DOCUMENT RESUME

ED 382 454 SE 055 891

TITLE Engineering, Scientific, and Related Occupations. Occupational Outlook Handbook Reprints. Bulletin 2450-3.

INSTITUTION Bureau of Labor Statistics, Washington, DC.

REPORT NO ISBN-0-16-043050-X

PUB DATE 94

NOTE 33p.

AVAILABLE FROM U.S. Government Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328; New orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954 (No. 2450-3, $1.75; payment or GPO deposit account number must accompany the order; make checks or money orders payable to the Superintendent of Documents, if using VISA or Master Card, include card number and expiration date).

PUB TYPE Guides - Non-Classroom Use (055)

EDRS PRICE MF01/PC02 Plus Postage.

DESCRIPTORS *Career Choice; *Engineering; Higher Education; *Science Careers; Science Education; Secondary Education

ABSTRACT

This document provides a description of engineering, scientific, and related occupations. Descriptions may include: (1) information on the nature of the work; (2) training required; (3) earnings; (4) job prospects, and (5) sources of additional information. Among the occupations described, the following job titles are included: Engineering, Science, and Data Processing Managers; Aerospace Engineers; Chemical Engineers; Mechanical Engineers; Nuclear Engineers; Biological and Medical Scientists; Chemists; Meteorologists; and Surveyors. (ZWH)

Engineering, Scientific, and Related Occupations

Reprinted from the
Occupational Outlook Handbook, 1994-95 Edition

U.S. Department of Labor
Bureau of Labor Statistics

Bulletin 2450-3

ISBN 0-16-043050-X
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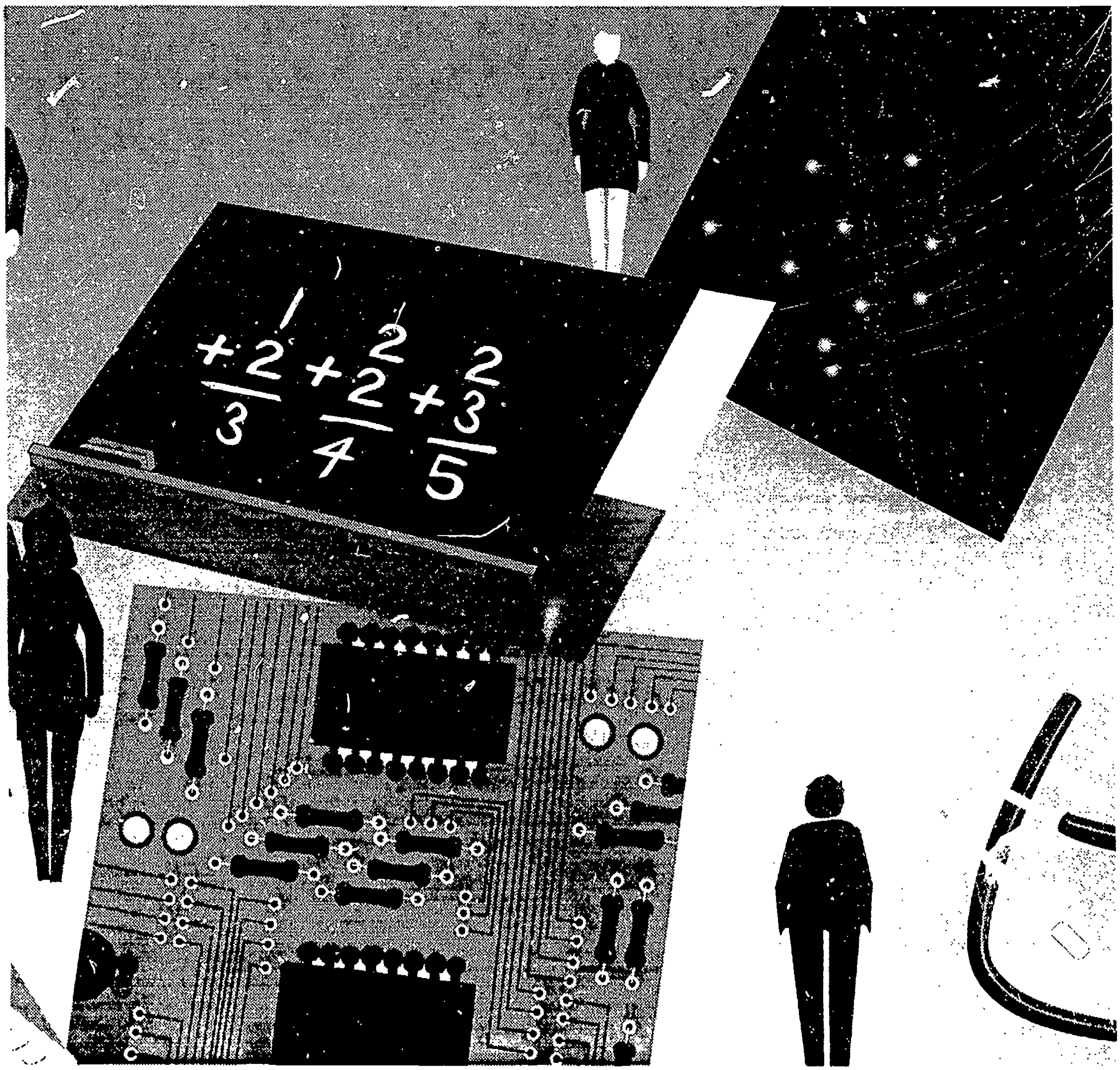
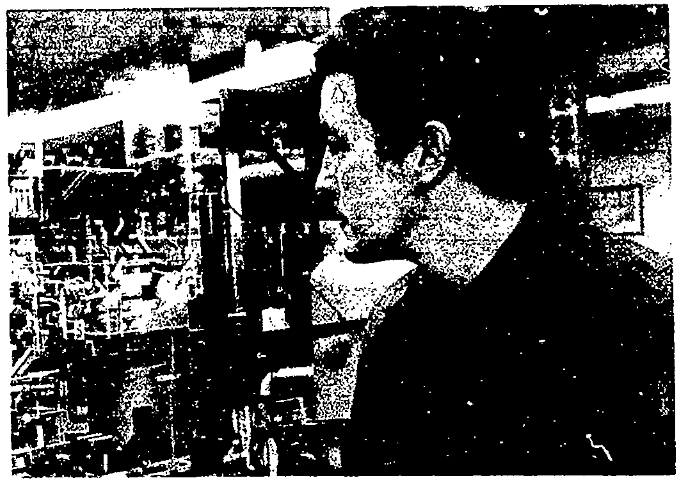


Engineering, Science, and Data Processing Managers

(D.O.T. 002.167-018; 003.167-034 and -070; 005.167-010 and -022; 007.167-014; 008.167-010; 010.161-010, -014, and .167-018; 011.161-010; 012.167-058 and -062; 018.167-022; 019.167-014; 022.161-010; 024.167-010; 029.167-014; 162.117-030; 169.167-030 and -082; and 189.117-014)



Engineering managers direct the research, development, and manufacture of a product.

Nature of the Work

Engineering, science, and data processing managers plan, coordinate, and direct research, development, design, production, and computer related activities. They supervise a staff which may include engineers, scientists, technicians, computer specialists, data processing workers, along with support personnel.

Engineering, science, and data processing managers determine scientific and technical goals within broad outlines provided by top management. These goals may include the redesign of an industrial machine, improvements in manufacturing processes, the development of a large computer program, or advances in basic scientific research. Managers make detailed plans for the accomplishment of these goals—for example, they may develop the overall concepts of new products or identify problems standing in the way of project completion. They forecast costs and equipment and personnel needs for projects and programs. They hire and assign scientists, engineers, technicians, computer specialists, data processing workers, and support personnel to carry out specific parts of the projects, supervise their work, and review their designs, programs, and reports.

Managers coordinate the activities of their unit with other units or organizations. They confer with higher levels of management; with financial, industrial production, marketing, and other managers; and with contractors and equipment suppliers. They also establish working and administrative procedures and policies.

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

Natural science managers oversee activities in agricultural science, chemistry, biology, geology, meteorology, or physics. They manage research and development projects and direct and coordinate testing, quality control, and production activities in industrial plants.

Electronic data processing managers direct, plan, and coordinate data processing activities. Top level managers direct all computer-related activities in an organization. Others manage computer operations, software development, or data bases. They analyze the data processing requirements of their organization and assign, schedule, and review the work of systems analysts, computer programmers, and computer operators. They determine computer hardware requirements, evaluate equipment options, and make purchasing decisions.

Some engineering, science, and data processing managers head a section of perhaps 3 to 10 or more scientists, engineers, or computer professionals. Above them are heads of divisions composed of a number of sections, with as many as 15 to 50 scientists or engineers. A few are directors of large laboratories or directors of research.

Working Conditions

Engineering, science, and data processing managers spend most of their time in an office. Some managers, however, may also work in laboratories or industrial plants, where they normally are exposed to the same conditions as research scientists and may occasionally be exposed to the same conditions as production workers. Most 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 within a short time or within a tight budget.

Employment

Engineering, science, and data processing managers held about 337,000 jobs in 1992. Although these managers are found in almost all industries, nearly two-fifths are employed in manufacturing, especially in the industrial machinery and equipment, electrical and electronic equipment, transportation equipment, instruments, and chemicals industries. They also work for engineering, management, and computer and data processing services companies. Others work for government, colleges and universities, and nonprofit research organizations. The majority are most likely engineering managers, often managing industrial research, development, and design projects.

Training, Other Qualifications, and Advancement

Experience as an engineer, mathematician, natural scientist, or computer professional is the usual requirement for becoming an engineering, science, or data processing manager. Consequently, educational requirements are similar to those for scientists, engineers, and data processing professionals.

Engineering managers start as engineers. A bachelor's degree in engineering from an accredited engineering program is acceptable for beginning engineering jobs, but many engineers increase their chances for promotion to manager by obtaining a master's degree in engineering or business administration. A degree in business administration or engineering management is especially useful for becoming a general manager.

Natural science managers usually start as a chemist, physicist, biologist, or other natural scientist. Most natural scientists engaged in basic research have a Ph.D. degree. Some in applied research and other activities may have lesser degrees. First-level science managers are usually specialists in the work they supervise. For example, the manager of a group of physicists doing optical research is almost always a physicist who is an expert in optics.

Most data processing managers have been systems analysts, although some may have experience as programmers, operators, or in other computer specialties. There is no universally accepted way of

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ISBN 0-16-043050-X

preparing for a job as a systems analyst. Many have degrees in computer or information science, computer information systems, or data processing and have experience as computer programmers. A bachelor's degree is usually required and a graduate degree often is preferred. A typical career advancement progression in a large organization would be from programmer to programmer/analyst, to systems analyst, and then to project leader or senior analyst. The first real managerial position might be as project manager, programming supervisor, systems supervisor, or software manager.

In addition to educational requirements, scientists, engineers, or computer specialists generally must have demonstrated above-average technical skills to be considered for promotion to manager. Superiors also look for leadership and communication skills, as well as managerial attributes such as the ability to make rational decisions, to manage time well, to organize and coordinate work effectively, to establish good working and personal relationships, and to motivate others. Also, a successful manager must have the desire to manage. Many scientists, engineers, and computer specialists want to be promoted but actually prefer doing technical work.

Some scientists and engineers become managers in marketing, personnel, purchasing, or other areas or become general managers.

Job Outlook

Employment of engineering and science managers is expected to increase faster than the average for all occupations through the year 2005. Opportunities for those who wish to become engineering, science, and data processing managers should be closely related to the growth of the occupations they supervise and the industries in which they are found. (See the statements on natural scientists, engineers, computer programmers, and computer scientists and systems analysts elsewhere in the *Handbook*.)

Underlying much of the growth of managers in science and engineering are competitive pressures and advancing technologies which force companies to update and improve products more frequently. Research and investment in plants and equipment to expand output of goods and services and to raise productivity also will add to employment requirements for science and engineering managers involved in research and development, design, and the operation and maintenance of production facilities.

Many of the industries which employ engineers and scientists derive a large portion of their business from defense contracts. Because defense expenditures are being reduced, employment growth and job outlook for managers in these industries may not be as strong in the future as in the 1980's, when defense expenditures were increasing.

Employment of data processing managers will increase rapidly due to the fast paced expansion of the computer and data processing services industry and the increased employment of computer systems analysts. Large computer centers are consolidating or closing as small computers become more powerful, and more automated systems are resulting in fewer opportunities for data processing managers at computing centers. However, as the economy expands and as advances in technology lead to broader applications for computers, opportunities should increase and employment growth should be brisk.

Despite growth in employment, most job openings will result from the need to replace workers who leave the occupation. Because many engineers, natural scientists, and computer specialists are eligible for management and seek promotion, there can be substantial competition for these openings.

Earnings

Earnings for engineering, science, and data processing managers vary by specialty and level of management. Science and engineering managers had average salaries that ranged from $50,000 to well over $100,000 for the most senior managers in large organizations, according to the limited data available. Data processing managers had salaries that ranged from $35,000 to $80,000. Managers often earn about 15 to 25 percent more than those they directly supervise, although there are cases where some employees are paid more than the manager who supervises them, especially in research.

In addition, engineering, science, and data processing managers, especially those at higher levels, often are provided more benefits than non-managerial workers in their organizations. Higher level managers often are provided with expense accounts, stock option plans, and bonuses.

Related Occupations

The work of engineering, science, and data processing managers is closely related to that of engineers, natural scientists, computer personnel, and mathematicians. It is also related to the work of other managers, especially general managers and top executives.

Sources of Additional Information

Contact the sources of additional information on engineers, natural scientists, and systems analysts that are listed in statements on these occupations elsewhere in the *Handbook*.

Engineers

Nature of the Work

Engineers apply the theories and principles of science and mathematics to the economical solution of practical technical problems. Often their work is the link between a scientific discovery and its application. Engineers design machinery, products, systems, and processes for efficient and economical performance. They design industrial machinery and equipment for manufacturing goods and defense and weapons systems for the Armed Forces. Many engineers design, plan, and supervise the construction of buildings, highways, and rapid transit systems. They also design and develop consumer products and systems for control and automation of manufacturing, business, and management processes.

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

In addition to design and development, many engineers work in testing, production, or maintenance. They 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 work in engineering management or in sales, where an engineering background enables them to discuss the technical aspects of a product and assist in planning its installation or use. (See the statements on engineering, science, and data processing managers and manufacturers' and wholesale sales representatives elsewhere in the *Handbook*.)

Most engineers specialize; more than 25 major specialties are recognized by professional societies. Within the major branches are numerous subdivisions. Structural, environmental, and transportation engineering, for example, are subdivisions of civil engineering. Engineers also may specialize in one industry, such as motor vehicles, or in one field of technology, such as propulsion or guidance systems.

This section, which contains an overall discussion of engineering, is followed by separate sections on 10 engineering branches: Aerospace; chemical; civil; electrical and electronics; industrial; mechanical; metallurgical, ceramic, and materials; mining; nuclear; and petroleum engineering. Branches of engineering not covered in detail, but in which there are established college programs include: Architectural engineering—the design of a building's internal support structure; biomedical engineering—the application of engineering to medical and physiological problems; environmental engineering—a small but growing discipline involved with identifying, solving, and alleviating environmental problems; and marine engineering—the design and installation of ship machinery and propulsion systems.

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

Engineers often use computers to simulate and test how a machine, structure, or system operates. Many engineers also use computer-aided design systems to produce and analyze designs. They also spend a great deal of time writing reports and consulting with other engineers. Complex projects require many engineers, each working with a small part of the job. Supervisory engineers are responsible for major components or entire projects.

Working Conditions

Many engineers work in laboratories, industrial plants, or construction sites, where they inspect, supervise, or solve onsite problems. Others work in an office almost all of the time. Engineers in branches such as civil engineering may work outdoors part of the time. A few engineers travel extensively to plants or construction sites.

Many engineers work a standard 40-hour week. At times, deadlines or design standards may bring extra pressure to a job. When this happens, engineers may work long hours and experience considerable stress.

Employment

In 1992, engineers held 1,354,000 jobs. Just under one-half of all engineering jobs were located in manufacturing industries—mostly in electrical and electronic equipment, aircraft and parts, machinery, scientific instruments, chemicals, motor vehicles, fabricated metal products, and primary metals industries. In 1992, 713,000 jobs were in nonmanufacturing industries, primarily in engineering and architectural services, research and testing services, and business services, where firms designed construction projects or did other engineering work on a contract basis for organizations in other parts of the economy. Engineers also worked in the communications, utilities, and construction industries.

Federal, State, and local governments employed about 190,000 engineers. Over half of these were in the Federal Government, mainly in the 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. Some engineers are self-employed consultants.

