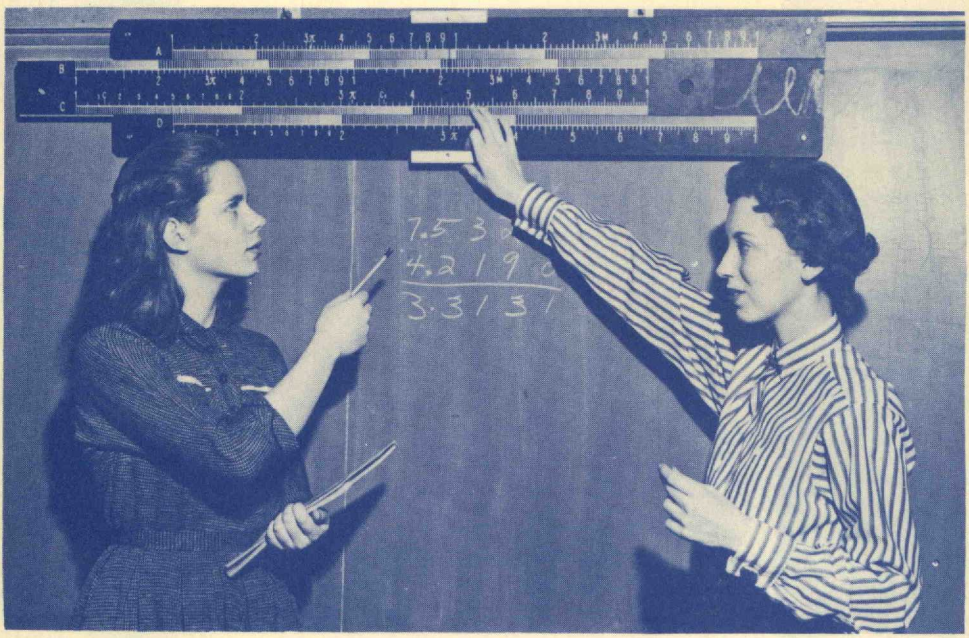
Employment Opportunities for

WOMEN MATHEMATICIANS and STATISTICIANS



WOMEN'S BUREAU BULLETIN No. 262

U. S. DEPARTMENT OF LABOR
James P. Mitchell, Secretary
WOMEN'S BUREAU
Mrs. Alice K. Leopold, Director

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Women's Bureau Bulletin No. 262

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FOREWORD

This review of the current demand for women in mathematics and statistics, with its estimate of the future outlook, has been prepared with the help of many individuals, organizations, colleges, and employers.

Special thanks are due to Dr. Howard Meyerhoff, Executive Director, Scientific Manpower Commission, whose interest in the subject prompted us to undertake to bring up to date our information in this field and whose cooperation in making data on women available from the Commission's surveys made our task easier. In a similar way we were aided by the cooperation of Dr. Alan Waterman, Director of the National Science Foundation, and of Dr. Leon W. Cohen, Dr. Howard F. Foncannon, and Miss Eleanor Rings of his staff, who made available preliminary tabulations on women from the Foundation's 1954–55 survey of mathematicians.

The bulletin, which supersedes an earlier Women's Bureau publication on the same subject, was prepared and written by Shirley Montag under the supervision of Marguerite W. Zapoleon.

We hope that it will help teachers, counselors, and others who assist young women—and mature women, too—in their occupational planning and that it will have an effect on what appears to be a serious national shortage.

Alice K. Leopold,
Director, Women's Bureau.

Acknowledgments for Illustrations

For the illustrations, some of which were taken especially for this bulletin, the Women's Bureau is indebted to the following:

Anacostia High School, Washington, D. C. (fig. 6);

Bennington College (fig. 1);

Goucher College (cover picture and fig. 3);

International Business Machines Corporation (fig. 1);

National Bureau of Standards (fig. 4);

Radcliffe College (fig. 5);

Royal Neighbors of America (fig. 2);

University of Michigan (fig. 8);

Westinghouse Electric Corporation (fig. 7).

