemics and to improve human health.

Opportunities in epidemiology also should be highly competitive, as the number of available positions remains limited. However, an increasing focus on monitoring patients at hospitals and healthcare centers to ensure positive patient outcomes will contribute to job growth. In addition, a heightened awareness of bioterrorism and infectious diseases such as West Nile Virus or SARS should also spur demand for these workers. As hospitals enhance their infection control programs, many will seek to boost the quality and quantity of their staff. Besides job openings due to employment growth, additional openings will result as workers leave the labor force or transfer to other occupations. Because employment of epidemiologists is somewhat tied to the healthcare industry, industry conditions will influence occupational demand.

Medical scientists and some epidemiologists are less likely to lose their jobs during recessions than are those in many other occupations because they are employed on long-term research projects. However, a recession could influence the amount of money allocated to new research and development efforts, particularly in areas of risky or innovative medical research. A recession also could limit the possibility of extension or renewal of existing projects.

Earnings

Median annual earnings of medical scientists, except epidemiologists, were $56,980 in 2002. The middle 50 percent earned between $40,180 and $82,720. The lowest 10 percent earned less than $29,980, and the highest 10 percent earned more than $114,640. Median annual earnings in the industries employing the largest numbers of medical scientists in 2002 were:

Pharmaceutical and medicine manufacturing	$72,330
Scientific research and development services	61,470
General medical and surgical hospitals	50,660
Colleges, universities, and professional schools	35,520

Median annual earnings of epidemiologists were $53,840 in 2002. The middle 50 percent earned between $44,900 and $66,510. The lowest 10 percent earned less than $35,910, and the highest 10 percent earned more than $85,930.

Related Occupations

Many other occupations deal with living organisms and require a level of training similar to that of medical scientists. These include biological scientists, agricultural and food scientists, and health occupations such as physicians and surgeons, dentists, and veterinarians.

Sources of Additional Information

For a brochure entitled *Is a Career in the Pharmaceutical Sciences Right for Me?*, contact:

➤ American Association of Pharmaceutical Scientists (AAPS), 2107 Wilson Blvd., Suite #700, Arlington, VA 22201.

For a career brochure entitled *A Million and One,* contact:

➤ American Society for Microbiology, Education Department, 1752 N St. NW., Washington, D.C. 20036-2804. Internet: **http://www.asmusa.org**

For information on infectious diseases training programs, contact:

➤ Infectious Diseases Society of America, Guide to Training Programs, 66 Canal Center Plaza, Suite # 600, Alexandria, VA 22314. Internet: **http://www.idsociety.org**

Information on obtaining a medical scientist position with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (703) 724-1850; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: **http://www.usajobs.opm.gov**.

Physicists and Astronomers

(0*NET 19-2011.00, 19-2012.00)

Significant Points

- Scientific research and development services firms and the Federal Government employ 3 out of 5 physicists and astronomers.
- Most jobs are in basic research and development, usually requiring a doctoral degree; master's degree holders qualify for many jobs in applied research and development, while bachelor's degree holders may qualify as technicians or research assistants.
- Ph.D. graduates will face competition for basic research jobs.

Nature of the Work

Physicists explore and identify basic principles governing the structure and behavior of matter, the generation and transfer of energy, and the interaction of matter and energy. Some physicists use these principles in theoretical areas, such as the nature of time and the origin of the universe; others apply their physics knowledge to practical areas, such as the development of advanced materials, electronic and optical devices, and medical equipment.

Physicists design and perform experiments with lasers, particle accelerators, telescopes, mass spectrometers, and other equipment. Based on observations and analysis, they attempt to discover and explain laws describing the forces of nature, such as gravity, electromagnetism, and nuclear interactions. Physicists also find ways to apply physical laws and theories to problems in nuclear energy, electronics, optics, materials, communications, aerospace technology, and medical instrumentation.

Astronomy is sometimes considered a subfield of physics. *Astronomers* use the principles of physics and mathematics to learn about the fundamental nature of the universe, including the sun, moon, planets, stars, and galaxies. They also apply their knowledge to solve problems in navigation, space flight, and satellite communications, and to develop the instrumentation and techniques used to observe and collect astronomical data.

Most physicists work in research and development. Some do basic research to increase scientific knowledge. Physicists who conduct applied research build upon the discoveries made through basic research and work to develop new devices, products, and processes. For example, basic research in solid-state physics led to the development of transistors and, then, integrated circuits used in computers.

Physicists also design research equipment. This equipment often has additional unanticipated uses. For example, lasers are used in surgery, microwave devices are used in ovens, and measuring instruments can analyze blood or the chemical content of foods. A small number of physicists work in inspection, testing, quality control, and other production-related jobs in industry.

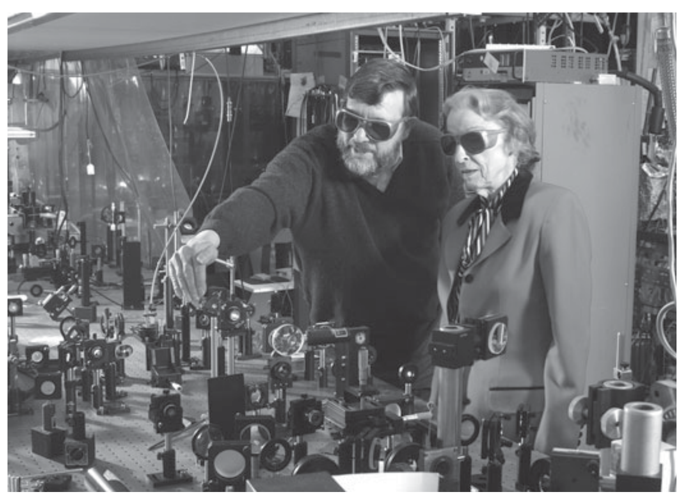
Much physics research is done in small or medium-sized laboratories. However, experiments in plasma, nuclear, and high energy and in some other areas of physics require extremely large, expensive equipment, such as particle accelerators. Physicists in these subfields often work in large teams. Although physics research may require extensive experimentation in laboratories, research physicists still spend time in offices planning, recording, analyzing, and reporting on research.