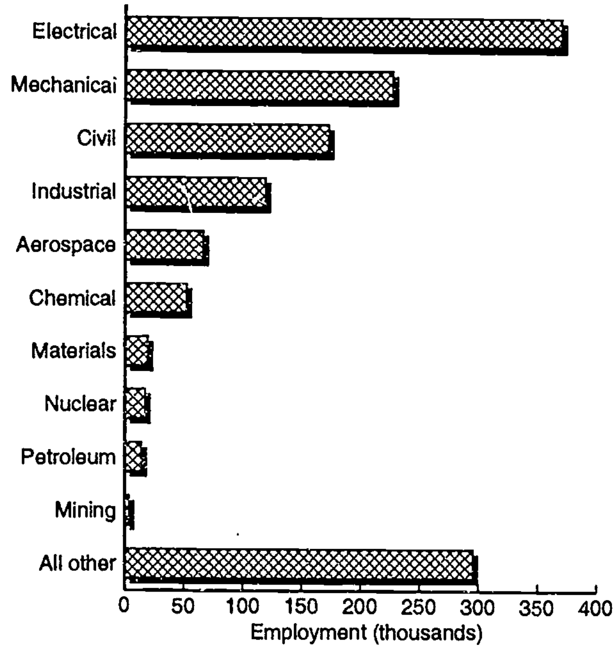
Engineers are employed in every State, in small and large cities, and in rural areas. Some branches of engineering are concentrated in particular industries and geographic areas, as discussed in statements later in this chapter.

Training, Other Qualifications, and Advancement

A bachelor's degree in engineering from an accredited engineering program is usually required for beginning engineering jobs. College graduates with a degree in a physical science or mathematics may occasionally qualify for some engineering jobs, especially in engineering specialties in high demand. Most engineering degrees are granted in branches such as electrical, mechanical, or civil engineering. However, engineers trained in one branch may work in another. This flexibility allows employers to meet staffing needs in new technologies and specialties in short supply. It also allows engineers to shift to fields with better employment prospects, or ones that match their interests more closely.

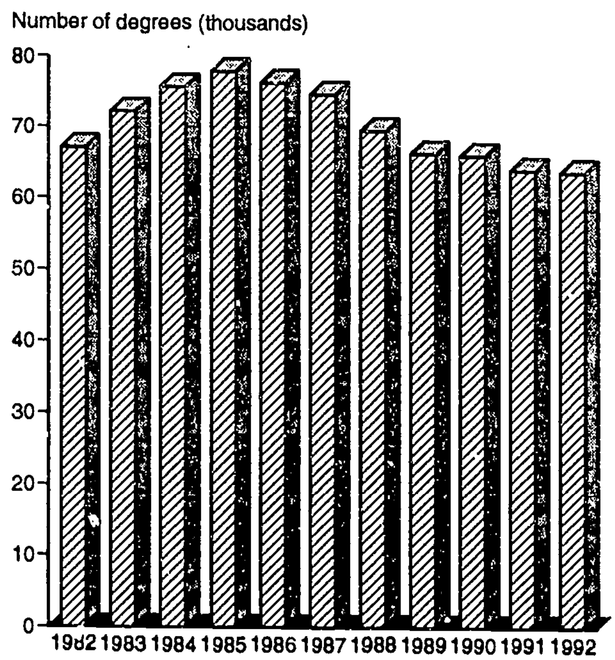
In addition to the standard engineering degree, many colleges offer degrees in engineering technology, which are offered as either 2- or 4-year programs. These programs prepare students for practical design and production work rather than for jobs that require more theoretical, scientific and mathematical knowledge. Graduates of 4-year technology programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. In fact, some employers regard them as having skills between those of a technician and an engineer.

Electrical engineering accounts for more than one-fourth of all engineers.



Source: Bureau of Labor Statistics

The number of degrees granted in engineering continues its declining trend.



Source: Engineering Workforce Commission

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Graduate training is essential for engineering faculty positions but is not required for the majority of entry level engineering jobs. Many engineers obtain a master's degree to learn new technology, to broaden their education, and to enhance promotion opportunities.

Nearly 390 colleges and universities offer a bachelor's degree in engineering, and nearly 300 colleges offer a bachelor's degree in engineering technology, although not all are accredited programs. Although most institutions offer programs in the larger branches of engineering, only a few offer some of the smaller specialties. Also, programs of the same title may vary in content. For example, some emphasize industrial practices, preparing students for a job in industry, while others are more theoretical and are better for students preparing to take graduate work. Therefore, students should investigate curriculums and check accreditations carefully before selecting a college. Admissions requirements for undergraduate engineering schools include courses in advanced high school mathematics and the physical sciences.

Bachelor's degree programs in engineering are typically 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 basic sciences (mathematics, physics, and chemistry), introductory engineering, and the humanities, social sciences, and English. 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 such as 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.

A few 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 preengineering subjects and 2 years in the engineering school and receives a bachelor's degree from each. Some colleges and universities offer 5-year master's degree programs.

Some 5- or even 6-year cooperative plans combine classroom study and practical work, permitting students to gain valuable experience and finance part of their education.

All 50 States and the District of Columbia require registration for engineers whose work may affect life, health, or property, or who offer their services to the public. In 1992, nearly 380,000 engineers were registered. Registration generally requires a degree from an engineering program accredited by the Accreditation Board for Engineering and Technology, 4 years of relevant work experience, and passing a State examination. Some States will not register people with degrees in engineering technology.

Beginning engineering graduates usually do routine work under the supervision of experienced engineers and, in larger companies, may also receive formal classroom or seminar-type training. As they gain knowledge and experience, they are assigned more difficult tasks with greater independence to develop designs, solve problems, and make decisions. Engineers may become technical specialists or may supervise a staff or team of engineers and technicians. Some eventually become engineering managers or enter other managerial, management support, or sales jobs. (See the statements under executive, administrative, and managerial occupations; under sales occupations; and on computer systems analysts elsewhere in the *Handbook*.) Some engineers obtain graduate degrees in engineering or business administration to improve advancement opportunities; others obtain law degrees and become patent attorneys. Many high level executives in government and industry began their careers as engineers.

Engineers should be able to work as part of a team and should have creativity, an analytical mind, and a capacity for detail. In addition, engineers should be able to express themselves well—both orally and in writing.

Job Outlook

Employment opportunities in engineering have been good for a number of years. They are expected to continue to be good through the year 2005 because employment is expected to increase about as fast as the average for all occupations while the number of degrees granted in engineering is expected to remain near present levels through the year 2005.

Many of the jobs in engineering are related to national defense. Defense expenditures will decline in the future, so employment growth and job outlook for engineers may not be as strong as in the 1980's, when defense expenditures were increasing. However, graduating engineers will continue to be in demand for jobs in engineering and other areas, possibly even at the same time other engineers, especially defense industry engineers, are being laid off.

Employers will need more engineers as they increase investment in plant and equipment to further increase productivity and expand output of goods and services. In addition, competitive pressures and advancing technology will force companies to improve and update product designs more frequently. Finally, more engineers will be needed to improve deteriorating roads, bridges, water and pollution control systems, and other public facilities.

Freshman engineering enrollments began declining in 1983, and the number of bachelor's degrees in engineering began declining in 1987. Although it is difficult to project engineering enrollments, this decline may continue through the late 1990's because the total college-age population is projected to decline. Furthermore, the proportion of students interested in engineering careers has declined as prospects for college graduates in other fields have improved and interest in other programs has increased.

Only a relatively small proportion of engineers leave the profession each year. Despite this, three-fourths of all job openings will arise from replacement needs. A greater proportion of replacement openings is created by engineers who transfer to management, sales, or other professional specialty occupations than by those who leave the labor force.

Most industries are less likely to lay off engineers than other workers. Many engineers work on long-term research and development projects or in other activities which may continue even during recessions. In industries such as electronics and aerospace, however, large government cutbacks in defense or research and development have resulted in layoffs for engineers.

New computer-aided design systems enable engineers to produce or modify designs much more rapidly than previously. This increased productivity might have resulted in fewer engineering jobs had engineers not used these systems to improve the design process. They now produce and analyze many more design variations before selecting a final one. Therefore, this technology is not expected to limit employment opportunities.

It is important for engineers to continue their education throughout their careers because much of their value to their employer depends on their knowledge of the latest technology. In 1990, about 110,000 persons, or 7.5 percent of all engineers were enrolled in graduate engineering programs. The pace of technological change varies by engineering specialty and industry. Engineers in high-technology areas such as advanced electronics or aerospace may find that their knowledge becomes obsolete rapidly. Even those who continue their education are vulnerable to obsolescence if the particular technology or product they have specialized in becomes obsolete. Engineers whom employers consider not to have kept up may find themselves passed over for promotions and are particularly vulnerable to layoffs. On the other hand, it is often 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. (The outlook for 10 branches of engineering is discussed in separate sections.)

Earnings

Starting salaries for engineers with the bachelor's degree are significantly higher than starting salaries of bachelor's degree graduates in other fields. According to the College Placement Council, engineering graduates with a bachelor's degree averaged about $34,000 a year in private industry in 1992; those with a master's degree and no experience, $39,200 a year; and those with a Ph.D., $54,400. Starting salaries for those with the bachelor's degree vary by branch, as shown in the following tabulation.

Petroleum	$40,679
Chemical	39,203
Mechanical	34,462
Nuclear	34,447
Electrical	33,754
Materials	33,502
Industrial	32,348
Aerospace	31,826
Mining	31,177
Civil	29,376

A survey of workplaces in 160 metropolitan areas reported that beginning engineers had median annual earnings of about $31,000 in 1992, with the middle half earning between about $28,800 and $37,400 a year. Experienced midlevel engineers with no supervisory responsibilities had median annual earnings of about $52,500, with the middle half earning between about $48,200 and $57,300 a year. Median annual earnings for engineers at senior managerial levels were about $87,000. Median annual earnings for these and other levels of engineers are shown in the following tabulation.

Engineer I	$32,864
Engineer II	37,232
Engineer III	43,368
Engineer IV	52,520
Engineer V	63,596
Engineer VI	75,504
Engineer VII	87,048
Engineer VIII	102,544

The average annual salary for engineers in the Federal Government in nonsupervisory, supervisory, and managerial positions was $54,422 in 1993.

Related Occupations

Engineers apply the principles of physical science and mathematics in their work. Other workers who use scientific and mathematical principles include physical scientists, life scientists, computer scientists, mathematicians, engineering and science technicians, and architects.

Sources of Additional Information

A number of engineering-related organizations provide information on engineering careers. JETS-Guidance, at 1420 King St., Suite 405, Alexandria, VA 22314, serves high school students as a central distribution point for information from most of these organizations. To receive information, write JETS-Guidance and enclose a stamped, self-addressed business-size envelope.

Societies representing many of the individual branches of engineering are listed in this chapter. Each can provide information about careers in the particular branch.

Aerospace Engineers

(D.O.T. 002.061 and .167)

Nature of the Work

Aerospace engineers design, develop, test, and help manufacture commercial and military aircraft, missiles, and spacecraft. They develop new technologies in commercial aviation, defense systems, and space exploration, often specializing in areas like structural design, guidance, navigation and control, instrumentation and communication, or production methods. They also may specialize in one type of aerospace product, such as commercial transports, helicopters, spacecraft, or rockets. Aerospace engineers may be experts in aerodynamics, propulsion, thermodynamics, structures, celestial mechanics, acoustics, or guidance and control systems.

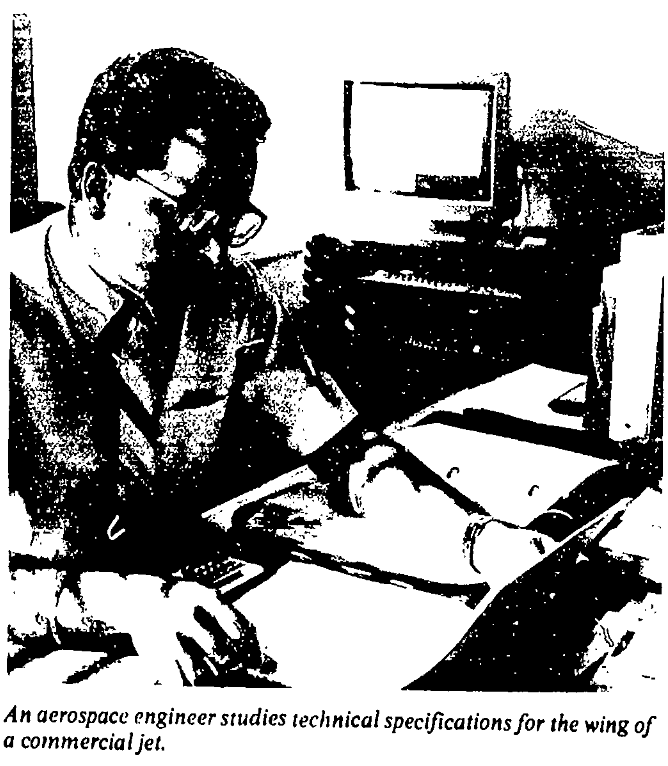
Employment

Aerospace engineers held about 66,000 jobs in 1992. Almost 55 percent were in the aircraft and parts and guided missile and space vehicle manufacturing industries. Federal Government agencies, primarily the Department of Defense and the National Aeronautics and Space Administration, provided more than 1 out of 10 jobs. Business services, engineering and architectural services, research and testing services, and communications equipment manufacturing firms accounted for most of the remainder.

California, Washington, and Texas, States with large aerospace manufacturers, have the most aerospace engineers.

Job Outlook

Those seeking employment as aerospace engineers are likely to face keen competition because the number of job opportunities is expected to be significantly fewer than the relatively large pool of graduates. Defense Department expenditures for military aircraft, missiles, and other aerospace systems are declining. Growth in the civilian sector, which needs to replace the present fleet of airliners with quieter and more fuel-efficient aircraft, is projected to be much slower than previously anticipated due to the financial problems of



An aerospace engineer studies technical specifications for the wing of a commercial jet.

airlines. Consequently, employment of aerospace engineers is expected to grow more slowly than the average for all occupations through the year 2005. Future growth of employment in this field could also be limited because a higher proportion of engineers in aerospace manufacturing may come from the materials, mechanical, or electrical engineering fields. Most job openings will result from the need to replace aerospace engineers who transfer to other occupations or leave the labor force.

Because a large proportion of aerospace engineering jobs are defense related, unexpected cancellation of a defense contract and other defense expenditure cutbacks can result in layoffs of aerospace engineers.

Sources of Additional Information

For information on aerospace careers, send $3 to:

☞ American Institute of Aeronautics and Astronautics, Inc., AIAA Student Programs, The Aerospace Center, 370 L'Enfant Promenade SW., Washington, DC 20024-2518.

(See introductory section of this chapter for information on training requirements and earnings.)

Chemical Engineers

(D.O.T. 008.061)

Nature of the Work

Chemical engineers apply the principles of chemistry and engineering to solve problems involving the production or use of chemicals. Many work in the production of chemicals and chemical products. They design equipment and develop processes for manufacturing chemicals in chemical plants, plan and test methods of manufacturing the products, and supervise production. Chemical engineers also work in industries other than chemical manufacturing such as electronics or aircraft manufacturing. Because the knowledge and duties of chemical engineers cut across many fields, they apply principles of chemistry, physics, mathematics, and mechanical and electrical engineering in their work. They frequently specialize in a particular operation such as oxidation or polymerization. Others specialize in a particular area such as pollution control or the production of a specific product like automotive plastics or chlorine bleach.

Employment

Chemical engineers held over about 52,000 jobs in 1992. Seventy percent were in manufacturing industries, primarily in the chemical, petroleum refining, and related industries. Most of the rest worked for engineering services, research and testing services, or consulting firms that design chemical plants or do other work on a contract basis, or worked for government agencies or as independent consultants.

A chemical engineer studies data describing the results of a chemical reaction trial run.

Job Outlook

Although employment in the chemical manufacturing industry is projected to grow very little through 2005, chemical engineers should find favorable job opportunities. The number of positions arising from employment growth, which is expected to be as fast as the average for all occupations through the year 2005, and the need to replace those who leave the occupation should be sufficient to absorb the number of graduates with degrees in chemical engineering and other entrants.

Areas relating to the production of industrial chemicals, biotechnology, and materials science may provide better opportunities than other portions of the chemical industry. Much of the projected growth in employment, however, will be in nonmanufacturing industries, especially service industries.

Sources of Additional Information

☞ American Institute of Chemical Engineers, 345 East 47th St., New York, NY 10017.

☞ American Chemical Society, Career Services, 1155 16th St. NW., Washington, DC 20036.