Two mathematics students test some calculations in trigonometry on the demonstration slide rule in their classroom (cover picture).

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FINDINGS

On the basis of the analysis of current information on mathematicians and statisticians presented in this bulletin, the Women's Bureau finds that:

1. More women mathematicians and statisticians are currently needed, and interesting jobs await those trained at the bachelor's degree as well as graduate levels.
2. Young women in high school should be encouraged to try mathematics and if they have the qualifications for success in mathematics and statistics should be encouraged to prepare for these fields; anticipated shortages make the long-run outlook exceptionally favorable.
3. Young women who combine the qualifications for teaching with ability in mathematics should be encouraged to teach, at least part time, since in teaching they can magnify their contribution to the Nation's progress.
4. Mature college women who have majored in mathematics, possess the personal qualifications for teaching, and have time available to work, should prepare themselves through refresher courses in mathematics and education for teaching positions, if they live in one of the many communities experiencing or anticipating a shortage of mathematics teachers.

Employment Opportunities for

WOMEN MATHEMATICIANS AND STATISTICIANS

"Never before in the history of the world have there been such wonderful opportunities for mathematics and mathematicians." This statement was made by a representative of a manufacturer of electronic calculators at the first conference on training personnel for the computing-machine field, held in 1954. "In a few years," he

Figure 1.—A programer whose college major was mathematics operates a magnetic drum data-processing machine.

said, his company will have "as many opportunities for mathematicians with advanced training as the whole country could use a few years ago" (*5*).* And a Women's Bureau comparison of information from selected industrial firms in 1946–47 and in 1953 indicated that the number of women employed as mathematicians in industry had doubled between the two dates.

Evidence presented in this report backs the conclusion that mathematics is a flourishing field—and that its growth has made it an opportunity-filled area for women.

*Numbers in parentheses indicate references listed in the appendix. (See p. 36.)

Who ARE Mathematicians and Statisticians? **

Professional mathematicians work in higher mathematics. The pure mathematician works with mathematical laws and principles, pursuing his "self-motivated progress along dimly discernible paths of growth toward intellectually satisfying goals" (*12*). The applied mathematician directs the results obtained by his colleagues in pure mathematics to problems in business, government, industry, engineering, and the natural and social sciences. The utility of mathematics as a tool in other fields of endeavor has given applied mathematics new emphasis. This is the area in which opportunities have developed most rapidly since the Women's Bureau published its first report on the Outlook for Women in Mathematics and Statistics nearly 10 years ago (*22*). Programers who set up the problems for the new electronic calculators work in applied mathematics.

Statistics is described as a branch of applied mathematics (*6*). Mathematical statisticians who investigate and develop statistical theory and method are highly trained mathematicians. Other statisticians use statistics as a tool to further an ever-increasing range of activity in economics, sociology, finance, public health, the physical and biological sciences, personnel administration, advertising, opinion polling, education, and certain manufacturing industries like aircraft. Especially on higher levels, the same individual may function as both mathematical and applied statistician.

Formal professional standards are most specific for actuaries. Members of this rapidly growing profession apply the theory of probability to keep insurance plans, including employee-benefit and workmen's compensation plans, on a financially sound basis.

Assistants to professional mathematicians in these fields are usually college-trained workers, variously known as mathematical aids or assistants, statistical technicians, research assistants or clerks, or statistical machine operators; they are included in this report. Although their primary preparation has likewise been in mathematics, engineers and engineering aids are discussed in a separate bulletin on engineering (Women's Bureau Bulletin No. 254).

Teachers of mathematics, at the college and high-school levels, needed now more than ever to instruct future mathematicians and scientists, are of course included in this report.