Almost all astronomers do research. Some are theoreticians, working on the laws governing the structure and evolution of astronomical objects. Others analyze large quantities of data gathered by observatories and satellites, and write scientific papers or reports on their findings. Some astronomers actually operate large space- or ground-based telescopes, usually as part of a team. However, astronomers may spend only a few weeks each year making observations with optical telescopes, radio telescopes, and other instruments. For many years, satellites and other space-based instruments, such as the Hubble space telescope, have provided tremendous amounts of astronomical data. New technology resulting in improvements in analytical techniques and instruments, such as computers and optical telescopes and mounts, is leading to a resurgence in ground-based research. A small number of astronomers work in museums housing planetariums. These astronomers develop and revise programs presented to the public, and may direct planetarium operations.

Physicists generally specialize in one of many subfields—elementary particle physics, nuclear physics, atomic and molecular physics, physics of condensed matter (solid-state physics), optics, acoustics, space physics, plasma physics, or the physics of fluids. Some specialize in a subdivision of one of these subfields. For example, within condensed matter physics, specialties include superconductivity, crystallography, and semiconductors. However, all physics involves the same fundamental principles, so specialties may overlap, and physicists may switch from one subfield to another. Also, growing numbers of physicists work in interdisciplinary fields, such as biophysics, chemical physics, and geophysics.

Working Conditions

Physicists often work regular hours in laboratories and offices. At times, however, those who are deeply involved in research may work long or irregular hours. Most do not encounter unusual hazards in their work. Some physicists temporarily work away from home at national or international facilities with unique equipment, such as particle accelerators. Astronomers who make observations using ground-based telescopes may spend long periods in observatories; this work usually involves travel to remote locations and may require long hours, including nightwork.



Most physicist and astronomer jobs are in basic research and development, usually requiring a doctoral degree.

Physicists and astronomers whose work depends on grant money often are under pressure to write grant proposals to keep their work funded.

Employment

Physicists and astronomers held about 14,000 jobs in 2002. Jobs for astronomers accounted for only 7 percent of the total. Nearly one-third of physicists and astronomers worked for scientific research and development services firms. The Federal Government employed 29 percent, mostly in the U.S. Department of Defense, but also in the National Aeronautics and Space Administration (NASA), and in the U.S. Departments of Commerce, Health and Human Services, and Energy. Other physicists and astronomers worked in colleges and universities in nonfaculty, usually research, positions, or for State governments, information technology companies, pharmaceutical and medicine manufacturing companies, or electronic equipment manufacturers.

Besides the jobs described above, many physicists and astronomers held faculty positions in colleges and universities. (See the statement on teachers—postsecondary elsewhere in the *Handbook*.)

Although physicists and astronomers are employed in all parts of the country, most work in areas in which universities, large research and development laboratories, or observatories are located.

Training, Other Qualifications, and Advancement

Because most jobs are in basic research and development, a doctoral degree is the usual educational requirement for physicists and astronomers. Additional experience and training in a postdoctoral research appointment, although not required, is important for physicists and astronomers aspiring to permanent positions in basic research in universities and government laboratories. Many physics and astronomy Ph.D. holders ultimately teach at the college or university level.

Master's degree holders usually do not qualify for basic research positions but do qualify for many kinds of jobs requiring a physics background, including positions in manufacturing and applied research and development. Increasingly, many master's degree programs specifically prepare students for physics-related research and development that does not require a Ph.D. degree. These master's degree programs teach students specific research skills that can be used in private industry jobs. A master's degree may suffice for teaching jobs in high schools or at 2-year colleges.

Those with bachelor's degrees in physics are rarely qualified to fill positions in research or in teaching at the college level. They are, however, usually qualified to work as technicians or research assistants in engineering-related areas, in software development and other scientific fields, or in setting up computer networks and sophisticated laboratory equipment. Some may qualify for applied research jobs in private industry or nonresearch positions in the Federal Government. Some become science teachers in secondary schools. Astronomy bachelor's or master's degree holders often enter a field unrelated to astronomy, and they are qualified to work in planetariums running science shows, to assist astronomers doing research, and to operate space-based and ground-based telescopes and other astronomical instrumentation. (See the statements on engineers; environmental scientists and geoscientists; computer programmers; computer systems analysts, database administrators, and computer scientists; and computer software engineers, elsewhere in the *Handbook*.)

More than 500 colleges and universities offer a bachelor's degree in physics. Undergraduate programs provide a broad background in the natural sciences and mathematics. Typical physics courses include electromagnetism, optics, thermodynamics, atomic physics, and quantum mechanics.

About 180 colleges and universities have departments offering Ph.D. degrees in physics. More than 70 additional colleges offer a master's as their highest degree in physics. Graduate students usually concentrate in a subfield of physics, such as elementary particles or condensed matter. Many begin studying for their doctorate immediately after receiving their bachelor's degree.

About 70 universities grant degrees in astronomy, either through an astronomy, physics, or combined physics/astronomy department. Currently, more than 30 departments are combined with the physics department and nearly 40 are administered separately. With fewer than 40 doctoral programs in astronomy, applicants face considerable competition for available slots. Those planning a career in astronomy should have a very strong physics background. In fact, an undergraduate degree in either physics or astronomy is excellent preparation, followed by a Ph.D. in astronomy.

Mathematical ability, problem-solving and analytical skills, an inquisitive mind, imagination, and initiative are important traits for anyone planning a career in physics or astronomy. Prospective physicists who hope to work in industrial laboratories applying physics knowledge to practical problems should broaden their educational background to include courses outside of physics, such as economics, information technology, and business management. Good oral and written communication skills also are important because many physicists work as part of a team, write research papers or proposals, or have contact with clients or customers with nonphysics backgrounds.