(See introductory part of this section for information on training requirements and earnings.)

Civil Engineers

(D.O.T. 005.061, .167-014 and -018; and 019.167-018)

Nature of the Work

Civil engineers, who work in the oldest branch of engineering, design and supervise the construction of roads, airports, tunnels, bridges, water supply and sewage systems, and buildings. Major specialties within civil engineering are structural, water resources, environmental, construction, transportation, and geotechnical engineering.

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

A civil engineer completes plans for a city park recreational complex and roadway system.

Employment

Civil engineers held about 173,000 jobs in 1992. Over 40 percent of the jobs were in Federal, State, and local government agencies. Over one-third were in firms that provide engineering consulting services, primarily developing designs for new construction projects. The construction industry, public utilities, transportation, and manufacturing industries accounted for most of the rest.

Civil engineers usually are found working 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 about as fast as the average for all occupations through the year 2005, spurred by population growth and an expanding economy. More civil engineers will be needed to design and construct higher capacity transportation, water supply, and pollution control systems, large buildings, and other structures, and repair or replace existing roads, bridges, and other public structures. Most job openings, however, 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.

Sources of Additional Information

☞ American Society of Civil Engineers, 345 E. 47th St., New York, NY 10017.

(See introductory part of this section for information on training requirements and earnings.)

Electrical and Electronics Engineers

(D.O.T. 003.061, .167 except -034 and -070, and .187)

Nature of the Work

Electrical and electronics engineers design, develop, test, and supervise the manufacture of electrical and electronic equipment. Electrical equipment includes power generating and transmission equipment used by electric utilities, and electric motors, machinery controls, and lighting and wiring in buildings, automobiles, and aircraft. Electronic equipment includes radar, computer hardware, and communications and video equipment.

The specialties of electrical and electronics engineers include several major areas—such as power generation, transmission, and distribution; communications; computer electronics; and electrical equipment manufacturing—or a subdivision 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 370,000 jobs in 1992, making it the largest branch of engineering. Most jobs were in firms that manufacture electrical and electronic equipment, business machines, professional and scientific equipment, and aircraft and aircraft parts. Computer and data processing services firms, engineering and business consulting firms, public utilities, and government agencies accounted for most of the remaining jobs.

Job Outlook

Employment opportunities for electrical and electronics engineers are expected to be good through the year 2005. Most job openings

An electrical engineer designs the lighting system for a city traffic circle.

will result from job growth and the need to replace electrical engineers who transfer to other occupations or leave the labor force. These openings should be sufficient to absorb the number of new graduates and other entrants.

Employment in this engineering specialty is expected to increase about as fast as the average for all occupations. Job growth is expected to be fastest in industrial sectors other than manufacturing. Increased demand by businesses and government for computers and communications equipment is expected to account for much of the projected employment growth. Consumer demand for electrical and electronic goods and increased research and development on computers, robots, and other types of automation should create additional jobs.

Because many electrical engineering jobs are defense related, cutbacks in defense spending could result in layoffs of electrical engineers, especially if a defense-related project or contract is unexpectedly cancelled. Furthermore, engineers who fail to keep up with the rapid changes in technology in most specialties risk technological obsolescence, which makes them more susceptible to layoffs or, at a minimum, likely to be passed over for advancement.

Sources of Additional Information

☞ Institute of Electrical and Electronics Engineers, 1828 L St. NW., Suite 1202, Washington, DC 20036.

(See introductory part of this section for information on training requirements and earnings.)

Industrial Engineers

(D.O.T. 005.167-026; 012.061 -018, .067, .167 except -022, -026, -034, -058, and -062, and .187)

Nature of the Work

Industrial engineers determine the most effective ways for an organization to use the basic factors of production—people, machines, materials, information, and energy—to make or process a product. They are the bridge between management and operations. They are more concerned with increasing productivity through the management of people and methods of business organization than are engineers in other specialties, who generally work more with products or processes.

To solve organizational, production, and related problems most efficiently, industrial engineers carefully study the product and its requirements, design manufacturing and information systems, and use mathematical analysis methods such as operations research to meet those requirements. They develop management control systems to aid in financial planning and cost analysis, design production planning and control systems to coordinate activities and control product quality, and design or improve systems for the physical distribution of goods and services. Industrial engineers conduct surveys to find plant locations with the best combination of raw materials, transportation, and costs. 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.

Employment

Industrial engineers held about 119,000 jobs in 1992; about 80 percent of jobs were in manufacturing industries. Because their skills can be used in almost any type of organization, industrial engineers are more widely distributed among manufacturing industries than other engineers.

Their skills can be readily applied outside manufacturing as well. For example, some work for insurance companies, banks, hospitals, and retail organizations. Others work for government agencies or are independent consultants.

Job Outlook

Employment of industrial engineers is expected to grow about as fast as the average for all occupations through the year 2005, making for favorable opportunities. Most job openings, however, will result from the need to replace industrial engineers who transfer to other occupations or leave the labor force.

Industrial growth, more complex business operations, and the greater use of automation in factories and in offices underlie the projected employment growth. Because the main function of an industrial engineer is to make a higher quality product as efficiently as possible, their services should be in demand in the manufacturing sector as firms seek to reduce costs and increase productivity through scientific management and safety engineering.

Industrial engineers determine the most productive way the resources of a business can be used in the production of a product.

Sources of Additional Information

☞ Institute of Industrial Engineers, Inc., 25 Technology Park/Atlanta, Norcross, GA 30092.

(See introductory part of this section for information on training requirements and earnings.)

Mechanical Engineers

(D.O.T. 007.061, .161-022, -034, and -038, and .267-010)

Nature of the Work

Mechanical engineers plan and design tools, engines, machines, and other mechanical equipment. They design and develop power-producing machines such as internal combustion engines, steam and gas turbines, and jet and rocket engines. They also design and develop power-using machines such as refrigeration and air-conditioning equipment, robots, machine tools, materials handling systems, and industrial production equipment.

The work of mechanical engineers varies by industry and function. Specialties include, among others, applied mechanics, design engineering, heat transfer, power plant engineering, pressure vessels and piping, and underwater technology. Mechanical engineers design tools needed by other engineers for their work.

Mechanical engineering is the broadest engineering discipline, extending across many interdependent specialties. Some mechanical engineers work in production operations, maintenance, and technical sales. Many are administrators or managers.

Employment

Mechanical engineers held about 227,000 jobs in 1992. More than 3 out of 5 jobs were in manufacturing—of these, most were in the machinery, transportation equipment, electrical equipment, instruments, and fabricated metal products industries. Business and engineering consulting services and government agencies provided most of the remaining jobs.

Job Outlook

Employment of mechanical engineers is expected to grow about as fast as the average for all occupations through the year 2005. Although overall employment in manufacturing is expected to decline, employment of mechanical engineers in manufacturing should increase as the demand for machinery and machine tools grows and

A mechanical engineer uses a CAD workstation to design an improved industrial lathe.

industrial machinery and processes become increasingly complex. Employment of mechanical engineers in other sectors of the economy, such as construction and services, is expected to grow faster than average as firms in these industries learn to apply these engineers' skills.

Job prospects in this field should be favorable through the year 2005. Most of the expected job openings resulting from employment growth and the need to replace those who will leave the occupation should be sufficient to absorb the supply of new graduates and other entrants.

Many mechanical engineering jobs are in defense related industries. Reductions in defense spending has and may continue to result in layoffs in these industries.

Sources of Additional Information

☞ The American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

☞ American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE., Atlanta, GA 30329.

(See introductory part of this section for information on training requirements and earnings.)

A materials engineer prepares a thin-film deposition experiment.

Metallurgical, Ceramic, and Materials Engineers

(D.O.T. 006.061; 011.061; and 019.061-014)

Nature of the Work

Metallurgical, ceramic, and materials engineers develop new types of metal alloys, ceramics, composites, and other materials which meet special requirements. Examples are graphite golf club shafts that are light but stiff, ceramic tiles on the space shuttle that protect it from overheating during reentry, and the alloy turbine blades in a jet.

Most metallurgical engineers work in one of the three main branches of metallurgy—extractive or chemical, physical, and mechanical or process. Extractive metallurgists are concerned with removing metals from ores and refining and alloying them to obtain useful metal. Physical metallurgists study the nature, structure, and physical properties of metals and their alloys, and methods of processing metals into final products. Mechanical metallurgists develop and improve metalworking processes such as casting, forging, rolling, and drawing.

Ceramic engineers develop new ceramic materials and methods for making ceramic materials into useful products. Ceramics include all nonmetallic, inorganic materials which require high temperatures in their processing. Ceramic engineers work on products as diverse as glassware, semiconductors, automobile and aircraft engine components, fiber-optic phone lines, tile, and electric power line insulators.

Materials engineers evaluate technical requirements and material specifications to develop materials that can be used, for example, to reduce the weight, but not the strength of an object. Materials engineers also test and evaluate materials and develop new materials, such as the composite materials now being used in "stealth" aircraft.

Employment

Metallurgical, ceramic, and materials engineers held nearly 19,000 jobs in 1992. About one-quarter worked in metal-producing and processing industries. They also worked in industries that manufacture aircraft and aircraft parts, machinery, and electrical equipment, and in engineering consulting firms, research and testing services, and government agencies.

Job Outlook

Employment of metallurgical, ceramic, and materials engineers is expected to increase faster than the average for all occupations through the year 2005. Many of the industries in which they are concentrated, such as stone, clay, and glass products, primary metals, fabricated metal products, and transportation equipment industries, are expected to experience little if any employment growth through the year 2005. Anticipated employment growth in service industries such as research and testing services and engineering and architectural services, however, should provide significant job openings as these firms are employed to develop improved materials for their industrial customers.

Those seeking to become employed as metallurgical, ceramic, and materials engineers should find good opportunities, as the anticipated growth should be sufficient to absorb the relatively low number of new graduates in this engineering discipline.

Sources of Additional Information

☞ The Minerals, Metals, & Materials Society, 420 Commonwealth Dr., Warrendale, PA 15086-7514.

☞ ASM International, Student Outreach Program, Materials Park, OH 44073.

(See introductory part of this section for information on training requirements and earnings.)

Mining Engineers

(D.O.T. 010.061 except -018)

Nature of the Work

Mining engineers find, extract, and prepare metals and minerals for manufacturing industries to use. They design open pit and underground mines, 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 they are mixed with. Mining engineers frequently specialize in the mining of one mineral, such as coal or gold.

With increased emphasis on protecting the environment, many mining engineers have been working to solve problems related to land reclamation and water and air pollution.

Employment

Mining engineers held about 3,600 jobs in 1992. Over two-thirds worked in the mining industry. Other jobs were located in engineering consulting firms, government agencies, or in manufacturing industries.

A mining engineer studies a map of a strip mine.

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

Job Outlook

Opportunities in the mining industry are closely related to the price of the metals and minerals they produce. If the price of these products is high, it makes it worthwhile for a mining company to invest the many millions of dollars in material moving equipment and ore processing technology necessary to operate the mine and make a profit.

In the mid-1980's, mining engineers experienced poor employment opportunities because low prices for oil and metals reduced profitab ity in coal, metal, and other mining. The prices of these commodities, metals in particular, have increased recently to levels high enough to raise output and expand employment opportunities. Although the long-term business environment for mining generally is perceived to be favorable, a mine takes years of research, planning, and development to become fully operational, and, even then, may not contribute to rapid expansion in employment opportunities for mining engineers. In fact, little change in employment is expected through the year 2005. However, the number of annual openings arising from the need to replace those who transfer out of the occupation or retire should be sufficient to absorb the expected small number of new graduates and other entrants.

Sources of Additional Information

☞ The Society for Mining, Metallurgy, and Exploration, Inc., P.O. Box 625002, Littleton, CO 80162-5002.

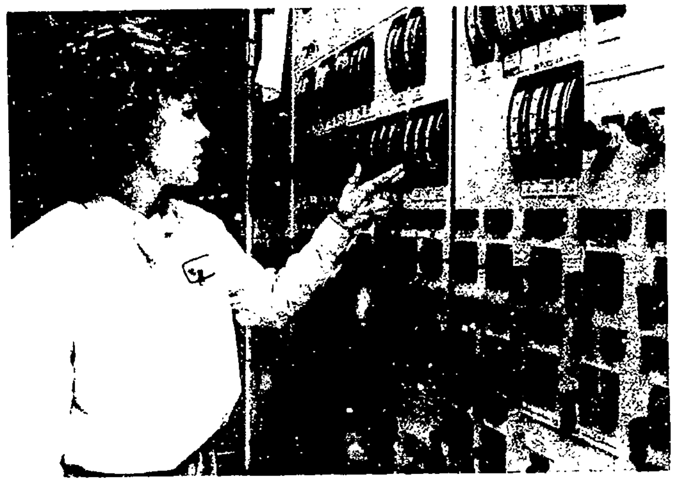
(See introductory part of this section for information on training requirements and earnings.)

Nuclear Engineers

(D.O.T. 015.061, .067, .137, and .167)

Nature of the Work

Nuclear engineers conduct research on nuclear energy and radiation. They design, develop, monitor, and operate nuclear power plants used to generate electricity and power Navy ships. For example, they may work on the nuclear fuel cycle—the production, handling, and use of nuclear fuel and the safe disposal of waste produced by nuclear energy—or on fusion energy. Some specialize in the development of nuclear weapons; others develop industrial and medical uses for radioactive materials such as equipment to help diagnose and treat medical problems.



A nuclear engineer assesses the operation of a reactor and its power generating unit.

Employment

Nuclear engineers held about 17,000 jobs in 1992; one-fifth each were in the Federal Government, research and testing services, and utilities. Nearly half of all federally employed nuclear engineers were civilian employees of the Navy, about one-third worked for the Nuclear Regulatory Commission, and most of the rest worked for the Department of Energy or the Tennessee Valley Authority. Most nonfederally employed nuclear engineers worked for public utilities or engineering consulting companies. Some worked for defense manufacturers or manufacturers of nuclear power equipment.

Job Outlook

Because of concerns over the cost and safety of nuclear power, it is unlikely that any new nuclear power plants will be built by the year 2005. Nevertheless, nuclear engineers will be needed to operate existing plants. In addition, nuclear engineers will be needed to work in defense-related areas and to improve and enforce safety standards. Therefore, employment of nuclear engineers is expected to change little through the year 2005.

Despite the expected absence of employment growth, good opportunities for nuclear engineers should exist because the number of persons graduating with degrees in nuclear engineering is likely to be in rough balance with the number of job openings. Those openings will arise as nuclear engineers transfer to other occupations or leave the labor force.

Sources of Additional Information

☞ American Nuclear Society, 555 North Kensington Ave., LaGrange Park, IL 60525.

(See introductory part of this section for information on training requirements and earnings.)

Petroleum Engineers

(D.O.T. 010.061 except -014 and -026, .161-010, and .167-010 and -014)

Nature of the Work

Petroleum engineers explore for and produce oil and natural gas. If a workable reservoir containing oil or natural gas is discovered, petroleum engineers work to achieve the maximum profitable recovery from the reservoir by determining and developing the most efficient production methods.

Beacause only a small proportion of the oil and gas in a reservoir will flow out under natural forces, petroleum engineers develop and use various enhanced recovery methods. These include injecting

A petroleum engineer checks the flow of crude oil at a pumping unit.

water, chemicals, or steam into an oil reservoir to force more of the oil out, and horizontal drilling or fracturing to connect more of a gas reservoir to a well. Since even the best methods in use today recover only a portion of the oil and gas in a reservoir, petroleum engineers work to find ways to increase this proportion.

Employment

Petroleum engineers held over 14,000 jobs in 1992, mostly in the petroleum industry and closely allied fields. Employers include major oil companies and hundreds of smaller, independent oil exploration, production, and service companies. Engineering consulting firms, government agencies, oil field services, and equipment suppliers also employ petroleum engineers. Others work as independent consultants.

Because petroleum engineers specialize in the discovery and production of oil and gas, relatively few are employed in the refining, transportation, and retail sectors of the oil and gas industry.

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

Job Outlook

The price of oil has a major effect on the level of employment opportunities for petroleum engineers in the United States. A high price of oil and gas makes it profitable for oil exploration firms to seek oil and gas reservoirs, and they will hire petroleum engineers to do so. With low oil prices, however, it is cheaper to purchase needed oil from the Organization of Petroleum Exporting Countries (OPEC), such as Saudi Arabia, who have vast oil reserves.

Employment of petroleum engineers is expected to decline through the year 2005 unless oil and gas prices unexpectedly increase enough to encourage increased exploration for oil in this country. Even if new job growth doesn't materialize, employment opportunities for petroleum engineers should be good because the number of degrees granted in petroleum engineering has traditionally been low. So, new graduates are not likely to significantly exceed the number of job openings that will arise as petroleum engineers transfer to other occupations or leave the labor force.