Number of Women Mathematicians and Statisticians

There were about 20,000 mathematicians in the United States in 1955, according to a preliminary estimate of the National Science Foundation. Possibly 1 out of 8 or 10 were women. This includes

**See appendix for Dictionary of Occupational Titles definitions.

mathematical statisticians, but not other statisticians of whom there were possibly 20,000, including some 7,000 women. The Bureau of Labor Statistics uses an estimate ranging from 10,000 to 20,000. Among the 1,600 to 1,800 professional actuaries, there were fewer than 100 women. The National Science Foundation estimate also does not include approximately 29,000 high-school teachers who were instructing in mathematics full time and another 35,000 who were instructing in mathematics and other subjects as well, according to estimates of the United States Office of Education. Roughly 1 out of 3 of these high-school mathematics teachers were women.

Figure 2.—A woman actuary in an insurance company discusses calculations with an assistant actuary and an actuarial assistant.

Characteristics of Surveyed Groups

The characteristics of women mathematicians included in the National Register of Scientific and Technical Personnel in 1954–55 who reported their employment offer a clue to the specializations and functions of an experienced group of women mathematicians. This registered group are more highly trained than many of the younger women mathematicians who have not had as much opportunity to obtain a higher degree, and who are believed to be markedly underrepresented in the Register, which distributed its questionnaires for registration through professional societies. The median age of the

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women included in the Register was 40 years, and 8 out of 10 had received either the master's or the doctoral degree. (See table 1.)

Table 1.—Education of employed women mathematicians in the National Register of Scientific and Technical Personnel, 1954–55

Educational level	Number	Percent
Total reporting both employment and level of education	449	100. 0
Doctor's degree	165	36. 7
Master's degree	197	43. 9
Bachelor's degree	86	19. 2
Less than bachelor's degree	1	0. 2

Source: National Science Foundation (preliminary unpublished data).

Four out of ten of these women mathematicians reported themselves as general mathematicians (see table 2), most of whom teach undergraduate college mathematics. Roughly 1 out of 10 women mathematicians were in each of the following specialties: analysis; applied mathematics; statistics, probability, and stochastic processes; and algebra and number theory, with a somewhat smaller proportion in geometry and topology. The largest group among the women employed in private industry who reported their specializations were those in numerical analysis, classified under applied mathematics in table 2. This was the only group of specialists among women mathematicians in which the employment in industry was higher than it was in educational institutions. Algebra and numerical analysis provide important theoretical background for programing in electronic calculating.

Table 2.—Specialties of employed women mathematicians in the National Register of Scientific and Technical Personnel, 1954–55

Specialty	Number	Percent
Total reporting employment and specialty	471	100. 0
General mathematics	191	40. 6
Analysis	48	10. 2
Applied mathematics	48	10. 2
Statistics, probability, and stochastic processes	47	9. 9
Algebra and number theory	46	9. 8
Geometry and topology	32	6. 8
Other mathematical specialties	59	12. 5

Source: National Science Foundation (preliminary unpublished data).

The close relationship of mathematicians to physical scientists and engineers is indicated in an earlier survey in which mathematicians reported their second interests most often in physics, electronics, or engineering (*19*). Secondary-school mathematics teachers, too, are often expected to add general science to their schedule, with social studies the next most likely assignment (*14*).

Women statisticians covered in a 1952 survey of social scientists were similar to the women mathematicians reported in the Register in age, but different in educational level. Their median age was about the same, 41 years, but a much lower proportion of the statisticians had the doctoral degree and a much higher proportion had the bachelor's degree only. (Compare tables 1 and 3.)