Many physics and astronomy Ph.D. holders begin their careers in a postdoctoral research position, in which they may work with experienced physicists as they continue to learn about their specialty and develop ideas and results to be used in later work. Initial work may be under the close supervision of senior scientists. After some experience, physicists perform increasingly complex tasks and work more independently. Those who develop new products or processes sometimes form their own companies or join new firms to exploit their own ideas.

Job Outlook

Employment of physicists and astronomers is expected to grow more slowly than the average for all occupations through 2012. Federal research expenditures are the major source of physics-related and astronomy-related research funds, especially for basic research. Although these expenditures are expected to steadily increase over the 2002-12 projection period, resulting in some growth in employment and opportunities, the limited research funds available still will result in competition among Ph.D. holders for basic research jobs. The need to replace physicists and astronomers who retire or otherwise leave the occupation permanently will account for most expected job openings.

Although research and development budgets in private industry will continue to grow, many research laboratories in private industry are expected to continue to reduce basic research, which includes much physics research, in favor of applied or manufacturing research and product and software development.

Nevertheless, persons with a physics background continue to be in demand in the areas of information technology, semiconductor technology, and other applied sciences. This trend is expected to continue; however, many of the new workers will have job titles such as computer software engineer, computer programmer, engineer, and systems developer, rather than physicist.

Through the 1990s, the number of doctorates granted in physics was much greater than the number of job openings for physicists, resulting in keen competition, particularly for research positions in colleges and universities and in research and development centers. Competitive conditions have eased somewhat because the number of doctorate degrees awarded has been dropping for several years, in line with declining enrollment in graduate physics programs. Recent increases in undergraduate physics enrollments, however, may again lead to growth in enrollments in graduate physics programs, meaning that, toward the end of the projection period, there may be an increase in the number of doctoral degrees granted that will intensify the competition for job openings.

Opportunities may be more numerous for those with a master's degree, particularly graduates from programs preparing students for applied research and development, product design, and manufacturing positions in private industry. Many of these positions, however, will have titles other than physicist, such as engineer or computer scientist.

Persons with only a bachelor's degree in physics or astronomy are not qualified to enter most physicist or astronomer research jobs but may qualify for a wide range of positions related to engineering, mathematics, computer science, and environmental science. Those who meet State certification requirements can become high school physics teachers, an occupation in strong demand in many school districts. Most States require new teachers to obtain a master's degree in education within a certain time. (See the statement on teachers—preschool, kindergarten, elementary, middle, and secondary elsewhere in the *Handbook.*) Despite competition for traditional physics and astronomy research jobs, individuals with a physics degree at any level will find their knowledge of science and mathematics useful for entry to many other occupations.

Earnings

Median annual earnings of physicists were $85,020 in 2002. The middle 50 percent earned between $66,680 and $107,410. The lowest 10 percent earned less than $50,350, and the highest 10 percent earned more than $129,250.

Median annual earnings of astronomers were $81,690 in 2002. The middle 50 percent earned between $53,390 and $106,230; the lowest 10 percent, less than $40,140, and the highest 10 percent more than $126,320.

According to a 2003 National Association of Colleges and Employers survey, the average annual starting salary offer to physics doctoral degree candidates was $55,485.

The American Institute of Physics reported a median annual salary of $95,000 in 2002 for its full time members with Ph.D.'s (excluding those in postdoctoral positions); the median was $87,000 for those with master's degrees, and $78,000 for bachelor's degree holders. Those working in temporary postdoctoral positions earned significantly less.

The average annual salary for physicists employed by the Federal Government was $95,685 in 2003; for astronomy and space scientists, it was $100,591.

Related Occupations

The work of physicists and astronomers relates closely to that of engineers; chemists and materials scientists; atmospheric scientists; environmental scientists and geoscientists; computer systems analysts, computer scientists, and database administrators; computer programmers; and mathematicians.

Sources of Additional Information

General information on career opportunities in physics is available from:

➤American Institute of Physics, Career Services Division and Education and Employment Division, One Physics Ellipse, College Park, MD 20740-3843. Internet: **http://www.aip.org**

➤The American Physical Society, One Physics Ellipse, College Park, MD 20740-3844. Internet: **http://www.aps.org**

Science Technicians

(0*NET 19-4011.01, 19-4011.02, 19-4021.00, 19-4031.00, 19-4041.01, 19-4041.02, 19-4051.01, 19-4051.02, 19-4091.00, 19-4092.00, 19-4093.00)

Significant Points

- Science technicians in production jobs can be employed on day, evening, or night shifts.
- Many employers prefer applicants who have at least 2 years of specialized training or an associate degree.
- Job opportunities are expected to be best for graduates of applied science technology programs.
- Job growth will be concentrated in pharmaceutical manufacturing, chemical manufacturing, and biotechnological research and development firms.

Nature of the Work

Science technicians use the principles and theories of science and mathematics to solve problems in research and development and to help invent and improve products and processes. However, their jobs are more practically oriented than those of scientists. Technicians set up, operate, and maintain laboratory instruments, monitor experiments, make observations, calculate and record results, and often develop conclusions. They must keep detailed logs of all of their work-related activities. Those who work in production monitor manufacturing processes and may be involved in ensuring quality by testing products for proper proportions of ingredients, for purity, or for strength and durability.

As laboratory instrumentation and procedures have become more complex in recent years, the role of science technicians in research and development has expanded. In addition to performing routine tasks, many technicians also develop and adapt laboratory procedures to achieve the best results, interpret data, and devise solutions to problems, under the direction of scientists. Moreover, technicians must master the laboratory equipment so that they can adjust settings when necessary and recognize when equipment is malfunctioning.

The increasing use of robotics to perform many routine tasks has freed technicians to operate more sophisticated laboratory equipment. Science technicians make extensive use of computers, computer-interfaced equipment, robotics, and high-technology industrial applications, such as biological engineering.