Sources of Additional Information

☞ **Society of Petroleum Engineers, 222 Palisades Creek Dr., Richardson, TX 75080.**

(See introductory part of this section for information on training requirements and earnings.)

Agricultural Scientists

(D.O.T. 040.061-010, -014, -018, -038, -042, and -058; 041.061-014, -018, -046, and -082; and 041.081)

Nature of the Work

The work agricultural scientists do has played an important part in the Nation's sharply rising agricultural productivity. Agricultural scientists study farm crops and animals and develop ways of improving their quantity and quality. They look for ways to improve crop yield and quality 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, and other sciences to solve problems in agriculture. They often work with biological scientists on basic biological research and in applying to agriculture the advances in knowledge brought about by biotechnology.

Many agricultural scientists 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. Many work in basic or applied research and development. Some agricultural scientists are consultants to business firms, private clients, or to government.

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

Food science. Food scientists or technologists are usually employed in the food processing industry, universities, or the Federal Government, and help meet consumer demand for food products that are healthful, safe, palatable, and convenient. To do this, they use their knowledge of chemistry, microbiology, and other sciences to develop new or better ways of preserving, processing, packaging, storing, and delivering foods. Some 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. Many food technologists work in product development. Others enforce government regulations, inspecting food processing areas and ensuring that sanitation, safety, quality, and waste management standards are met.

Plant science. Another important area of agricultural science is plant science, which includes the disciplines of agronomy, crop science, entomology, and plant breeding, among others. These scientists 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. Some crop scientists study the breeding, physiology, and management of crops and use genetic engineering to develop crops resistant to pests and drought.

Soil science. Soil scientists study the chemical, physical, biological, and mineralogical composition of soils as they relate to plant or crop growth. They 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 and how 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. Since 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 develop better, more efficient ways of producing and processing meat, poultry, eggs, and milk. Dairy scientists, poultry scientists, animal breeders, and other related scientists 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, 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 working environment for those engaged in applied research or product development varies, depending on the discipline of agricultural science and 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 or State research stations may spend part of their time at dairies, farrowing houses, feedlots, farm animal facilities, or outdoors conducting research associated with livestock. Soil and crop scientists also spend time outdoors conducting research on farms or agricultural research stations.

Employment

Agricultural scientists held about 29,000 jobs in 1992. In addition, several thousand persons held agricultural science faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook.*)

About two-fifths of all nonfaculty agricultural scientists work for Federal, State, or local governments. Nearly 3 out of 10 worked for the Federal Government in 1992, mostly in the Department of Agriculture. In addition, large numbers 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,

Agricultural scientists who specialize in agronomy work to improve crop yield and quality.

pharmaceutical companies, wholesale distributors, and food products companies. About 5,000 agricultural scientists were self-employed in 1992, mainly as consultants.

Training, Other Qualifications, and Advancement

Training requirements for agricultural scientists depend on specialty and the type of work they perform. A bachelor's degree in agricultural science is sufficient for some jobs in applied research or in assisting in basic research, but a master's or doctoral degree is required for basic research. A Ph.D. degree in agricultural science is usually 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 at least one land-grant college which 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, 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; students preparing as food scientists take courses such as food chemistry, food analysis, food microbiology, and food processing operations; and 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 based on independent research.

Agricultural 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 agricultural scientists also need an understanding of basic business principles.

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 scientists is expected to grow about as fast as the average for all occupations through the year 2005. Additionally, the need to replace agricultural scientists who retire or otherwise leave the occupation permanently will account for even more job openings than projected growth. Although enrollments in agricultural science programs have begun to increase again after declining for several years during the 1980's, opportunities should still be available in most major subfields of agricultural science. Animal and plant scientists with a background in molecular biology, microbiology, genetics, or biotechnology, soil scientists with an interest in the environment, and food technologists may find the best opportunities.

Generally speaking, those with advanced degrees will be in the best position to enter jobs as agricultural scientists. However, competition for teaching positions in colleges or universities and for some basic research jobs may be keen, even for doctoral holders. Federal and State budget cuts may limit funding for these positions through the year 2005.

It is possible for bachelor's degree holders to work in some applied research and product development positions, but usually only in certain subfields, such as food science and technology. Also, the Federal Government hires bachelor's degree holders to work as soil scientists in the Soil Conservation Service. Despite the more limited opportunities for those with only a bachelor's degree to obtain jobs as agricultural scientists, 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. Four-year degrees may also help persons enter occupations such as farmer or farm manager, cooperative extension service agent, agricultural products inspector, technician, landscape architect, or purchasing or sales agent for agricultural commodities or farm supplies.

Earnings

According to the College Placement Council, beginning salary offers in 1992 for graduates with a bachelor's degree in animal science averaged $20,189 a year, and for graduates in plant science, $22,150.

Average Federal salaries for employees in nonsupervisory, supervisory, and managerial positions in certain agricultural science specialties in 1993 were as follows: Animal science, $55,631; agronomy, $45,911; soil science, $43,033; horticulture, $44,492; entomology, $53,889.

Related Occupations

The work of agricultural scientists is closely related to that of biologists and other natural scientists such as chemists and physicists. It is also related to agricultural production occupations such as farmer and farm manager and cooperative extension service agent as well as to the work of foresters and conservation scientists. Certain specialties of agricultural science are also related to other occupations. For example, the work of animal scientists is related to that of veterinarians; horticulturists, to landscape architects; and soil scientists, to soil conservationists.

Sources of Additional Information

Information on careers in agricultural science is available from:

☞ Office of Higher Education Programs, U.S. Department of Agriculture, Room 350A, Administration Bldg., 14th St. and Independence Ave. SW., Washington, DC 20250.

☞ American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711.

☞ 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.

For information on careers in animal science, write to:

☞ The American Society of Animal Science, 309 West Clark St., Champaign, IL 61820.

For information on careers in soil science in the Federal Government, write to:

☞ Soil Conservation Service, 14th St. and Independence Ave. SW., Washington, DC 20013.

Information on Federal job opportunities is available from local offices of State employment security agencies or offices of the U.S. Office of Personnel Management, located in major metropolitan areas.

Biological and Medical Scientists

(D.O.T. 022.081-010; 041.061, except -014, -018, -046, and -082; 041.067-010; 041.261-010)

Nature of the Work

Biological and medical scientists study living organisms and their relationship to their environment. Most specialize in some area of biology such as zoology (the study of animals) or microbiology (the study of microscopic organisms).

Many biological scientists and virtually all medical scientists work in research and development. Some conduct basic research to increase knowledge of living organisms. Others, in applied research, use knowledge provided by basic research to develop new medicines, increase crop yields, and improve the environment. Biological and 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 conduct experiments on laboratory animals or greenhouse plants. For some kinds of biological scientists, a good deal of research is performed outside of laboratories. For example, a botanist may do research in tropical rain forests to see what plants grow there, or an ecologist may study how a forest area recovers after a fire.

Some biological and medical scientists work in management or administration. They may plan and administer programs for testing foods and drugs, for example, or direct activities at zoos or botanical gardens. Some biological scientists work as consultants to business firms or to government, while others test and inspect foods, drugs, and other products or write for technical publications. Some work in sales and service jobs for companies manufacturing chemicals or other technical products. (See the statement on manufacturers' and wholesale sales representatives elsewhere in the *Handbook*.)

In recent years, advances in basic biological knowledge, especially at the genetic level, have spurred the field of biotechnology. Biological and medical scientists using this technology manipulate the genetic material of animals or plants, attempting to make organisms more productive or disease resistant. The first application of this technology has been in the medical and pharmaceutical areas. Many 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. Advances in biotechnology have opened up research opportunities in almost all areas of biology, including commercial applications in agriculture and the food and chemical industries.

Most biological scientists who come under the broad category of *biologist* 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 level have blurred some traditional classifications.

Aquatic biologists study plants and animals living in water. *Marine biologists* study salt water organisms and *limnologists* study fresh water organisms. Marine biologists are sometimes called oceanographers, but oceanography usually refers to the study of the physical characteristics of oceans and the ocean floor. (See the statement on geologists and geophysicists elsewhere in the *Handbook*.)

Biochemists study the chemical composition of living things. They try to understand the complex chemical combinations and reactions involved in metabolism, reproduction, growth, and heredity. Much of the work in biotechnology is done by biochemists and molecular biologists because this technology involves understanding the complex chemistry of life.

Botanists study plants and their environment. Some study all aspects of plant life; others specialize in areas such as identification and classification of plants, the structure and function of plant parts, the biochemistry of plant processes, or the causes and cures of plant diseases.

Microbiologists investigate the growth and characteristics of microscopic organisms such as bacteria, algae, or fungi. *Medical microbiologists* study the relationship between organisms and disease or the effect of antibiotics on microorganisms. Other microbiologists may specialize in environmental, food, agricultural, or industrial microbiology, virology (the study of viruses), or immunology (the study of mechanisms that fight infections). Many microbiologists are using 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 may specialize in functions such as growth, reproduction, photosynthesis, respiration, or movement, or in the physiology of a certain area or system of the organism.

Zoologists study animals—their origin, behavior, diseases, and life processes. Some experiment with live animals in controlled or natural surroundings while others dissect dead animals to study their structure. Zoologists are usually identified by the animal group studied—ornithologists (birds), mammalogists (mammals), herpetologists (reptiles), and ichthyologists (fish).

Ecologists study the relationship among organisms and between organisms and their environments and the effects of influences such as population size, pollutants, rainfall, temperature, and altitude.

Agricultural scientists, who may also be classified as biological scientists, are included in a separate statement elsewhere in the *Handbook*.

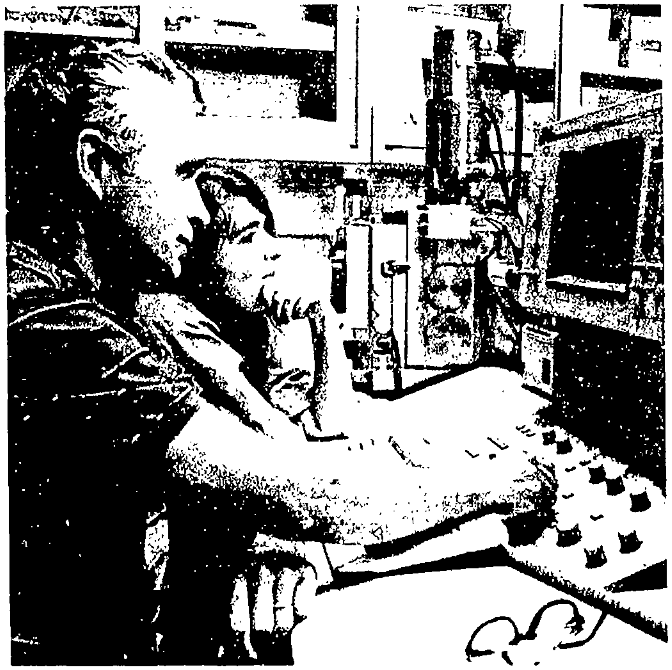
Biological scientists who do biomedical research are usually called *medical scientists*. Medical scientists working on basic research into normal biological systems often do so in order to understand the causes of and to discover treatment for disease and other health problems. Medical scientists may try to identify the kinds of changes in a cell, chromosome, or even gene that signal the development of medical problems, such as different types of cancer. After identifying structures of or changes in organisms that provide clues to health problems, medical scientists may then work on the treatment of problems. For example, a medical scientist involved in cancer research might try to formulate a combination of drugs which will lessen the effects of the disease. Medical scientists who have a medical degree might then administer the drugs to patients in clinical trials, monitor their reactions, and observe the results. (Medical scientists who do not have a medical degree normally collaborate with a medical doctor who deals directly with patients.) The medical scientist might then return to the laboratory to examine the results and, if necessary, adjust the dosage levels to reduce negative side effects or to try to induce even better results. In addition to using basic research to develop treatments for health problems, medical scientists attempt to discover ways to prevent health problems from developing, such as affirming the link between smoking and increased risk of lung cancer, or alcoholism and liver disease.

Working Conditions

Biological and medical scientists generally work regular hours in offices or laboratories and usually are not exposed to unsafe or unhealthy conditions. Some work with dangerous organisms or toxic substances in the laboratory, so strict safety procedures must be followed to avoid contamination. Medical scientists also spend time working in clinics and hospitals administering drugs and treatments to patients in clinical trials. Many biological scientists such as botanists, ecologists, and zoologists take field trips which involve strenuous physical activity and primitive living conditions.

Employment

Biological and medical scientists held about 117,000 jobs in 1992. In addition, many biological and medical scientists held biology faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook*.)



Research biological scientists use a variety of sophisticated laboratory equipment, such as scanning electron microscopes

Almost 4 in 10 nonfaculty biological scientists were employed by Federal, State, and local governments. Federal biological scientists worked mainly in the U.S. Departments of Agriculture, the Interior, and Defense, and in the National Institutes of Health. Most of the rest worked in the pharmaceutical industry, hospitals, or research and testing laboratories. About one-fifth of medical scientists worked in research and testing laboratories, with most of the remainder found in hospitals and the pharmaceutical industry.

Training, Other Qualifications, and Advancement

For biological scientists, the Ph.D. degree generally is required for college teaching, independent research, and for advancement to administrative positions. A master's degree is sufficient for some jobs in applied research and for jobs in management, inspection, sales, and service. The bachelor's degree is adequate for some nonresearch jobs. 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. Others become biological technicians, medical laboratory technologists or, with courses in education, high school biology teachers. (See the statements on clinical laboratory technologists and technicians; science technicians; and kindergarten, elementary, and secondary school teachers elsewhere in the *Handbook*.) Many with a bachelor's degree in biology enter medical, dental, veterinary, or other health profession schools. Some enter a wide range of occupations with little or no connection to biology.

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. Advanced degree programs include classroom and field work, laboratory research, and a thesis or dissertation. Biological scientists who have advanced degrees usually begin in research or teaching. With experience, they may become managers or administrators within biology; others leave biology for nontechnical managerial, administrative, and 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 doing field research in remote areas must have physical stamina.

The Ph.D. degree in a biological science is the minimum education required for prospective medical scientists 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. Medical scientists who administer drug or gene therapy to human patients, or who otherwise interact medically with patients (such as drawing blood, excising tissue, or performing other invasive procedures) must have a medical degree. It is particularly helpful for medical scientists to earn both Ph.D. and medical degrees.

In addition to the formal education, medical scientists are usually expected to spend several years in a post-doctoral position before they are offered permanent jobs. Post-doctoral work provides valuable laboratory experience, including experience in specific processes and techniques (such as gene splicing) which are transferable to other research projects later on. In some institutions, the post-doctoral position can lead to a permanent position.

Job Outlook

Employment of biological and medical scientists is expected to increase faster than the average for all occupations through the year 2005. Biological and medical scientists will continue to conduct genetic and biotechnological research and help develop and produce products developed by new biological methods. In addition, efforts to clean up and preserve the environment will continue to add to growth. More biological scientists will be needed to determine the environmental impact of industry and government actions and to correct past environmental problems. Expected expansion in research related to health issues, such as AIDS, cancer, and the Human Genome project, should also result in growth. However, much research and development, including many areas of medical research, is funded by the Federal Government. Anticipated budget tightening should lead to slower employment growth of biological and medical scientists in the public sector and in some private industry research laboratories as the number and amount of government grants increases more slowly than in the past.

Many persons with a bachelor's degree in biological science find jobs as science or engineering technicians or health technologists and technicians. Some become high school biology teachers, where they are usually regarded as teachers rather than biologists. Those with a doctorate in biological science may become college and university faculty. (See statements on science and engineering technicians, health technologists and technicians, high school teachers, and college and university faculty elsewhere in the *Handbook*.)

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

Earnings

Median annual earnings for biological and life scientists were about $34,500 in 1992; the middle 50 percent earned between $26,000 and $46,800. Ten percent earned less than $20,400, and 10 percent earned over $56,900. For medical scientists, median annual earnings were about $32,400; the middle 50 percent earned between $25,800 and $52,200. Ten percent earned less than $20,000, and 10 percent earned over $77,600. According to the College Placement Council, beginning salary offers in private industry in 1992 averaged $21,850 a year for bachelor's degree recipients in biological science.

In the Federal Government in 1993, general biological scientists in nonsupervisory, supervisory, and managerial positions earned an average salary of $45,155; microbiologists averaged $49,440; ecologists, $44,657; physiologists, $55,326; and geneticists, $55,709.