Table 3.—Education of 177 women statisticians, 1952

Educational level	Number	Percent
Total reporting level of education	177	100.0
Doctor's degree	17	9.6
Master's degree	82	46.3
Bachelor's degree	72	40.7
Less than bachelor's degree	6	3.4

Source: U. S. Department of Labor, Bureau of Labor Statistics, and the U. S. Department of Defense (*21*)

Specializations of women statisticians were not reported separately in the study, but among men and women combined, there were almost no generalists and by far the leading specialty was methodological techniques, in which almost 60 percent were engaged. Business and management, economics and economic theory, and sociology and the social sciences followed, in that order. Only 4 percent worked in the physical sciences. Since the questionnaire mailing list used in this survey was compiled from societies in the social sciences and the humanities, including the American Statistical Association, however, there is probably a marked underrepresentation of physical scientists. A survey made in 1948, with a list compiled primarily from *American Men of Science*, found biology and psychology the most frequent second fields of statisticians, after statistics (*19*). A 1950 estimate set the number of public health statisticians in the country at 400, or about 2 percent of all statisticians (*1*).

Demand for Women Mathematicians and Statisticians in 1955

A woman mathematician employed as a consultant at the United States Bureau of Standards, and described by her male colleagues as one of the outstanding workers in her field, is among the many who report that more than formerly women are finding jobs on all levels and in all areas of mathematics. This contrasts with the traditional pattern of most women mathematicians as teachers, most of the remainder in lowest level positions, and only a few at high levels. Women mathematicians may not be as much sought as they were during the war, when every mathematics major had her choice of many jobs—one woman's college, for instance, reported a choice of 25 or more jobs in industry and government for each mathematics major (*13*). However, the demand exceeds the supply and is growing. The general impression which might be formed from a superficial survey of employment literature is that, until recently, many women with the B. A., or even the M. A., in mathematics did routine work only, although some had opportunity for varied and interesting assignments. The advent of the electronic calculators, for which programing is not routine, has opened a new field for B. A. mathematicians, although workers with advanced degrees are preferred where available. It is a fact that many industrial laboratories employ only women for their computing groups; others employ a high percentage of women. In one instance, for example, 67 percent of the programing staff are women—many of them with only a bachelor's degree (*3*).

The diversity of job possibilities among which the woman graduated with a bachelor's degree in mathematics today may choose is indeed impressive. Recent surveys verify the fact that a very high proportion of women with mathematics as a major are utilizing their mathematics training on their first jobs.

Of the women graduated as mathematics majors by nine eastern women's colleges in 1954 or 1955, nearly 5 out of 7 were employed after graduation in work connected with mathematics. Placement directors report that the others were not employed in mathematics as a matter of preference rather than lack of opportunity. The largest number of these 53 employed graduates were teaching mathematics, or were working as actuarial trainees or as engineering aids. Five were computers and two were programers. Other positions held included those of draftsman, technical writer or editor, market researcher, research assistant, statistical analyst, utilities technician, bank trainee, and trainee in biostatistics.

The number of business and teaching positions among these recent graduates suggests that many of the mathematics majors reported in a National Science Foundation survey of 1951 college graduates employed in 1952 in business and commerce and in education were probably utilizing their mathematics training directly. Table 4 shows that 1 out of 3 of the women graduated with a bachelor's degree in mathematics in 1951 who reported their employment specialization in 1952 were working in mathematics, science, or engineering. Another 1 out of 3 were in educational work and about 1 out of 5 were in business and commerce.

Table 4.—Employment specialization in 1952 of women graduated with a bachelor's degree in mathematics in 1951

Employment specialization	Number	Percent
Total reporting employment specialization	178	100. 0
Education	64	35. 9
Mathematics	40	22. 5
Business and commerce	37	20. 8
Natural science, except mathematics	11	6. 2
Engineering	7	3. 9
All other fields	19	10. 7

Source: U. S. National Science Foundation. Education and Employment Specialization in 1952 of June 1951 College Graduates. 1955.

Women mathematicians are usually welcomed to higher level positions, too, but it is reported that their qualifications must be much better than those of the available men. The demand is such, however, that there frequently are no men available. There are even openings for which there are no women applicants with required qualifications. In statistics it is said that failure to realize or accept opportunities awaiting them, rather than discrimination, accounts for the comparatively small number of women doing professional statistical work (*11*). Less than 2 percent of the men and women statisticians covered in a 1952 survey were unemployed (*21*).