Most science technicians specialize, learning skills and working in the same disciplines in which scientists work. Occupational titles, therefore, tend to follow the same structure as those for scientists. *Agricultural technicians* work with agricultural scientists in food, fiber, and animal research, production, and processing. Some conduct tests and experiments to improve the yield and quality of crops or to increase the resistance of plants and animals to disease, insects, or other hazards. Other agricultural technicians do animal breeding and nutrition work. *Food science technicians* assist food scientists and technologists in research and development, production technology, and quality control. For example, food science technicians may conduct tests on food additives and preservatives to ensure FDA compliance on factors such as color, texture, and nutrients. They analyze, record, and compile test results; order supplies to maintain laboratory inventory; and clean and sterilize laboratory equipment.

Biological technicians work with biologists studying living organisms. Many assist scientists who conduct medical research—helping to find a cure for cancer or AIDS, for example. Those who work in pharmaceutical companies help develop and manufacture medicinal and pharmaceutical preparations. Those working in the field of microbiology generally work as lab assistants, studying living organisms and infectious agents. Biological technicians also analyze organic substances, such as blood, food, and drugs, and some examine evidence in a forensic science laboratory. Biological technicians working in biotechnology labs use the knowledge and techniques gained from basic research by scientists, including gene splicing and recombinant DNA, and apply them in product development.

Chemical technicians work with chemists and chemical engineers, developing and using chemicals and related products and equipment. Generally, there are two types of chemical technicians—research and development technicians who work in experimental laboratories, and process control technicians who work in manufacturing or other industrial plants. Many research and development chemical technicians conduct a variety of laboratory procedures, from routine process control to complex research projects. For example, they may collect and analyze samples of air and water to monitor pollution levels or produce compounds through complex organic synthesis. Most process technicians work in manufacturing, where they test packaging for design, integrity of materials, and environmental acceptability. Often, process technicians who work in plants also focus on quality assurance: there, they monitor product quality or production processes and develop new production techniques. A few work in shipping to provide technical support and expertise for these functions.

Environmental science and protection technicians perform laboratory and field tests to monitor environmental resources and determine the contaminants and sources of pollution. They may collect samples for testing or be involved in abating, controlling, or remediating sources of environmental pollutants. Some are responsible for waste management operations, control and management of hazardous materials inventory, or general activities involving regulatory compliance.

Many science technicians make extensive use of computers, computer-interfaced equipment, robotics, and high-technology industrial applications.

Forensic science technicians investigate crimes by collecting and analyzing physical evidence. Often, they specialize in areas such as DNA analysis or firearm examination, performing tests on weapons or substances such as fiber, hair, tissue, or body fluids to determine significance to the investigation. They also prepare reports to document their findings and the laboratory techniques used, and may provide information and expert opinion to investigators. When criminal cases come to trial, forensic science technicians often provide testimony, as expert witnesses, on specific laboratory findings by identifying and classifying substances, materials, and other evidence collected at the crime scene.

Forest and conservation technicians compile data on the size, content, and condition of forest land tracts. These workers usually work in a forest under the supervision of a forester, conducting specific tasks such as measuring timber, supervising harvesting operations, assisting in roadbuilding operations, and locating property lines and features. They also may gather basic information, such as species and population of trees, disease and insect damage, tree seedling mortality, and conditions that may cause fire danger. Forest and conservation technicians also train and lead forest and conservation workers in seasonal activities, such as planting tree seedlings, putting out forest fires, and maintaining recreational facilities.

Geological and petroleum technicians measure and record physical and geologic conditions in oil or gas wells, using advanced instruments lowered into wells or by analysis of the mud from wells. In oil and gas exploration, these technicians collect and examine geological data or test geological samples to determine petroleum and mineral and element composition using scanning electron microscopes. Some petroleum technicians, called *scouts*, collect information about oil and gas well drilling operations, geological and geophysical prospecting, and land or lease contracts.

Nuclear technicians operate nuclear test and research equipment, monitor radiation, and assist nuclear engineers and physicists in research. Some also operate remote control equipment to manipulate radioactive materials or materials to be exposed to radioactivity.

Other science technicians collect weather information or assist oceanographers.

Working Conditions

Science technicians work under a wide variety of conditions. Most work indoors, usually in laboratories, and have regular hours. Some occasionally work irregular hours to monitor experiments that cannot be completed during regular working hours. Production technicians often work in 8-hour shifts around the clock. Others, such as agricultural, forest and conservation, geological and petroleum, and environmental science and protection technicians, perform much of their work outdoors, sometimes in remote locations.

Some science technicians may be exposed to hazards from equipment, chemicals, or toxic materials. Chemical technicians sometimes work with toxic chemicals or radioactive isotopes, nuclear technicians may be exposed to radiation, and biological technicians sometimes work with disease-causing organisms or radioactive agents. Forensic science technicians often are exposed to human body fluids and firearms. However, these working conditions pose little risk, if proper safety procedures are followed. For forensic science technicians, collecting evidence from crime scenes can be distressing and unpleasant.

Employment

Science technicians held about 208,000 jobs in 2002. As indicated by the following tabulation, chemical and biological technicians accounted for over half of all jobs:

Chemical technicians	69,000
Biological technicians	48,000
Environmental science and protection technicians, including health	28,000
Agricultural and food science technicians	20,000
Forest and conservation technicians	19,000
Geological and petroleum technicians	11,000
Forensic science technicians	8,400
Nuclear technicians	5,700

Chemical technicians held jobs in a wide range of manufacturing and service industries, but were concentrated in chemical manufacturing, where they held 26,000 jobs. About 17,000 worked in professional, scientific, or technical services firms; about 17,000 biological technicians also worked in professional, scientific, or technical services firms. Most other biological technicians worked in pharmaceutical and medicine manufacturing or for Federal, State, or local governments. Significant numbers of environmental science and protection technicians also worked for State and local governments and professional, scientific, and technical services firms. Almost two-thirds of forest and conservation technicians held jobs in the Federal Government; another 20 percent worked for State governments. Around 22 percent of agricultural and food science technicians worked for food processing companies; most of the rest worked for scientific research and development services firms and State governments. Over one-fifth of all geological and petroleum technicians worked for oil and gas extraction companies, and forensic science technicians worked primarily for State and local governments.