Related Occupations

Many other occupations deal with living organisms and require a level of training similar to that of biological and medical scientists. These include the conservation occupations of forester, range manager, and soil conservationist; animal breeders, horticulturists, soil scientists, and most other agricultural scientists; and life science technicians. Many health occupations are also related to those in the biological sciences, such as medical doctors, dentists, and veterinarians.

Sources of Additional Information

For information on careers in physiology, contact:

☞ American Physiological Society, Membership Services Dept., 9650 Rockville Pike, Bethesda, MD 20814.

For information on careers in biochemistry, contact:

☞ American Society for Biochemistry and Molecular Biology, 9650 Rockville Pike, Bethesda, MD 20814.

For information on careers in botany, contact:

☞ Business Office, Botanical Society of America, 1725 Neil Ave., Columbus, OH 43210-1293.

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.

Information on Federal job opportunities is available from local offices of State employment services or offices of the U.S. Office of Personnel Management, located in major metropolitan areas.

Foresters and Conservation Scientists

(D.O.T. 040.061-030, -046, -050, -054, and -062; .167-010; 049.127)

Nature of the Work

Forests and rangelands serve a variety of needs: They supply wood products, livestock forage, minerals, and water; serve as sites for recreational activities; and provide habitats for wildlife. Foresters and conservation scientists manage, develop, use, and help protect these and other natural resources.

Foresters manage timberland, which involves a variety of duties. Those working in private industry may procure timber from private landowners. To do this, 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 the purchase of timber, 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 is performed to the landowner's, as well as federal, state, and local environmental specifications. Forestry consultants often act as agents for the forest owner, performing the above duties and negotiating timber sales with industrial procurement foresters.

Throughout the process, foresters consider the economics of the purchase as well as the environmental impact on natural resources, a function which has taken on added importance in recent years. To do this, they determine how best to preserve 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.

Foresters also supervise the planting and growing of new trees, a process called regeneration. 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 trees to ensure healthy growth and to determine the best time for harvesting. If they detect signs of disease or harmful insects, they decide on the best course of treatment to prevent contamination or infestation of healthy trees.

Foresters who work for State and Federal governments manage public parks and forests and also 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 heights, diameter tapes measure the diameter, and increment borers and bark gauges measure the growth of trees so that timber volumes can be computed and future growth estimated. Photogrammetry and remote sensing (aerial photographs taken from airplanes and satellites) are often used for mapping large forest areas and for detecting widespread trends of forest and land use. Computers are used extensively, both in the office and in the field, for the storage, retrieval, and analysis of information required to manage the forest land and its resources.

Range managers, also called *range conservationists, range ecologists*, or *range scientists*, 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 the 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 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, they maintain soil stability and vegetation for other uses such as wildlife habitats and outdoor recreation.

Soil conservationists provide technical assistance to farmers, ranchers, and others concerned with the conservation of soil, water, and related natural resources. They develop programs designed to get the most productive use of land without damaging it. Soil conservationists do most of their work in the field. Conservationists visit areas with erosion problems, find the source of the problem, and help landowners and managers develop management practices to combat it.

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

Working Conditions

Working conditions for foresters and conservation scientists vary considerably. Although some of the work is solitary, they also deal regularly with landowners, loggers, forestry technicians and aides, farmers, ranchers, government officials, special interest groups, and the public in general. Some work regular hours in offices or labs.

The work can still be physically demanding, though. Many foresters and conservation scientists often work outdoors in all kinds of weather, sometimes in isolated areas. Some foresters may need to walk long distances through densely wooded land to carry out their work. Foresters and conservation scientists also may work long hours fighting fires or in other emergencies.

Employment

Foresters and conservation scientists held about 35,000 jobs in 1992. About one-third of the salaried workers were in the Federal Government, primarily in the Department of Agriculture's Forest Service and Soil Conservation Service and in the Department of the Interior's Bureau of Land Management. The Forest Service alone employed over 5,000 foresters and over 400 range conservationists in 1992. Another 25 percent worked for State governments, and 8 percent worked for local governments. The remainder worked in private industry, mainly in the forestry industry. Other significant employers included logging and lumber companies and sawmills. Some were self-employed as consultants for private landowners, State and Federal governments, and forestry-related businesses.

Most soil conservationists work for the Department of Agriculture's Soil Conservation Service. Others are employed by State and local governments in their soil conservation districts.

Although foresters and conservation scientists work in every State, employment is concentrated in the western and southeastern States, where many national and private forests and parks are, and where most of the lumber and pulpwood-producing forests are. 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.

Training, Other Qualifications, and Advancement

A bachelor's degree in forestry is the minimum educational requirement for professional careers in forestry. In the Federal Government, a combination of experience and appropriate education can occasionally substitute for a 4-year forestry degree, but job competition makes this difficult.

A forester consults a map to locate a client's property.

Thirteen States have mandatory licensing or registration requirements which a forester must meet in order to acquire the title "professional forester." Becoming licensed or registered usually requires a 4-year degree in forestry, a minimum period of training time, and passing an exam.

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

In 1993, about 55 colleges and universities offered bachelor's or higher degrees in forestry; 45 of these were accredited by the Society of American Foresters. Curriculums stress science, mathematics, communications skills, and computer science, as well as technical forestry subjects. Courses in forest economics and business administration supplement the student's scientific and technical knowledge. Prospective foresters should also have a strong grasp on policy issues and on the increasingly numerous and complex environmental regulations which affect many forestry-related activities. Many colleges require students to complete a field session in a camp operated by the college. 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 generally are required for teaching and research positions. In 1992, 31 colleges and universities offered degrees in range management or range science or in a closely related discipline with a range management or range science option. A number of other schools offered some courses in range management or range science. Specialized range management courses combine plant, animal, and soil sciences with principles of ecology and resource management. Desirable electives include economics, forestry, hydrology, agronomy, wildlife, animal husbandry, computer science, and recreation.

Very few colleges and universities offer degrees in soil conservation. Most soil conservationists have degrees in agronomy, general agriculture, or crop or soil science; a few have degrees in related fields such as wildlife biology, forestry, and range management. Programs of study generally 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 must also work well with people and have good communications 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 regional forest supervisor or to a top administrative position. 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 decision making. 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, many foresters become consulting foresters, working alone or with one or several partners. They advise 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 foresters and conservation scientists is expected to grow more slowly than the average for all occupations through the year 2005, partly due to budgetary constraints in the Federal Government, where employment is concentrated. However, an expected wave of retirements in the Federal Government should create additional job openings for both foresters and range conservationists. Job opportunities for foresters outside of the Federal Government are expected to be better. Demand will continue to increase at the State and local government level in response to the emphasis on environmental protection and responsible land management. For example, urban foresters are increasingly needed to do environmental impact studies in urban areas, and to help regional planning commissions make land use decisions, particularly in the Northeast and in other major population centers of the country. At the State level, more numerous and complex environmental regulations have created demand for more foresters to deal with these issues. Also, the nationwide Stewardship Incentive Program, funded by the Federal Government, provides money to the States to encourage landowners to practice multiple-use forest management. Foresters will be needed to assist landowners in making decisions about how to manage their forested property. In private industry, more foresters should be needed to improve forest and logging practices and increase output and profitability.

Certain areas of the country offer greater job opportunities for foresters and range conservationists than others. Employment for range conservationists is concentrated in the West and Midwest, and most forestry-related employment is in the South and West.

Earnings

Most graduates entering the Federal Government as foresters, range managers, or soil conservationists with a bachelor's degree started at $18,340 or $22,717 a year, in 1993, depending on academic achievement. Those with a master's degree could start at $22,717 or $27,789. Holders of doctorates could start at $33,623 or, in research positions, at $40,298. In 1993, the average Federal salary for foresters in nonsupervisory, supervisory, and managerial positions was $42,440; for soil conservationists, $39,448; and for forest products technologists, $56,5?9.

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

Foresters and conservation scientists who work for Federal, State, and local governments and large private firms generally receive more generous benefits—for example, pension and retirement plans, health and life insurance, and paid vacations—than those working for smaller firms.

Related Occupations

Foresters and conservation scientists are not the only workers who manage, develop, and protect natural resources. Other workers with similar responsibilities include agricultural scientists, agricultural engineers, biological scientists, environmental scientists, farmers, farm managers, ranchers, ranch managers, soil scientists and soil conservation technicians, and wildlife managers.

Sources of Additional Information

Information about the forestry profession and lists of schools offering education in forestry are available from:

☞ Society of American Foresters, 5400 Grosvenor Ln., Bethesda, MD 20814.

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

☞ Society for Range Management, 1839 York St., Denver, CO 80206.

Information about a career as a soil conservationist is available from:

☞ Soil and Water Conservation Society, 7515 Northeast Ankeny Rd., RR #1, Ankeny, IA 50021-9764.

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

☞ Bureau of Land Management, U.S. Department of the Interior, Room 3619, 1849 C St. NW., Washington, DC 20240.

☞ Chief, U.S. Forest Service, U.S. Department of Agriculture, P.O. Box 96090, Washington, DC 20090-6090.

☞ Soil Conservation Service, U.S. Department of Agriculture, 14th St. and Independence Ave. SW., Washington, DC 20013.

Chemists

(D.O.T. 022.061-010, -014, and .137-010)

Nature of the Work

Chemists search for and put to practical use new knowledge about chemicals. Although chemicals are often thought of as artificial or toxic substances, all physical things, whether naturally occurring or of human design, are composed of chemicals. Chemists have developed a tremendous variety of new and improved synthetic fibers, paints, adhesives, drugs, electronic components, lubricants, and other products. They also develop processes which 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 areas.

Many chemists work in research and development. In basic research, chemists investigate the properties, composition, and structure of matter and the laws that govern the combination of elements and reactions of substances. In applied research and development, 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 (polymerization).

Chemists also work in production and quality control in chemical manufacturing plants. They prepare instructions for plant workers which specify ingredients, mixing times, and temperatures for each stage in the process. They also monitor automated processes to ensure proper product yield, and they test samples to ensure they meet industry and government standards. Chemists also record and report on test results. Others are marketing or sales representatives who sell and provide technical information on chemical products.

Chemists often specialize in a subfield. *Analytical chemists* determine the structure, composition, and nature of substances 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. Many commercial products, such as drugs, plastics, and fertilizers, have been developed by organic chemists. *Inorganic chemists* study compounds consisting mainly of elements other than carbon, such as those in electronic components. *Physical chemists* study the physical characteristics of atoms and molecules and investigate how chemical reactions work. Their research may result in new and better energy sources.

Biochemists, whose work encompasses both biology and chemistry, are included under biological scientists elsewhere in the *Handbook*.

Working Conditions

Chemists usually work regular hours in offices and laboratories. Research chemists 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 and may incorporate prototype chemical manufacturing facilities as well as advanced equipment. Chemists may also do some of their research in a chemical plant or outdoors—while gathering samples of 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 held about 92,000 jobs in 1992. The majority of chemists are employed in manufacturing firms—mostly in the chemical manufacturing industry, which includes firms that produce plastics and synthetic materials, drugs, soap and cleaners, paints, industrial organic chemicals, and other miscellaneous chemical products. Chemists also work for State and local governments, primarily in health and agriculture, and for Federal agencies, chiefly in the Departments of Defense, Health and Human Services, and Agriculture.

Chemists contribute to the development of a variety of practical products, including pharmaceuticals, paints, and synthetic fibers and materials.

Others work for research and testing services. In addition, thousands of persons held chemistry faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook*.)

Chemists 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 is usually the minimum education necessary to work as a chemist. However, most research and college teaching jobs require a Ph.D. degree.

Many colleges and universities offer a bachelor's degree program in chemistry, about 602 of which are approved by the American Chemical Society. Approximately 325 colleges and universities also offer advanced degree programs in chemistry.

Students planning careers as chemists should enjoy studying science and mathematics, and should like working with their hands building scientific apparatus and performing experiments. Perseverance, curiosity, and the ability to concentrate on detail and to work independently are essential. In addition to required courses in analytical, inorganic, organic, and physical chemistry, undergraduate chemistry majors usually study biological sciences, mathematics, and physics. Computer courses are also important, as chemists increasingly use computers as a tool in their everyday work.

Because research and development chemists are increasingly expected to work on interdisciplinary teams, some understanding of other disciplines, including business and marketing, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships or co-op programs in industry, also is useful.

Although graduate students typically specialize in a subfield of chemistry, such as analytical chemistry or polymer chemistry, students usually 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 narrowly define their interests. Some employers provide new bachelor's degree chemists with additional training or education.

In government or industry, beginning chemists with a bachelor's degree work in technical sales or services, quality control, or assist senior chemists in research and development laboratories. Some may work in research positions, analyzing and testing products, but these are often technicians' positions, with limited upward mobility. Many employers prefer chemists with a Ph.D. to work in basic and applied research. A Ph.D. is also generally required for a 4-year college faculty position and for advancement to many administrative positions. Chemists who work in sales, marketing, or professional research positions often move into management eventually.

Many people with a bachelor's degree in chemistry enter other occupations in which a chemistry background is helpful, such as technical writers or sales representatives in chemical marketing. Some enter medical, dental, veterinary, or other health profession schools. Others choose from a wide range of occupations with little or no connection to chemistry.

Chemistry graduates may become high school teachers. However, they usually are then regarded as science teachers rather than chemists. Others may qualify as engineers, especially if they have taken some courses in engineering.

Job Outlook

Employment of chemists is expected to grow about as fast as the average for all occupations through the year 2005. The chemical industry should face continued demand for goods such as new and better pharmaceuticals and personal care products, as well as more specialty chemicals designed to address specific problems or applications. To meet these demands, research and development expenditures will continue to increase, contributing to employment growth for chemists.

However, employment will not grow as rapidly as in the past because, overall, research and development budgets are expected to grow more slowly compared to those of the 1980's as firms restructure and streamline their operations. Also, temporary slowdowns in automobile manufacturing and construction, end users of many of the products of the chemical industry, will have a short-term dampening effect on chemists' employment. Regardless of the outlook, hiring may slow and layoffs occur during periods of economic recession, especially in the oil and industrial chemicals industries.

Earnings

According to a 1992 survey by the American Chemical Society, the median starting salary for recently graduated chemists with a bachelor's degree was about $24,000 a year; with a master's degree, $32,000; with a Ph.D., $48,000.

The American Chemical Society also reports that the median salary of their members of all experience levels with a bachelor's degree was $42,000 a year in 1992; with a master's degree, $50,000; and with a Ph.D., $60,000.

In 1993, chemists in nonsupervisory, supervisory, and managerial positions in the Federal Government earned an average salary of $51,537.

Related Occupations

The work of chemical engineers, agricultural scientists, biological scientists, and chemical technicians is closely related to the work done by chemists. The work of other physical and life science occupations may also be similar to that of chemists.

Sources of Additional Information

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

☞ American Chemical Society, Career Services, 1155 16th St. NW., Washington, DC 20036.

Information on Federal job opportunities is available from local offices of State employment services or offices of the U.S. Office of Personnel Management, located in major metropolitan areas.

Geologists and Geophysicists

(D.O.T. 024.061 except -014, and .161)

Nature of the Work

Geologists and geophysicists study the physical aspects and history of the earth. They identify and examine rocks, study information collected by remote sensing instruments in satellites, conduct geological surveys, construct maps, and use instruments to measure the earth's gravity and magnetic field. They also analyze information collected through seismic prospecting, which involves bouncing sound waves off buried rock layers. Many geologists and geophysicists search for oil, natural gas, minerals, and underground water.

Increasingly, geologists, geophysicists, and other earth scientists are becoming known as geological scientists or geoscientists, terms which better describe their role in studying all aspects of the earth.

Geoscientists play an increasingly important part in studying, preserving, and cleaning up the environment. Many design and monitor waste disposal sites, preserve water supplies, and reclaim contaminated land and water to comply with stricter Federal environmental rules. They also help locate safe sites for hazardous waste facilities and landfills.

Geologists and geophysicists examine chemical and physical properties of specimens in laboratories, sometimes under controlled temperature and pressure. They may study fossil remains of animal and plant life or experiment with the flow of water and oil through rocks. Some geoscientists use two- or three-dimensional computer modeling to portray water layers and the flow of water or other fluids through rock cracks and porous materials. A large variety of sophisticated laboratory instruments is used, including x-ray diffractometers, which determine the crystal structure of minerals, and petrographic microscopes, for study of rock and sediment samples. The locations and intensities of earthquakes are determined using seismographs, instruments which measure energy waves resulting from movements in the earth's crust.

Geologists and geophysicists also apply geological knowledge to engineering problems in constructing large buildings, dams, tunnels, and highways. Some administer and manage research and exploration programs, and others become general managers in petroleum and mining companies.