Training, Other Qualifications, and Advancement

There are several ways to qualify for a job as a science technician. Many employers prefer applicants who have at least 2 years of specialized training or an associate degree in applied science or science-related technology. Because employers' preferences vary, however, some science technicians have a bachelor's degree in chemistry, biology, or forensic science, or have taken several science and math courses at 4-year colleges.

Many technical and community colleges offer associate degrees in a specific technology or a more general education in science and mathematics. A number of 2-year associate degree programs are designed to provide easy transfer to a 4-year college or university, if desired. Technical institutes usually offer technician training, but provide less theory and general education than do technical or community colleges. The length of programs at technical institutes varies, although 1-year certificate programs and 2-year associate degree programs are common.

More than 20 colleges or universities offer a bachelor's degree program in forensic science; more than 10 additional schools offer a bachelor's of science in chemistry, biochemistry, or genetic engineering with an emphasis on forensic science; a few additional schools offer a bachelor's of science degree with an emphasis in a specialty area, such as criminalistics, pathology, jurisprudence, odontology, toxicology, or forensic accounting.

In contrast to some other science technician positions that require only a 2-year degree, a 4-year degree in forensics science is usually necessary to work in the field. Knowledge and understanding of legal procedures also can be helpful. Forestry and conservation technicians can choose from more than 20 associate degree programs in forest technology accredited by the Society of American Foresters.

Most chemical process technicians have a 2-year degree, usually an associate degree in process technology, although in some cases a high school diploma is sufficient. They usually receive additional on-the-job training. Entry-level workers whose college training encompasses extensive hands-on experience with a variety of diagnostic laboratory equipment usually require less on-the-job training. Those with a high school diploma typically begin work as trainees under the direct supervision of a more experienced process technician. Many with only a high school diploma eventually earn a 2-year degree in process technology, often paid for by their employer.

Some schools offer cooperative-education or internship programs, allowing students the opportunity to work at a local company or other workplace while attending classes in alternate terms. Participation in such programs can significantly enhance a student's employment prospects.

Persons interested in careers as science technicians should take as many high school science and math courses as possible. Science courses taken beyond high school, in an associate or bachelor's degree program, should be laboratory oriented, with an emphasis on bench skills. A solid background in applied basic chemistry, physics, and math is vital. Because computers often are used in research and development laboratories, technicians should have strong computer skills. Communication skills also are important; technicians often are required to report their findings both orally and in writing. Additionally, technicians should be able to work well with others, because teamwork is common. Organizational ability, an eye for detail, and skill in interpreting scientific results also are important. High mechanical aptitude, attention to detail, and analytical thinking are all important characteristics of science technicians.

Prospective science technicians can acquire good career preparation through 2-year formal training programs that combine the teaching of scientific principles and theory with practical hands-on application in a laboratory setting with up-to-date equipment. Graduates of 4-year bachelor's degree programs in science who have considerable experience in laboratory-based courses, have completed internships, or have held summer jobs in laboratories also are well qualified for science technician positions and are preferred by some employers. However, those with a bachelor's degree who accept technician jobs generally cannot find employment that uses their advanced academic education.

Technicians usually begin work as trainees in routine positions, under the direct supervision of a scientist or a more experienced technician. Job candidates whose training or educational background encompasses extensive hands-on experience with a variety of laboratory equipment, including computers and related equipment, usually require a short period of on-the-job training. As they gain experience, technicians take on more responsibility and carry out assignments under only general supervision, and some eventually become supervisors. However, technicians employed at universities often have their fortunes tied to those of particular professors; when professors retire or leave, these technicians face uncertain employment prospects.

Job Outlook

Overall employment of science technicians is expected to increase about as fast as the average for all occupations through the year 2012. Continued growth of scientific and medical research, particularly research related to biotechnology, as well as the development and production of technical products, should stimulate demand for science technicians in many industries. The increase in the number of biological technicians will be about as fast as average, as the growing number of agricultural and medicinal products developed using biotechnology techniques will boost demand for these workers. Also, stronger competition among pharmaceutical companies and an aging population are expected to contribute to the need for innovative and improved drugs, further spurring demand for biological technicians. Fastest employment growth of biological technicians should occur in the pharmaceutical and medicine manufacturing industry and in scientific research and development services firms.

Job growth for chemical technicians is projected to grow more slowly than average. The chemical manufacturing industry, the major employer of chemical technicians, will experience a decline in overall employment as companies downsize and turn to outside contractors to provide specialized services. Job opportunities are expected to be more plentiful in pharmaceutical and medicine manufacturing as the public continues to demand newer and better pharmaceuticals. To meet this demand, pharmaceutical manufacturing firms are expected to continue to devote money to research and development, either through in-house teams, or, increasingly, by contracting to scientific research and development services firms, spurring employment growth of chemical technicians in that industry. An increasing focus on quality assurance will require a greater number of process technicians, further stimulating demand for these workers.

Employment of environmental science and protection technicians should grow much faster than average to help regulate waste products; to collect air, water, and soil samples for measuring levels of pollutants; to monitor compliance with environmental regulations; and to clean up contaminated sites.

There will be limited demand for forest and conservation technicians at the Federal and State government levels, leading to slower-than-average growth, due to general downsizing and reductions in timber harvesting on Federal lands. However, increased emphasis on specific conservation issues, such as environmental protection, water resources preservation, and control of exotic and invasive pests, may provide some employment opportunities.