Geology and geophysics are closely related fields, but there are some major differences. Geologists study the composition, structure, and history of the earth's crust. They try to find out how rocks were formed and what has happened to them since their formation. Geophysicists use the principles of physics and mathematics to study not only the earth's surface but its internal composition, ground and surface waters, atmosphere, and oceans as well as its magnetic, electrical, and gravitational forces. Both, however, commonly apply their skills to the search for natural resources and to solve environmental problems.

Geologists and geophysicists often specialize. *Geological oceanographers* study and map the ocean floor. They collect information using remote sensing devices aboard surface ships or underwater research craft. *Physical oceanographers* study the physical aspects of oceans such as currents and the interaction of the surface of the sea with the atmosphere. *Chemical oceanographers* study the chemical composition, dissolved elements, and nutrients of oceans. Although biological scientists who study ocean life are also called oceanographers (as well as marine biologists), the work they do and the training they need are related to biology rather than geology or geophysics. (See the statement on biological scientists elsewhere in the *Handbook*.) *Hydrologists* study the distribution, circulation, and physical properties of underground and surface waters. They study the form and intensity of precipitation, its rate of infiltration into the soil, and its return to the ocean and atmosphere. *Petroleum geologists* explore for oil and gas by studying and mapping the subsurface of the ocean or land. They use sophisticated geophysical instrumentation, well log data, and computers to collect information. *Mineralogists* analyze and classify minerals and precious stones according to composition and structure. *Paleontologists* study fossils found in geological formations to trace the evolution of plant and animal life and the geologic history of the earth. *Seismologists* interpret data from seismographs and other geophysical instruments to detect earthquakes and locate earthquake-related faults. *Stratigraphers* help to locate minerals by studying the distribution and arrangement of sedimentary rock layers and by examining the fossil and mineral content of such layers.

Working Conditions

Some geoscientists spend the majority of their time in an office, others divide their time between fieldwork and office or laboratory work. Geologists often travel to remote field sites by helicopter or four-wheel drive vehicles and cover large areas by foot. Exploration geologists and geophysicists often work overseas or in remote areas, and job relocation is not unusual. Geological and physical oceanographers may spend considerable time at sea.

Employment

Geologists and geophysicists held about 48,000 jobs in 1992. In addition, thousands of persons held geology, geophysics, and oceanography faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook*.)

About 1 in 4 were employed in oil and gas companies or oil and gas field service firms. Many other geologists worked for consulting firms and business services, especially engineering services, which often provide services to oil and gas companies. About 1 geologist in 10 was self-employed; most of these were consultants to industry or government.

The Federal Government employed about 6,400 geologists, geophysicists, oceanographers, and hydrologists in 1992. Over one-half worked for the Department of the Interior in the U.S. Geological Survey, the Bureau of Land Management, the Minerals Management Service, the Bureau of Mines, and the Bureau of Reclamation. Others worked for the Departments of Defense, Agriculture, Commerce, and Energy, and the Environmental Protection Agency. Some worked for State agencies such as State geological surveys and State departments of conservation. Geologists and geophysicists also worked for nonprofit research institutions. Some were employed by American firms overseas for varying periods of time.

Training, Other Qualifications, and Advancement

A bachelor's degree in geology or geophysics is adequate for entry into some lower level geology jobs, but better jobs with good advancement potential usually require at least a master's degree in geology or geophysics. Persons with strong backgrounds in physics, chemistry, mathematics, or computer science also may qualify for some geophysics or geology jobs. A Ph.D. degree is essential for most college or university teaching positions, and is important for work in Federal agencies that involves basic research.

Geologists and geophysicists often apply their knowledge of the physical aspects of the earth to solve or prevent environmental problems.

Over 500 colleges and universities offer a bachelor's degree in geology, geophysics, oceanography, or other geoscience. Other programs offering related training for beginning geological scientists include geophysical technology, geophysical engineering, geophysical prospecting, engineering geology, petroleum geology, and geochemistry. In addition, more than 300 universities award advanced degrees in geology or geophysics.

Geologists and geophysicists need to be able to work as part of a team. Computer modeling, data processing, and effective oral and written communication skills are important, as well as the ability to think independently and creatively. Those involved in fieldwork must have physical stamina.

Traditional geoscience courses emphasizing classical geologic methods and concepts (such as mineralogy, paleontology, stratigraphy, and structural geology) are important for all geoscientists. However, those students interested in working in the environmental or regulatory fields should take courses in hydrology, hazardous waste management, environmental legislation, chemistry, fluid mechanics, and geologic logging.

Geologists and geophysicists often begin their careers in field exploration or as research assistants in laboratories. They are given more difficult assignments as they gain experience. Eventually they may be promoted to project leader, program manager, or other management and research positions.

Job Outlook

Employment of geologists and geophysicists is expected to grow about as fast as the average for all occupations through the year 2005. Many jobs for geologists and geophysicists are in or related to the petroleum industry, especially the exploration for oil and gas. This industry is subject to cyclical fluctuations. Low oil prices, higher production costs, improvements in energy efficiency, and restrictions on potential drilling sites have caused exploration activities to be curtailed in the United States. If these conditions continue, there will be few openings in the petroleum industry for geoscientists working in the United States.

As a result of generally poor job prospects in the past few years, the number of students enrolling in geology and geophysics has dropped considerably. Although enrollments are rising again, the number of students trained in petroleum geology is likely to be so low that even a small increase in openings in the oil industry will be greater than the number of petroleum geologists and geophysicists available to fill them, creating good employment opportunities if exploration activities increase.

Despite the generally poor job prospects encountered by geoscientists in recent years in the petroleum industry, the demand for these professionals in environmental protection and reclamation has been growing rapidly. Geologists and geophysicists will be needed to help clean up contaminated sites in the United States, and to help private companies and government comply with more numerous and complex environmental regulations. In particular, jobs requiring training in engineering geology, hydrology and geochemistry should be in demand. However, if the number of geo-scientists who obtain training in these areas increases very rapidly, they may experience competition despite the increasing number of jobs available.

Earnings

Surveys by the College Placement Council indicate that graduates with bachelor's degrees in the geological sciences received an average starting offer of $25,704 a year in 1992.

According to a 1991 American Geological Institute survey, the average starting salaries for inexperienced geoscientists were about $23,100 for those with a bachelor's degree, $28,100 for those with a master's degree, and $33,600 for those with a Ph.D. However, the starting salaries can vary widely depending on the employing industry. For example, the oil and gas industry offered an average starting salary of $36,250 for bachelor's degree holders, while in research institutions, colleges, and universities, new hires with a bachelor's degree averaged about $21,000.

Although the petroleum, mineral, and mining industries offer higher salaries, the competition in these areas is normally intense, and the job security less than in other areas.

In 1993, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was $51,800; for geophysicists, $57,929; for hydrologists, $47,793; and for oceanographers, $54,552.

Related Occupations

Many geologists and geophysicists work in the petroleum and natural gas industry. This industry also employs many other workers in the scientific and technical aspects of petroleum and natural gas exploration and extraction, including engineering technicians, science technicians, petroleum engineers, and surveyors. Also, some life scientists, physicists, chemists, and meteorologists, as well as mathematicians, computer scientists, soil scientists, and mapping scientists, do related work in both 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:

☞ American Geological Institute, 4220 King St., Alexandria, VA 22302-1507.

☞ Geological Society of America, P.O. Box 9140, 3300 Penrose Pl., Boulder, CO 80301.

☞ American Association of Petroleum Geologists, Communications Department, P.O. Box 979, Tulsa, OK 74101.

Information on training and career opportunities for geophysicists is available from:

☞ American Geophysical Union, 2000 Florida Ave. NW., Washington, DC 20009.

☞ Society of Exploration Geophysicists, P.O. Box 70240, Tulsa, OK 74170.

Information on training and career opportunities in oceanography is available from:

☞ Marine Technology Society, 1828 L St. NW., Suite 906, Washington, DC 20036.

Information on Federal job opportunities is available from local offices of State employment services or offices of the U.S. Office of Personnel Management located in major metropolitan areas.

Meteorologists

(D.O.T. 025.062-010)

Nature of the Work

Meteorology is the study of the atmosphere, the air that covers the earth. Meteorologists study the atmosphere's physical characteristics, motions, and processes, and the way the atmosphere affects the rest of our environment. The best-known application of this knowledge is in forecasting the weather. However, weather information and meteorological research also are applied in air-pollution control, agriculture, air and sea transportation, defense, and the study of trends in the earth's climate such as global warming or ozone depletion.

Meteorologists 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 they apply physical and mathematical relationships to make short- and long-range weather forecasts. Their data come from weather satellites, weather radar, and remote sensors and observers in many parts of the world. Meteorologists use sophisticated computer models of the world's atmosphere to help forecast the weather and interpret the results of these models to make long-term, short-term, and local-area forecasts. These forecasts inform not only the general public, but also those who need accurate weather information for both economic and safety reasons, as in the shipping, aviation, agriculture, fishing, and utilities industries.

The use of weather balloons, launched twice a day, to measure wind, temperature, and humidity in the upper atmosphere, is being supplemented by more sophisticated weather equipment which transmits data as frequently as every few minutes. Doppler radar, for example, can detect rotational patterns in violent storm systems, allowing forecasters to better predict thunderstorms, tornadoes, flash floods, as well as their direction and intensity.

Some meteorologists engage 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 formation of clouds, rain, snow, and other weather phenomena, such as severe storms. *Climatologists* collect, analyze, and interpret past records of wind, rainfall, sunshine, and temperature in specific areas or regions. Their studies are used to design buildings and to plan heating and cooling systems, effective land use, and agricultural production. Other research meteorologists may examine the most effective ways to control or diminish air pollution or improve weather forecasting using mathematical models.

Working Conditions

Jobs in weather stations, most of which operate around the clock 7 days a week, often involve night, weekend, and holiday work and rotating shifts. Operational meteorologists are often under pressure to meet forecast deadlines. Weather stations are found all over the country: At airports, in or near cities, and in isolated and remote areas. Meteorologists in smaller weather offices often work alone; in larger ones, they work as part of a team. Meteorologists not doing forecasting work regular hours, usually in offices.

Employment

Meteorologists held about 6,100 jobs in 1992. The largest employer of civilian meteorologists is the National Oceanic and Atmospheric Administration (NOAA), which employs about 2,400 meteorologists. The majority of NOAA's meteorologists work in the National Weather Service at stations in all parts of the United States. The remainder of NOAA's meteorologists work mainly in research or in program management. The Department of Defense employs about 280 civilian meteorologists. Others work for private weather consultants, research and testing services, and computer and data processing services.

Hundreds of people teach meteorology and related courses in college and university departments of meteorology or atmospheric science, physics, earth science, and geophysics. (See the statement on college and university faculty elsewhere in the *Handbook*.)

Meteorologists involved in weather forecasting sometimes work evenings, weekends, or holidays.

In addition to civilian meteorologists, thousands of members of the Armed Forces do forecasting and other meteorological work.

Training, Other Qualifications, and Advancement

A bachelor's degree with a major in meteorology or a closely related field with coursework in meteorology is the usual minimum requirement for a beginning job as a meteorologist.

The preferred educational requirement for entry level meteorologists in the Federal Government is a bachelor's degree—not necessarily in meteorology—with at least 20 semester hours of meteorology courses, including 6 hours in weather analysis and forecasting and 6 hours in dynamic meteorology. In addition to meteorology coursework, differential and integral calculus and 6 hours of college physics are required. These requirements will probably be upgraded soon, and most likely will include coursework in computer science and additional coursework appropriate for a physical science major, such as statistics, chemistry, physical oceanography, or physical climatology. Sometimes, a combination of experience and education may be substituted for a degree.

Although positions in operational meteorology are available for those with only a bachelor's degree, obtaining a graduate degree enhances advancement potential. A master's degree is usually necessary for conducting research and development, and a Ph.D. is usually required for college teaching. Students who plan a career in teaching or research and development need not necessarily major in meteorology as an undergraduate. In fact, a bachelor's degree in mathematics, physics, or engineering is excellent preparation for graduate study in meteorology.

Because meteorology 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, and a strong background in mathematics and physics are expected to become more important to prospective employers as new, sophisticated weather equipment and radar systems become operational. Many programs combine the study of meteorology with another field, such as agriculture, engineering, or physics. For example, hydrometeorology is the blending of hydrology (the science of the earth's water) and meteorology, and this is an emerging field concerned with the impact of precipitation on the hydrologic cycle and the environment.

Beginning meteorologists often do routine data collection, computation, or analysis and some basic forecasting. Entry level meteorologists in the Federal Government are usually placed in intern positions for training and experience. Experienced meteorologists may advance to various supervisory or administrative jobs, or may handle more complex forecasting jobs. Increasing numbers of meteorologists establish their own weather consulting services.

Job Outlook

Employment of meteorologists is expected to grow as fast as the average for all occupations through the year 2005. The National Weather Service, which employs many meteorologists, expects to increase its employment of meteorologists, mainly in its field offices, to improve short-term and local-area weather forecasts. Although some of these additional jobs are being filled internally through the upgrading of meteorological technicians, there still should be more openings in the National Weather Service in the next 5 years than there have been in the past. Employment of meteorologists in other parts of the Federal Government is not expected to increase. Additional jobs will be created in private industry with the increased use of private weather forecasting and meteorological services by farmers, commodity investors, utilities, transportation and construction firms, and radio and TV stations. For people in these and other areas, even a slight improvement in the detail and accuracy of weather information and forecasts over the general information provided by the National Weather Service can yield significant benefits. 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.

Along with the projected average growth, many of the job openings in this very small occupation will arise from the need to replace those who transfer to other occupations or leave the labor force.

Earnings

The average salary for meteorologists in nonsupervisory, supervisory, and managerial positions employed by the Federal Government was $48,266 in 1993. In 1993, meteorologists in the Federal Government with a bachelor's degree and no experience received a starting salary of $18,340 or $22,717 a year, depending on their college grades. Those with a master's degree could start at $22,717 or $27,790; those with the Ph.D. degree, at $33,623 or $40,299.

Related Occupations

Workers in other occupations concerned with the physical environment include oceanographers, geologists and geophysicists, hydrologists, and civil and environmental engineers.

Sources of Additional Information

Information on career opportunities in meteorology is available from:

☞ American Meteorological Society, 45 Beacon St., Boston, MA 02108-3693.

☞ National Weather Service, Personnel Branch, 1335 East West Hwy., SSMC1, Silver Spring, MD 20910.

Physicists and Astronomers

(D.O.T. 015.021-010; 021.067-010; 023.061-010, -014, and .067; 079.021-014)

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, while others work in practical areas such as the development of advanced materials, electronic and optical devices, and medical equipment.

Physicists design and perform experiments with lasers, cyclotrons, telescopes, mass spectrometers, and other equipment. Based on observations and analysis, they attempt to discover the laws that describe the forces of nature, such as gravity, electromagnetism, and nuclear interactions. They 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 apply their knowledge to problems in navigation and space flight.

Most physicists work in research and development. Some do basic research to increase scientific knowledge. For example, they investigate the structure of the atom or the nature of gravity.

Physicists who conduct applied research build upon the discoveries made through basic research and work to develop new devices, products, and processes. For instance, basic research in solid-state physics led to the development of transistors and then to the 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 for ovens; and measuring instruments can analyze blood or the chemical content of foods. A small number work in inspection, testing, quality control, and other production-related jobs in industry.

Much physics research is done in small or medium-size laboratories. However, experiments in plasma, nuclear, high energy, and 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. They analyze large quantities of data gathered by observatories and satellites and write scientific papers or reports on their findings. Most astronomers spend only a few weeks each year making observations with optical telescopes, radio telescopes, and other instruments. Contrary to the popular image, astronomers almost never make observations by looking directly through a telescope because enhanced photographic and electronic detecting equipment can see more than the human eye.

Most physicists specialize in one of many subfields—elementary particle physics; nuclear physics; atomic and molecular physics; physics of condensed matter (solid-state physics); optics; acoustics; 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 combined 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 work away from home temporarily at national or international facilities with unique equipment such as particle accelerators. Astronomers who make observations may travel to observatories, which are usually in remote locations, and routinely work at night.

Employment

Physicists and astronomers held nearly 21,000 jobs in 1992. Also, a significant number held physics or astronomy faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook*.) About two-fifths of all nonfaculty physicists worked for research, development, and testing laboratories in industry. The Federal Government employed almost one-fifth, mostly in the Departments of Defense and Commerce and in the National Aeronautics and Space Administration. Others worked in colleges and universities in nonfaculty positions and for

Research and development work is an integral part of most physicists' jobs.

aerospace firms, noncommercial research laboratories, electrical equipment manufacturers, engineering services firms, and the transportation equipment industry.