Employment of agricultural and food science technicians should grow more slowly than average, mainly due to limited growth in agriculture and the food processing industry. However, research will still be necessary, particularly biotechnological research in the private sector, as it becomes increasingly important to balance greater agricultural output with protection and preservation of soil, water, and the ecosystem. Specifically, research will be needed to combat insects and diseases as they continue to adapt to pesticides and as soil fertility and water quality continue to need improvement.

Jobs for forensic science technicians are expected to increase about as fast as average. Crime scene technicians who work for State Public Safety Departments may experience favorable employment prospects if the number of qualified applicants remains low.

Little or no growth in employment of geological and petroleum technicians is expected because employment in the oil and gas extraction and mining industries, among the largest employers of geological and petroleum technicians, is expected to decline. Job opportunities will be more favorable in professional, scientific, and technical services firms, as geological and petroleum technicians will be needed to consult companies regarding environmental policy and Federal Government mandates, such as those requiring lower sulfur emissions.

Job opportunities are expected to be best for graduates of applied science technology programs who are well trained on equipment used in industrial and government laboratories and production facilities. As the instrumentation and techniques used in industrial research, development, and production become increasingly more complex, employers are seeking individuals with highly developed technical and communication skills.

Along with opportunities created by growth, many job openings should arise from the need to replace technicians who retire or leave the labor force for other reasons. During periods of economic recession, layoffs of science technicians may occur.

Earnings

Median hourly earnings of science technicians in 2002 were as follows:

Nuclear technicians	$28.84
Forensic science technicians	19.73
Geological and petroleum technicians	18.96
Chemical technicians	18.00
Environmental science and protection technicians, including health	16.98
Biological technicians	15.73
Forest and conservation technicians	14.90
Agricultural and food science technicians	13.74

In 2003, the average annual salary in nonsupervisory, supervisory, and managerial positions in the Federal Government was $30,440 for biological science technicians; $44,068 for physical science technicians; $55,374 for geodetic technicians; $40,781 for hydrologic technicians; and $52,585 for meteorological technicians.

Related Occupations

Other technicians who apply scientific principles at a level usually acquired in 2-year associate degree programs include engineering technicians, broadcast and sound engineering technicians and radio operators, drafters, and health technologists and technicians, especially clinical laboratory technologists and technicians, diagnostic medical sonographers, and radiologic technologists and technicians.

Sources of Additional Information

For information about a career as a chemical technician, contact:

➤ American Chemical Society, Education Division, Career Publications, 1155 16th St. NW., Washington, DC 20036. Internet: **http://www.acs.org**

For career information and a list of undergraduate, graduate, and doctoral programs in forensic sciences, contact:

➤ American Academy of Forensic Sciences, P.O. Box 669, Colorado Springs, CO, 80901. Internet: **http://www.aafs.org**

For general education information on forestry technicians and lists of schools offering education in forestry, send a self-addressed, stamped business envelope to:

➤ Society of American Foresters, 5400 Grosvenor Ln., Bethesda, MD 20814. Internet: **http://www.safnet.org**

Surveyors, Cartographers, Photogrammetrists, and Surveying Technicians

(0*NET 17-1021.00, 17-1022.00, 17-3031.01, 17-3031.02)

Significant Points

- Almost 2 out of 3 jobs were in architectural, engineering, and related services.
- Opportunities will be best for surveyors, cartographers, and photogrammetrists who have at least a bachelor's degree and strong technical skills.
- Computer skills enhance employment opportunities.

Nature of the Work

Several different types of workers are responsible for measuring and mapping the earth's surface. Traditional *land surveyors* establish official land, air space, and water boundaries. They write descriptions of land for deeds, leases, and other legal documents; define airspace for airports; and measure construction and mineral sites. Other surveyors provide data relevant to the shape, contour, location, elevation, or dimension of land or land features. *Cartographers* compile geographic, political, and cultural information and prepare maps of large areas. *Photogrammetrists* measure and analyze aerial photographs that are subsequently used to prepare detailed maps and drawings. *Surveying technicians* assist land surveyors by operating survey instruments and collecting information in the field and by performing computations and computer-aided drafting in offices. *Mapping technicians* calculate mapmaking information from field notes. They also draw topographical maps and verify their accuracy.

Land surveyors manage survey parties who measure distances, directions, and angles between points and elevations of points, lines, and contours on, above, and below the earth's surface. They plan the fieldwork, select known survey reference points, and determine the precise location of important features in the survey area. Surveyors research legal records, look for evidence of previous boundaries, and analyze the data to determine the location of boundary lines. They also record the results of surveys, verify the accuracy of data, and prepare plots, maps, and reports. Surveyors who establish boundaries must be licensed by the State in which they work. Known as professional land surveyors, they are sometimes called to provide expert testimony in court cases concerning matters pertaining to surveying.

A survey party gathers the information needed by the land surveyor. A typical survey party consists of a party chief and one or more surveying technicians and helpers. The party chief, who may be either a land surveyor or a senior surveying technician, leads day-to-day work activities. Surveying technicians assist the party chief by adjusting and operating surveying instruments, such as the theodolite (used to measure horizontal and vertical angles) and electronic distance-measuring equipment. Surveying technicians or assistants position and hold the vertical rods, or targets, that the theodolite operator sights on to measure angles, distances, or elevations. In addition, they may hold measuring tapes, if electronic distance-measuring equipment is not used. Surveying technicians compile notes, make sketches, and enter the data obtained from surveying instruments into computers. Survey parties also may include laborers or helpers who perform less skilled duties, such as clearing brush from sight lines, driving stakes, or carrying equipment.

New technology is changing the nature of the work of surveyors and surveying technicians. On larger projects, surveyors are increasingly using the Global Positioning System (GPS), a satellite system that locates points on the earth to a high degree of precision by using radio signals transmitted via satellites. To use this system, a surveyor places a satellite signal receiver—a small instrument mounted on a tripod—on a desired point. The receiver simultaneously collects information from several satellites to establish a precise position. The receiver also can be placed in a vehicle for tracing out road systems. Because receivers now come in different sizes and shapes, and because the cost of receivers has fallen, much more surveying work can be done with GPS. Surveyors then must interpret and check the results produced by the new technology.