Although physicists are employed in all parts of the country, most work in areas that have universities and large research and development laboratories.

Training, Other Qualifications, and Advancement

A doctoral degree is the usual educational requirement for physicists and astronomers, because most jobs are in research and development or in teaching at large universities or 4-year colleges.

Those having bachelor's or master's degrees in physics are generally qualified to work in an engineering-related area or other scientific fields, to work as technicians, or to assist in setting up laboratories. Some may qualify for applied research jobs in private industry or nonresearch positions in the Federal Government, and a master's degree often suffices for teaching jobs in 2-year colleges. Astronomy bachelor's degree holders often enter a field unrelated to astronomy, but they are also qualified to work in planetariums running science shows or to assist astronomers doing research. (See statements on engineers, geologists and geophysicists, computer programmers, and computer scientists and systems analysts elsewhere in the *Handbook.*)

About 750 colleges and universities offer a bachelor's degree in physics. The undergraduate program provides a broad background in the natural sciences and mathematics. Typical physics courses include mechanics, electromagnetism, optics, thermodynamics, atomic physics, and quantum mechanics.

About 180 colleges and universities have physics departments which offer Ph.D. degrees 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 their bachelor's degree.

About 72 universities offer the Ph.D. degree in astronomy, either through an astronomy department, a physics department, or a combined physics/astronomy department. Applicants to astronomy doctoral programs face keen competition for available slots. Those planning a career in astronomy should have a very strong physics background—in fact, an undergraduate degree in physics is excellent preparation, followed by a Ph.D. in astronomy.

Mathematical ability, computer skills, an inquisitive mind, imagination, and the ability to work independently 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, computer technology, and current affairs. Good oral and written communication skills are also becoming increasingly important.

Most Ph.D. physics and astronomy graduates choose to take a postdoctoral position, which is helpful for those who want to continue research in their specialty and for those who plan a career teaching at the university level. Beginning physicists, especially those without a Ph.D., often do routine work under the close supervision of more senior scientists. After some experience, they are assigned more complex tasks and given more independence. Physicists who develop new products or processes sometimes form their own companies or join new firms to exploit their own ideas.

Job Outlook

A large proportion of physicists and astronomers are employed on research projects, many of which, in the past, were defense related. Expected reductions in defense-related research and an expected slowdown in the growth of civilian physics-related research will cause employment of physicists and astronomers to decline through the year 2005. Since the number of doctorates granted in physics is not expected to decrease much from present levels, competition is expected for the kind of research and academic jobs that those with new doctorates in physics have traditionally sought.

Although research and development budgets in private industry will continue to grow, many research laboratories in private industry are expected to reduce basic research, which is where much physics research takes place, in favor of applied research and product and software development. Furthermore, although the number of retiring academic physicists is expected to increase in the late 1990's, it is possible that many of them will not be replaced or will be replaced by faculty in other disciplines.

Persons with only a bachelor's degree in physics are not qualified to enter most physicist jobs. However, many find jobs as high school physics teachers and in engineering, technician, mathematics, and computer- and environment-related occupations. (See the statements on these occupations elsewhere in the *Handbook.*) Also, those with advanced degrees in physics will find their skills transferrable to many other occupations.

Earnings

Starting salaries for physicists averaged about $30,000 a year in 1992 for those with a bachelor's or master's degree, and about $41,000 for those with a doctoral degree, according to the College Placement Council.

The American Institute of Physics reported a median salary of $65,000 in 1992 for its members with Ph.D.'s. Those working in 4-year colleges (9-10 months a year) earned the least—$43,000—while those employed in industry and hospitals earned the most—$71,500 and 78,000, respectively.

Average earnings for physicists in nonsupervisory, supervisory, and managerial positions in the Federal Government in 1993 were $61,956 a year, and for astronomy and space scientists, $65,709.

Related Occupations

The work of physicists and astronomers relates closely to that of other scientific and mathematic occupations such as chemist, geologist, geophysicist, and mathematician. Engineers and engineering and science technicians also use the principles of physics in their work.

Sources of Additional Information

General information on career opportunities in physics is available from:

☞ American Institute of Physics, American Center for Physics, 1 Physics Ellipse, College Park, MD 20740.

☞ American Physical Society, American Center for Physics, 1 Physics Ellipse, College Park, MD 20740.

For a pamphlet containing information on careers in astronomy and on schools offering training in the field, send your request to:

☞ American Astronomical Society, Education Office, University of Texas, Department of Astronomy, Austin, TX 78712-1083.

Drafters

(D.O.T. 001.261-010, -014; 002.261; 003.131, .261 except -010, 281; 005.281; 007.161-010, -014, and -018, .261, and .281; 010.281 except -022; 014.281; 017 except .261-010 and .684; and 726.364-014)

Nature of the Work

Drafters prepare technical drawings used by production and construction workers to build spacecraft, automobiles, industrial machinery and other manufactured products, as well as structures such as office buildings, houses, bridges, and oil and gas pipelines. Their drawings show the technical details of the products and structures from all sides, with exact dimensions, the specific materials to be used, procedures to be followed, and other information needed to carry out the job. Drafters prepare and fill in technical details, using drawings, rough sketches, specifications, and calculations made by engineers, surveyors, architects, and scientists. For example, working from rough sketches, drafters use knowledge of standardized building techniques to draw the details of a structure, or employ knowledge of engineering and manufacturing theory to arrange the parts of a machine and determine the number and kind of fasteners needed. For this, they may use technical handbooks, tables, calculators, and computers.

There are two methods by which drawings are prepared. In the traditional method, drafters sit at drawing boards and use compasses, dividers, protractors, triangles, and other drafting devices to prepare the drawing manually. Drafters also use computer-aided drafting (CAD) systems. They use computer work stations to create the drawing on a video screen. They may print the drawing on paper but also store it electronically so that revisions and/or duplications can be made more easily. These systems also permit drafters to easily prepare many variations of a design.

When CAD systems were first introduced, some thought a new occupation—CAD operator—would result. It is now apparent that a person who produces a technical drawing using CAD is still a drafter, and needs all the knowledge of traditional drafters as well as CAD skills.

Because the cost of CAD systems is dropping rapidly, by the year 2005 it is likely that almost all drafters will use CAD systems regularly. However, manual drafting probably will still be used in certain applications, especially in low-volume firms that produce many one-of-a-kind drawings with little repetition.

Many drafters specialize. *Architectural drafters* draw architectural and structural features of buildings and other structures. They may specialize by the type of structure, such as schools or office buildings, or by material, such as reinforced concrete or stone.

Aeronautical drafters prepare engineering drawings used for the manufacture of aircraft and missiles.

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

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

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

Mechanical drafters draw detailed working diagrams of machinery and mechanical devices, including dimensions, fastening methods, and other engineering information.

Working Conditions

Drafters usually work in offices or rooms with lighting appropriate to their tasks. They often sit at drawing boards or computer terminals for long periods of time doing detailed work, which may cause eyestrain and back discomfort. Drafters who spend the majority of their time using a computer keyboard for CAD work risk repetitive motion injuries, such as carpal tunnel syndrome.

Computer-aided design systems enable drafters to make revisions to designs more easily.

Employment

Drafters held about 314,000 jobs in 1992. Over one-third of all drafters worked in engineering and architectural services, firms that design construction projects or do other engineering work on a contract basis for organizations in other parts of the economy; about one-third worked in durable goods manufacturing industries, such as machinery, electrical equipment, and fabricated metals; and the remainder were mostly employed in the construction, communications, utilities, and personnel supply services industries.

About 11,000 drafters worked in government in 1992, primarily at the State and local level.

Training, Other Qualifications, and Advancement

Employers prefer applicants for drafting positions who have post-high school training in technical institutes, junior and community colleges, or extension divisions of universities. Employers are most interested in applicants who have well-developed drafting and mechanical drawing skills, a solid background in computer-aided design techniques, and courses in mathematics, science, and engineering technology.

Many types of publicly and privately operated schools provide drafting training. The kind and quality of programs can 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 obtained by graduates, instructional facilities and equipment, and faculty qualifications.

Technical institutes offer intensive technical training but less theory and general education than junior and community colleges. Many offer 2-year associate degree programs, which are similar to or part of the programs offered by community colleges or State university systems. 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. Some are 2-year associate degree programs.

Junior and community colleges offer curriculums similar to those in technical institutes but may include more theory and liberal arts. Often there may be little or no difference between technical institute and community college programs. However, courses taken at junior or community colleges are more likely to be accepted for credit at 4-year colleges than those at technical institutes. After completing the 2-year program, some graduates qualify for jobs as drafters while others continue their education in a related field at 4-year colleges.

Four-year colleges usually do not offer drafting training, but college courses in engineering, architecture, and mathematics are useful for obtaining a job as a drafter.

Area vocational-technical schools are 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 may be obtained in the Armed Forces in technical areas which can be applied in civilian drafting jobs. Some additional training may be needed, depending on the military skills acquired and the kind of job, but often this is gained on the job.

Those planning careers in drafting should be able to draw freehand three-dimensional objects and do 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 communication skills because they work closely with engineers, surveyors, architects, and other workers.

In 1992, the American Design Drafting Association (ADDA) established a certification program for drafters. Although drafters are not required to be certified, certification demonstrates to employers that nationally recognized standards have been met. Individuals who wish to become certified must pass the Drafter Certification Test, which is administered periodically at ADDA-authorized test sites. Applicants are tested on their knowledge and understanding of basic drafting concepts such as geometric construction, working drawings, and architectural terms and standards.

Entry level drafters usually do routine work under close supervision. After gaining experience, they do more difficult work with less supervision and may advance to senior drafter, designer, or supervisor. With appropriate college courses, they may become engineers or architects.

Job Outlook

Employment of drafters is expected to grow more slowly than the average for all occupations through the year 2005. Industrial growth and the increasingly complex design problems associated with new products and processes will increase the demand for drafting services. However, greater use of CAD equipment by architects and engineers, as well as drafters, is expected to offset some of this growth in demand. Although productivity gains from CAD have been relatively modest since CAD use became widespread, CAD technology continues to advance. CAD is expected to become an increasingly powerful tool, simplifying many traditional drafting tasks. Nevertheless, as in other areas, the ease of obtaining computer-generated information stimulates a demand for more information, so there will continue to be growth in the occupation. Individuals who have at least 2 years of training in a technically strong drafting program and who have experience with CAD systems will have the best opportunities. Although growth in employment will create many job openings, most job openings are expected to arise as drafters retire or leave the labor force for other reasons.

Drafters are highly concentrated in industries that are sensitive to cyclical swings in the economy, such as engineering and architectural services and durable goods manufacturing. During recessions, when fewer buildings are designed, drafters may be laid off.

Earnings

Median annual earnings of drafters who worked year round, full time were about $27,400 in 1992; the middle 50 percent earned between $20,600 and $35,100 annually; 10 percent earned more than $43,500; 10 percent earned less than $15,900.

According to a survey of workplaces in 160 metropolitan areas, experienced drafters had median earnings of about $30,200 a year in 1992, with the middle half earning between about $27,100 and $34,000 a year.

Related Occupations

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

Sources of Additional Information

State employment service offices can provide information about job openings for drafters.

Engineering Technicians

(D.O.T. 002.261-014, .262-010; 003 161, .261-010, .362; 005.261; 006.261; 007.161-026 and -030, .167-010, .181 and .267-014; 008.261; 010.261-010 and -026; 011.261-010, -014, -018, and -022, .281, .361; 012.261-014, .267; 013.161; 017.261-010; 019.161-014, .261-018, -022, -026, -030, and -034, .267, .281; 194.381, .382-010; 199.261-014; 726.261-010 and -014; 761.281-014; 828.261-018; and 869.261-026)

Nature of the Work

Engineering technicians use the principles and theories of science, engineering, and mathematics to solve problems in research and development, manufacturing, sales, construction, and customer service. Their jobs are more limited in scope and more practically oriented than those of scientists and engineers. Many engineering technicians assist engineers and scientists, especially in research and development. Others work in production or inspection jobs.

Engineering technicians who work in research and development build or set up equipment, prepare and conduct experiments, calculate or record the results, and help engineers in other ways. Some make prototype versions of newly designed equipment. They also assist in routine design work, often using computer-aided design equipment.

Engineering technicians who work in manufacturing follow the general directions of engineers. They may prepare specifications for materials, devise and run tests to ensure product quality, or study ways to improve manufacturing efficiency. They may also supervise production workers to make sure they follow prescribed procedures.

Civil engineering technicians help civil engineers plan and build highways, buildings, bridges, dams, wastewater treatment systems, and other structures and do related surveys and studies. Some inspect water and wastewater treatment systems to ensure that pollution control requirements are met. Others estimate construction costs and specify materials to be used. (See statement on cost estimators elsewhere in the *Handbook*.)

Electronics engineering technicians help develop, manufacture, and service electronic equipment such as radios, radar, sonar, television, industrial and medical measuring or control devices, navigational equipment, and computers, often using measuring and diagnostic devices to test, adjust, and repair equipment. Workers who only repair electrical and electronic equipment are discussed in several other statements elsewhere in the *Handbook*. Many of these repairers are often called electronics technicians.

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 design and develop machinery, robotics, and other equipment by making sketches and rough layouts. They also 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 in manufacturing departments or work with engineers to eliminate production problems.

Chemical engineering technicians are usually employed in industries producing pharmaceuticals, chemicals, and petroleum products, among others. They help design, install, and test or maintain process equipment or computer control instrumentation, monitor quality control in processing plants, and make needed adjustments.

Working Conditions

Most engineering technicians work regular hours in laboratories, offices, electronics and industrial plants, or construction sites. Some may be exposed to hazards from equipment, chemicals, or toxic materials.

Employment

Engineering technicians held about 695,000 jobs in 1992. About two-fifths worked in manufacturing, mainly in the electrical and electronic machinery and equipment, transportation equipment, industrial machinery equipment, and computer and office equipment industries. Over one-fourth worked in service industries, mostly in engineering or business services companies who do engineering work on contract for government, manufacturing, or other organizations.

In 1992, the Federal Government employed about 59,000 engineering technicians. Major employers were the Departments of Defense, Transportation, Agriculture, and the Interior, the Tennessee Valley Authority, and the National Aeronautics and Space Administration. State governments employed about 30,000 and local governments about 28,000.

Training, Other Qualifications, and Advancement

Although it is possible to qualify for some engineering technician jobs with no formal training, most employers prefer to hire someone

Like engineers, engineering technicians specialize in a specific area, such as mechanics, electronics, or chemicals.

who will require less on-the-job training and supervision. Training is available at technical institutes, junior and community colleges, extension divisions of colleges and universities, public and private vocational-technical schools, and through some technical training programs in the Armed Forces. Persons with college courses in science, engineering, and mathematics may also qualify for some positions but may need additional specialized training and experience.

Many types of publicly and privately operated schools provide technical training. 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 obtained by graduates, instructional facilities and equipment, and faculty qualifications. Graduates of programs accredited by the Accreditation Board of Engineering and Technology (ABET) are generally recognized to have achieved a minimum level of competence in the mathematics, science, and technical courses required for this occupation.

Technical institutes offer intensive technical training but less theory and general education than junior and community colleges. Many offer 2-year associate degree programs, and are similar to or are part of a community college or are part of State university systems. 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. Some are 2-year associate degree programs.

Junior and community colleges offer curriculums similar to those in technical institutes but may include more theory and liberal arts. Often there may be little or no difference between technical institute and community college programs, 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 many of the courses they have taken if they choose to transfer to a 4-year engineering program.

Four-year colleges 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 are often hired to work as applied engineers, not technicians.

Area vocational-technical schools 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. Some additional training may be needed, depending on the military skills acquired and the kind of job, but often this is gained on the job. Some correspondence schools also offer training for engineering technicians.

Prospective engineering technicians should take as many high school science and math courses as possible. Engineering technicians need an aptitude for mathematics and science. For design work, creativity also is desirable. They should be able to work well with others since they are often part of a team of engineers and other technicians. Those in sales and service should be able to work independently and deal effectively with customers.

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

Job Outlook

Well-qualified engineering technicians should experience good employment opportunities through the year 2005. Employment is expected to increase as fast as the average for all occupations due to expected continued growth in the output of technical products. Competitive pressures and advancing technology will force companies to improve and update manufacturing facilities and product designs more rapidly than in the past. However, like engineers, employment of engineering technicians is influenced by local and national economic conditions. The employment outlook also varies with the area of specialization and industry. Some types of engineering technicians, such as civil engineering and aeronautical engineering technicians, experience greater cyclical fluctuations than others. Technicians whose jobs are defense related may experience fewer opportunities because of defense cutbacks.