Cartographers measure, map, and chart the earth's surface. Their work involves everything from performing geographical research and compiling data to actually producing maps. Cartographers collect, analyze, and interpret both spatial data—such as latitude, longitude, elevation, and distance—and nonspatial data—for example, population density, land-use patterns, annual precipitation levels, and demographic characteristics. They prepare maps in either digital or graphic form, using information provided by geodetic surveys, aerial photographs, and satellite data. *Photogrammetrists* prepare detailed maps and drawings from aerial photographs, usually of areas that are inaccessible, difficult, or less cost efficient to survey by other methods. *Map editors* develop and verify the contents of maps, using aerial photographs and other reference sources. Some States require photogrammetrists to be licensed as professional land surveyors.

Some surveyors perform specialized functions closer to those of cartographers than to those of traditional surveyors. For example, *geodetic surveyors* use high-accuracy techniques, including satellite observations (remote sensing), to measure large areas of the earth's surface. *Geophysical prospecting surveyors* mark sites for subsurface exploration, usually in relation to petroleum. *Marine or hydrographic surveyors* survey harbors, rivers, and other bodies of water to determine shorelines, the topography of the bottom, water depth, and other features.

Surveyors select known survey reference points and determine the precise location of important features in the survey area.

The work of surveyors and cartographers is changing because of advancements in technology, including not only the GPS, but also new earth resources data satellites, improved aerial photography, and geographic information systems (GIS)—computerized data banks of spatial data, along with the hardware, software, and staff needed to use them. These systems are capable of assembling, integrating, analyzing, and displaying data identified according to location. A GIS typically is used to handle maps which combine information that is useful for environmental studies, geology, engineering, planning, business marketing, and other disciplines. As more of these systems are developed, a new type of mapping scientist is emerging from the older specialties of photogrammetrist and cartographer: the *geographic information specialist* combines the functions of mapping science and surveying into a broader field concerned with the collection and analysis of geographic data.

Working Conditions

Surveyors usually work an 8-hour day, 5 days a week, and may spend a lot of time outdoors. Sometimes they work longer hours during the summer, when weather and light conditions are most suitable for fieldwork. Seasonal demands for longer hours are related to demand for specific surveying services. Home purchases traditionally are related to the start and end of the school year; construction is related to the materials to be used (unlike wood framing, concrete and asphalt are restricted by outside temperatures); and aerial photography is most effective when the leaves are off the trees.

Land surveyors and technicians engage in active, sometimes strenuous, work. They often stand for long periods, walk considerable distances, and climb hills with heavy packs of instruments and other equipment. They also can be exposed to all types of weather. Traveling often is part of the job, and land surveyors and technicians may commute long distances, stay away from home overnight, or temporarily relocate near a survey site.

Although surveyors can spend considerable time indoors, planning surveys, analyzing data, and preparing reports and maps, cartographers and photogrammetrists spend virtually all of their time in offices and seldom visit the sites they are mapping.

Employment

Surveyors, cartographers, photogrammetrists, and surveying technicians held about 124,000 jobs in 2002. Architectural, engineering, and related services firms—including firms that provided surveying and mapping services to other industries on a contract basis—provided about two-thirds of jobs for these workers. Federal, State, and local governmental agencies provided almost 1 in 6 jobs. Major Federal Government employers are the U.S. Geological Survey (USGS), the Bureau of Land Management (BLM), the Army Corps of Engineers, the Forest Service (USFS), the National Oceanic and Atmospheric Administration (NOAA), the National Imagery and Mapping Agency (NIMA), and the Federal Emergency Management Agency (FEMA). Most surveyors in State and local government work for highway departments and urban planning and redevelopment agencies. Construction firms, mining and oil and gas extraction companies, and utilities also employ surveyors, cartographers, photogrammetrists, and surveying technicians. Only a small number were self-employed in 2002.

Training, Other Qualifications, and Advancement

Most people prepare for a career as a licensed surveyor by combining postsecondary school courses in surveying with extensive on-the-job training. However, as technology advances, a 4-year college degree is increasingly becoming a prerequisite. About 50 universities now offer 4-year programs leading to a B.S. degree in surveying. Junior and community colleges, technical institutes, and vocational schools offer 1-, 2-, and 3-year programs in both surveying and surveying technology.

All 50 States and all U.S. territories (Puerto Rico, Guam, the Mariana Islands, and the Virgin Islands) license land surveyors. For licensure, most State licensing boards require that individuals pass a written examination given by the National Council of Examiners for Engineering and Surveying. Most States also require surveyors to pass a written examination prepared by the State licensing board. In addition, candidates must meet varying standards of formal education and work experience in the field.

In the past, many with little formal training in surveying started as members of survey crews and worked their way up to become licensed surveyors. However, because of advancing technology and rising licensing standards, formal education requirements are increasing. Specific requirements vary among States. Generally, the quickest route to licensure is a combination of 4 years of college, up to 4 years of experience under the supervision of an experienced surveyor (a few States do not require any such experience), and passing the licensing examinations. An increasing number of States require a bachelor's degree in surveying or in a closely related field, such as civil engineering or forestry (with courses in surveying), regardless of the number of years of experience. Many states also have a continuing education requirement.

High school students interested in surveying should take courses in algebra, geometry, trigonometry, drafting, mechanical drawing, and computer science. High school graduates with no formal training in surveying usually start as apprentices. Beginners with postsecondary school training in surveying usually can start as technicians or assistants. With on-the-job experience and formal training in surveying—either in an institutional program or from a correspondence school—workers may advance to senior survey technician, then to party chief, and, in some cases, to licensed surveyor (depending on State licensing requirements).

The National Society of Professional Surveyors, a member organization of the American Congress on Surveying and Mapping, has a voluntary certification program for surveying technicians. Technicians are certified at four levels requiring progressive amounts of experience, in addition to the passing of written examinations. Although not required for State licensure, many employers require certification for promotion to positions with greater responsibilities.

Surveyors should have the ability to visualize objects, distances, sizes, and abstract forms. They must work with precision and accuracy, because mistakes can be costly. Members of a survey party must be in good physical condition, because they work outdoors and often carry equipment over difficult terrain. They need good eyesight, coordination, and hearing to communicate verbally and manually (using hand signals). Surveying is a cooperative operation, so good interpersonal skills and the ability to work as part of a team are important. Good office skills also are essential, because surveyors must be able to research old deeds and other legal papers and prepare reports that document their work.

Cartographers and photogrammetrists usually have a bachelor's degree in a field such as engineering, forestry, geography, or a physical science. Although it is possible to enter these positions through previous experience as a photogrammetric or cartographic technician, nowadays most cartographic and photogrammetric technicians have had some specialized postsecondary school training. With the development of GIS, cartographers and photogrammetrists need additional education and stronger technical skills—including more experience with computers—than in the past.

The American Society for Photogrammetry and Remote Sensing has a voluntary certification program for photogrammetrists. To qualify for this professional distinction, individuals must meet work experience standards and pass an oral or a written examination.

Job Outlook

Overall employment of surveyors, cartographers, photogrammetrists, and surveying technicians is expected to grow about as fast as the average for all occupations through the year 2012. The widespread availability and use of advanced technologies, such as GPS, GIS, and remote sensing, will continue to increase both the accuracy and productivity of these workers, resulting in modest overall growth in employment. However, job openings will continue to result from the need to replace workers who transfer to other occupations or who leave the labor force altogether.

Employment of surveying and mapping technicians is expected to grow faster than the average for all occupations through 2012. The short training period needed to learn to operate the equipment, the current lack of any formal testing or licensing, the growing demand for people to do basic GIS-related data-entry work, and relatively lower wages all encourage demand for these technicians. However, many persons possess the basic skills needed to qualify for the jobs that are available, so competition for job openings may result.

As technologies become more complex, opportunities will be best for surveyors, cartographers, and photogrammetrists who have at least a bachelor's degree and strong technical skills. Increasing demand for geographic data, as opposed to traditional surveying services, will mean better opportunities for cartographers and photogrammetrists who are involved in the development and use of geographic and land information systems. New technologies, such as GPS and GIS, also may enhance employment opportunities for surveyors, as well as for those surveying technicians who have the educational background and who have acquired technical skills that enable them to work with the new systems. At the same time, upgraded licensing requirements will continue to limit opportunities for professional advancement for those without bachelor's degrees.

Opportunities for surveyors, cartographers, and photogrammetrists should remain concentrated in architectural, engineering, and related services firms. However, nontraditional areas, such as urban planning, emergency preparedness, and natural resource exploration and mapping, also should provide employment growth, particularly with regard to producing maps for the management of emergencies and updating maps with the newly available technology. Continued growth in construction through 2012 will require surveyors to lay out streets, shopping centers, housing developments, factories, office buildings, and recreation areas, while setting aside flood plains, wetlands, wildlife habitats, and environmentally sensitive areas for protection. However, employment may fluctuate from year to year along with construction activity or with mapping needs for land and resource management.

Earnings

Median annual earnings of cartographers and photogrammetrists were $42,870 in 2002. The middle 50 percent earned between $32,580 and $55,610. The lowest 10 percent earned less than $25,810 and the highest 10 percent earned more than $69,320.

Median annual earnings of surveyors were $39,970 in 2002. The middle 50 percent earned between $29,320 and $53,440. The lowest 10 percent earned less than $22,260, and the highest 10 percent earned more than $67,700. Median hourly earnings of surveyors employed in architectural, engineering, and related services were $38,370 in 2002.

Median annual earnings of surveying and mapping technicians were $29,230 in 2002. The middle 50 percent earned between $22,640 and $39,070 in 2002. The lowest 10 percent earned less than $18,490, and the highest 10 percent earned more than $48,970. Median annual earnings of surveying and mapping technicians employed in architectural, engineering, and related services were $27,130 in 2002, while those employed by local governments had median annual earnings of $33,680.

In 2003, land surveyors in nonsupervisory, supervisory, and managerial positions in the Federal Government earned an average salary of $62,980; cartographers, $67,989; geodetic technicians, $55,374; surveying technicians, $33,316; and cartographic technicians, $43,517.

Related Occupations

Surveying is related to the work of civil engineers, architects, and landscape architects because an accurate survey is the first step in land development and construction projects. Cartography and geodetic surveying are related to the work of environmental scientists and geoscientists, who study the earth's internal composition, surface, and atmosphere. Cartography also is related to the work of geographers and urban and regional planners, who study and decide how the earth's surface is to be used.

Sources of Additional Information

For career information on surveyors, cartographers, photogrammetrists, and surveying technicians, contact:

➤ The American Congress on Surveyong and Mapping, Suite #403, 6 Montgomery Village Ave., Gaithersburg, MD 20879. Internet: **http://www.acsm.net**

Information about career opportunities, licensure requirements, and the surveying technician certification program is available from:

➤ National Society of Professional Surveyors, Suite #403, 6 Montgomery Village Ave., Gaithersburg, MD 20879. Internet: **http://www.acsm.net/nsps**

For information on a career as a geodetic surveyor, contact:

➤ American Association of Geodetic Surveying (AAGS), Suite #403, 6 Montgomery Village Ave., Gaithersburg, MD 20879. Internet: **http://www.acsm.net/aags**

General information on careers in photogrammetry and remote sensing is available from:

➤ ASPRS: The Imaging and Geospatial Information Society, 5410 Grosvenor Ln., Suite 210, Bethesda, MD 20814-2160. Internet: **http://www.asprs.org**