In addition to growth, nearly as many job openings will be to replace technicians who retire or leave the labor force for other reasons.

Earnings

According to a survey of workplaces in 160 metropolitan areas, engineering technicians at the most junior level had median earnings of about $20,900 in 1992, with the middle half earning between about $18,900 and $22,600 a year. Engineering technicians with more experience and the ability to work with little supervision had median earnings of about $28,800, and those in supervisory or senior level positions earned about $41,400.

In the Federal Government, engineering technicians could start at about $14,600, $16,400, or $18,300 in 1993, depending on their education and experience. In 1993, the average annual salary for engineering technicians in supervisory, nonsupervisory, and management positions in the Federal Government was $37,337; for electronics technicians, $42,436; and for industrial engineering technicians, $38,006.

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, broadcast technicians, and health technologists and technicians.

Sources of Additional Information

A number of engineering technology-related organizations provide information on engineering technician and technology careers. JETS-Guidance, at 1420 King St., Suite 405, Alexandria, VA 22314, serves as a central distribution point for information from most of these organizations. Enclose a self-addressed, business-size envelope with four first class stamps to obtain a sampling of materials available.

For information on chemical engineering technicians, contact:

☞ American Institute of Chemical Engineers, Attention: Mr. Chung Lam, 345 East 47th St., New York, NY 10017.

Science Technicians

(List of D.O.T. codes available on request from the Chief, Division of Occupational Outlook, Bureau of Labor Statistics, Washington, DC 20212.)

Nature of the Work

Science technicians use the principles and theories of science and mathematics to solve problems in research and development and to investigate, invent, and help improve products. Their jobs are more practically oriented than those of scientists.

In recent years, laboratory instrumentation and procedures have become more complex, changing the work of science technicians in research and development. The increasing use of robotics to perform many routine tasks formerly done by technicians has freed technicians to operate other, more sophisticated laboratory equipment. Science technicians make extensive use of computers, computer-interfaced equipment, robotics, and high-technology industrial applications such as biological engineering.

Technicians set up, operate, and maintain laboratory instruments, monitor experiments, calculate and record results, and often develop conclusions. Those who work in production test products for proper proportions of ingredients or for strength and durability.

Agricultural technicians work with agricultural scientists in food and fiber 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.

Biological technicians work with biologists, studying living organisms. They may assist scientists who conduct medical research, helping to find a cure for cancer or AIDS, for example, or they may help conduct pharmaceutical research. Biological technicians also analyze organic substances such as blood, food, and drugs; some examine evidence in criminal investigations. 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 these techniques in product development.

Chemical technicians work with chemists and chemical engineers, developing and using chemicals and related products and equipment. Most do research and development, testing, or other laboratory work. For example, they might test packaging for design, materials, and environmental acceptability; assemble and operate new equipment to develop new products; monitor product quality; or develop new production techniques. Some chemical technicians collect and analyze samples of air and water to monitor pollution levels. Those who focus on basic research might produce compounds through complex organic synthesis.

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.

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

Other science technicians collect weather information or assist oceanographers.

Working Conditions

Science technicians work under a wide variety of conditions. Many work indoors, usually in laboratories, and have regular hours. Some occasionally work irregular hours to monitor experiments that can't be completed during regular working hours. Others, such as agricultural and petroleum technicians, perform much of their work outdoors, sometimes in remote locations, and some may be exposed to hazardous conditions. Chemical technicians sometimes work with toxic chemicals; nuclear technicians may be exposed to radiation; and biological technicians sometimes work with disease-causing organisms or radioactive agents. However, there is little risk if proper safety procedures are followed.

Employment

Science technicians held about 244,000 jobs in 1992. Nearly 40 percent worked in manufacturing, mostly in the chemical industry, but also in the petroleum refining and food processing industries. Almost 20 percent worked in colleges and universities and another 12 percent worked in research and testing services.

In 1992, the Federal Government employed about 19,000 science technicians, mostly in the Departments of Defense, Agriculture, Interior, and Commerce.

Training, Other Qualifications, and Advancement

There are several ways to qualify for a job as a science technician. Most employers prefer applicants who have at least 2 years of specialized training. Many junior 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 generally offer technician training but provide less theory and general education than junior or community colleges. The length of programs at technical institutes

Employers seek well trained individuals with good laboratory skills for science technician positions.

varies, although 2-year associate degree programs are common. Some of these schools offer cooperative-education programs, allowing students the opportunity to work at a local company while attending classes in alternate terms. Many science technicians have a bachelor's degree in science or mathematics, or have had science and math courses in 4-year colleges. Some people with bachelor's degrees in a physical or life science become science technicians because they can't find or don't want a job as a scientist or because employers couldn't find properly trained technicians with less education. In some cases, they may be able to move into jobs as scientists, managers, or technical sales workers.

Some companies offer formal or on-the-job training for science technicians. Technicians also may qualify for their jobs with some types of Armed Forces training.

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's or bachelor's program, should be laboratory oriented, with an emphasis on "bench" skills. Because computers and computer-interfaced equipment are often used in research and development laboratories, technicians should have strong computer skills. Communication skills are important, and technicians should be able to work well with others since technicians often are part of a team.

Technicians usually begin work as trainees in routine positions under the direct supervision of a scientist or 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 much shorter period of on-the-job training. As they gain experience, they take on more responsibility and carry out assignments under only general supervision. Some eventually become supervisors.

Job Outlook

Employment of science technicians is expected to increase about as fast as the average for all occupations through the year 2005. Continued growth of scientific research and development and the production of technical products should spur demand for all science technicians. Advances in biotechnology will increase the need for biological technicians in particular. However, growth of job openings will be moderated somewhat by an expected slowdown in overall employment growth in the chemical industry, where many chemical technicians are employed.

Nevertheless, job opportunities are expected to be very good for graduates of science technician training programs who are well-trained on the equipment currently in use in industrial and government laboratories As the instrumentation and techniques used in industrial research and development laboratories becomes more complex, employers are seeking well trained individuals with highly developed technical and communication skills.

Despite the projected growth, most job openings will arise from the need to replace technicians who retire or leave the labor force for other reasons.

Earnings

Median annual earnings of science technicians were about $25,300 in 1992; the middle 50 percent earned between $18,700 and $33,400. Ten percent earned less than $14,400, and 10 percent earned over $42,400. At all income levels, chemical technicians earned significantly more than biological technicians.

In the Federal Government in 1993, science technicians could start at $14,600, $16,390, or $18,340, depending on their education and experience. The average annual salary for biological science technicians in nonsupervisory, supervisory, and managerial positions employed by the Federal Government in 1993 was $24,828; for mathematical technicians, $29,239; for physical science technicians, $31,484; for geodetic technicians, $37,282; for hydrologic technicians, $28,635; and for meteorologic technicians, $36,408.

Related Occupations

Other technicians who apply scientific principles at a level usually taught in 2-year associate degree programs include engineering technicians, broadcast technicians, drafters, and health technologists and technicians. Some of the work of agricultural and biological technicians is related to that in agriculture and forestry occupations.

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.

Surveyors

(D.O.T. 018 except .167-022, and 024.061-014)

Nature of the Work

This statement covers three groups of workers who measure and map the earth's surface. *Land surveyors* establish official land, air space, and water boundaries. They write descriptions of land for deeds, leases, and other legal documents; define air space for airports; and measure construction and mineral sites. They are assisted by *survey technicians*, who operate surveying instruments and collect information. *Mapping scientists* and other surveyors collect geographic information and prepare maps and charts of large areas.

Land surveyors manage one or more survey parties that measure distances, directions, and angles between points and elevations of points, lines, and contours on the earth's surface. They plan the fieldwork, select known survey reference points, and determine the precise location of all important features of the survey area. They research legal records and look for evidence of previous boundaries. They record the results of the survey, verify the accuracy of data, and prepare plats, maps, and reports. Surveyors who establish official boundaries must be licensed by the State in which they work.

The information needed by the land surveyor is gathered by a survey party. A typical survey party is made up of a party chief and several survey technicians and helpers. The party chief, who may be either a land surveyor or a senior survey technician, leads the day-to-day work activities. The party chief is assisted by survey technicians, who adjust and operate surveying instruments such as the theodolite (used to measure horizontal and vertical angles) and electronic distance-measuring equipment. Survey technicians or helpers position and hold the vertical rods or targets that the theodolite operator sights on to measure angles, distances, or elevations. They may also hold measuring tapes and chains if electronic distance-measuring equipment is not used. Survey technicians also compile notes, make sketches, and enter the data obtained from these instruments into computers. Some survey parties include laborers or helpers to clear brush from sight lines, drive stakes, carry equipment, and perform other less skilled duties.

New technology is changing the nature of the work of surveyors and survey technicians. For larger surveying projects, surveyors are increasingly using the Global Positioning System (GPS), a satellite system which precisely locates points on the earth using radio signals transmitted by satellites. To use it, a surveyor places a satellite receiver—about the size of a backpack—on a desired point. The receiver collects information from several differently positioned satellites at once to locate its precise position. Two receivers are generally operated simultaneously, one at a known point and the other at the unknown point. The receiver can also be placed in a vehicle to trace out road systems, or for other uses. As the cost of the receivers falls, much more surveying work will be done by GPS.

Mapping scientists, like land surveyors, measure, map, and chart the earth's surface but generally cover much larger areas. Unlike land surveyors, however, mapping scientists work mainly in offices and may seldom or never visit the sites they are mapping. Mapping scientists include workers in several occupations. *Cartographers* prepare maps using information provided by geodetic surveys, aerial photographs, and satellite data. *Photogrammetrists* prepare maps and drawings by measuring and interpreting aerial photographs, using analytical processes and mathematical formulas. Photogrammetrists make detailed maps of areas that are inaccessible or difficult to survey by other methods. *Map editors* develop and verify map contents from aerial photographs and other reference sources.

Some surveyors perform specialized functions which are closer to mapping science than traditional surveying. *Geodetic surveyors* use high-accuracy techniques, including satellite observations, to measure large areas of the earth's surface. *Geophysical prospecting surveyors* mark sites for subsurface exploration, usually petroleum related. *Marine surveyors* survey harbors, rivers, and other bodies of water to determine shorelines, topography of the bottom, water depth, and other features.

The work of mapping scientists is also changing due to new technologies. The technologies include the GPS, Geographic Information Systems (GIS)—which are computerized data banks of spatial data—new earth resources data satellites, and improved aerial photography. From the older specialties of photogrammetrist or cartographer, a new type of mapping scientist is emerging. The *geographic information specialist* combines the functions of mapping science and surveying into a broader field concerned with the collection and analysis of geographic spatial information.

Working Conditions

Surveyors usually work an 8-hour day, 5 days a week, and spend a lot of their time outdoors. Sometimes they work longer hours during the summer, when weather and light conditions are most suitable for fieldwork.

Land surveyors and technicians do active and sometimes strenuous work. They often stand for long periods, walk long distances, and climb hills with heavy packs of instruments and equipment. They also are exposed to all types of weather. Occasionally, they may commute long distances, stay overnight, or even temporarily relocate near a survey site.

Surveyors also spend considerable time in offices, planning surveys, analyzing data, and preparing reports and maps. Most computations and map drafting are done at a computer. Mapping scientists spend almost all their time in offices.

Employment

Surveyors held about 99,000 jobs in 1992. Engineering, architectural, and surveying firms employed nearly three-fifths of all surveyors. Federal, State, and local government agencies employed an additional one-fourth. Major Federal Government employers are the U.S. Geological Survey, the Bureau of Land Management, the Army Corps of Engineers, the Forest Service, the National Oceanic and Atmospheric Administration, and the Defense Mapping Agency. 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 public utilities also employ surveyors. About 10,000 surveyors were self-employed.

Land surveyors measure distances and elevations along the earth's surface.

Training, Other Qualifications, and Advancement

Most persons prepare to be a licensed surveyor by combining postsecondary school courses in surveying with extensive on-the-job training. About 25 universities offer 4-year programs leading to a BS 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.

High school students interested in surveying should take courses in algebra, geometry, trigonometry, drafting, mechanical drawing, and computer science.

All 50 States license land surveyors. For licensure, most State licensing boards require that individuals pass two written examinations, one prepared by the State and one given by the National Council of Examiners for Engineering and Surveying. In addition, they must meet varying standards of formal education and work experience in the field. In the past, many surveyors started as members of survey crews and worked their way up to licensed surveyor with little formal training in surveying. However, due to advancing technology and an increase in licensing standards, more formal education is now required. Most States at the present time require some formal post-high school education courses and 5 to 12 years of surveying experience to gain licensure. However, requirements vary among the States. Generally, the quickest route is a combination of 4 years of college, 2 to 4 years of experience (a few States do not require any), 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.

High school graduates with no formal training in surveying usually start as a helper. Beginners with postsecondary school training in surveying can generally start as technicians. 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 finally, in some cases, to licensed surveyor (depending on State licensing requirements).

The American Congress on Surveying and Mapping has a voluntary certification program for survey technicians. Technicians are certified at four levels that require progressive amounts of experience; technicians who qualify are certified at a higher level after passing a written examination. Although not required for State licensure, many employers require certification for promotion to more responsible positions.

Cartographers and photogrammetrists usually have a bachelor's degree in engineering or a physical science, although it is possible to enter these jobs through experience as a photogrammetric or cartographic technician. Most cartographic and photogrammetry technicians have had some specialized postsecondary school training. With the development of Geographic Information Systems, cartographers, photogrammetrists, and other mapping scientists now need more education and experience in the use of computers than in the past.

The American Society for Photogrammetry and Remote Sensing has voluntary certification programs for photogrammetrists and mapping scientists. To qualify for these professional distinctions, individuals must meet work experience standards and pass an oral or written examination.

Surveyors should have the ability to visualize objects, distances, sizes, and other abstract forms and to work precisely and accurately because mistakes can be very costly. Surveying is a cooperative process, so good interpersonal skills and the ability to work as part of a team are important. Leadership qualities are important for party chief and other supervisory positions.

Members of a survey party must be in good physical condition to work outdoors and carry equipment over difficult terrain. They also need good eyesight, coordination, and hearing to communicate by hand or voice signals.

Job Outlook

Employment of surveyors is expected to grow more slowly than the average for all occupations through the year 2005. In addition to openings arising from growth in demand for surveyors, many will result from the need to replace those who transfer to other occupations or leave the labor force.

Growth in construction through the year 2005 should create jobs for surveyors who lay out streets, shopping centers, housing developments, factories, office buildings, and recreation areas. Road and highway construction and improvement also should create new surveying positions. However, employment may fluctuate from year to year along with construction activity.

Some growth in employment of mapping scientists and other surveyors may occur in private firms; little or no growth is expected in the Federal Government.

As a result of trends towards more complex technology, upgraded licensing requirements, and the increased demand for geographic spatial data (as opposed to traditional surveying services), opportunities will be best for surveyors and mapping scientists who have at least a bachelor's degree. New technology such as GPS and GIS may increase productivity for larger projects and may enhance employment opportunities for surveyors and survey technicians who have the educational background to use it, but limit opportunities for those with less education.

Earnings

In 1992, the median annual earnings for surveyors were about $26,800. The middle 50 percent earned between about $22,600 and $37,000 a year.

The median annual earnings for survey technicians were about $23,700 a year in 1992. The middle 50 percent earned between $17,900 and $31,700 a year; 10 percent earned less than $14,500 a year; 10 percent earned more than $38,500 a year.

In 1993, The Federal Government hired high school graduates with little or no training or experience at salaries or about $13,400 annually for entry level jobs on survey crews. Those with 1 year of related postsecondary training earned about $14,600 a year. Those with an associate degree that included courses in surveying generally started as instrument assistants with an annual salary of about $16,400. In 1993, persons starting as land surveyors or cartographers with the Federal Government earned about $18,300 or $22,700 a year, depending on their qualifications. The average annual salary for Federal land surveyors in 1993 was about $41,000, for cartographers, about $44,000, and for geodesists, about $47,600. The average annual salary for Federal surveying technicians was about $24,000, for cartographic technicians, about $30,100, and for geodetic technicians, about $37,300.

Related Occupations

Surveying is related to the work of civil engineers and architects, since an accurate survey is the first step in a construction project. Mapping science and geodetic surveying are related to the work of geologists and geophysicists, who study the earth's internal composition, surface, and atmosphere. Mapping science is also related to the work of geographers and urban planners, who study how the earth's surface is used.

Sources of Additional Information

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

☞ American Congress on Surveying and Mapping, 5410 Grosvenor Lane, Bethesda, MD 20814-2122.

General information on careers in photogrammetry is available from:

☞ American Society for Photogrammetry and Remote Sensing, 5410 Grosvenor Lane, Suite 200, Bethesda, MD 20814.

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