Unlike mathematicians, statisticians find their employment opportunities most numerous in private industry and government. Only 1 of 5 covered in the 1952 survey was working in an educational institution (*21*). And many of those employed by educational institutions were in research rather than in teaching. Among statisticians, research, operational, and administrative work is more common than teaching. The largest demand for women mathematicians, as indicated by the numbers employed, is still in educational institutions, although private industry, government, and other avenues of employment are channeling off an increasing number of new graduates each year, especially at the bachelor's level. Seven out of 10 of the women mathematicians in the National Register of Scientific and Technical Personnel in 1954–55 who reported their employment—an experienced, highly trained group as noted before—were working in educational institutions, most of them in colleges and universities. (See table 5.)

Table 5.—Type of employer of women mathematicians in the National Register of Scientific and Technical Personnel, 1954–55

Type of employer	Number	Percent
Total reporting employment	439	100. 0
Colleges and universities	281	64. 0
Other educational institutions	31	7. 1
Private industry	76	17. 3
Federal Government	40	9. 1
State or local government	1	. 2
Nonprofit foundations or organizations	10	2. 3

Source: National Science Foundation (preliminary unpublished data).

In educational institutions

Teachers of mathematics are needed to instruct not only future mathematicians but also engineers, scientists, statisticians, and the many who use mathematics in their daily work. Statistics on mathematics teachers from the census of 1950 showed about 5,600 college professors and instructors of mathematics, including about 1,100 women. This was a smaller number than the 1,700 women estimated by the Women's Bureau to be college teachers of mathematics in 1947 (*22*).

Statistics from these two sources are not exactly comparable, but evidence of a decline in the proportion of women mathematicians who are teaching mathematics in colleges is indicated by a comparison of the numbers in the 1954–55 and 1951 National Scientific Register. Although broader coverage was achieved in 1954–55 and the two groups should not be compared exactly, a considerably smaller proportion of the women mathematicians in the National Register of Scientific and Technical Personnel in 1955 were teaching as compared with those reached by the National Scientific Register in 1951 (*25*). The proportions of all registered mathematicians, men and women, in college teaching also declined markedly between 1951 and 1954–55, as demands for their services increased in industry and government.

The need for a higher degree in this type of work is reflected in the educational level of the registered women mathematicians who were teaching in 1954–55. Only 5 percent were without a graduate degree; the others were divided about equally between those with a master's and those with a doctor's degree.

The amount of research being conducted at colleges and universities has resulted in increasing the number of nonteaching opportunities for mathematicians on college campuses. In colleges and universities in

1954–55, for every six women mathematicians working as teachers there was one engaged primarily in research. It has also increased the opportunities for teacher participation part time in large research projects. In addition, there were widely scattered opportunities for women in colleges to do technical writing, design, consulting, or administrative work in mathematics.

Figure 3.—While her mathematics professor supervises, a college junior majoring in mathematics-chemistry learns how to save time by using the calculator on a problem in intermediate calculus.

The demand for high-school teachers of mathematics is large and growing. Reports from 29 States, the District of Columbia, Hawaii, and Puerto Rico to the National Education Association Research Division showed that in 1954–55 only 1,047 persons were graduated in those areas with qualifications for certificates as high-school teachers of mathematics and that of these roughly one-third did not enter the teaching profession after graduation. Positions that were filled September 1955 by new teachers of mathematics in these areas, on the other hand, numbered 1,919 (*14*).

Mathematicians employed by educational institutions, even at the college level, tend to be relatively unspecialized within mathematics. Of women mathematicians employed by colleges and universities, 47 percent consider general mathematics their field of highest competence, with algebra, geometry, analysis, and mathematical statistics ranking next in order. Although nearly half of the women mathematical statisticians included in the 1954–55 Register were in college and university work, only 19 percent of the men and women statisticians included in the 1952 survey, mostly social statisticians, worked there and less than two-thirds of these were in teaching (*21*).

In government

By contrast with the mathematical statisticians, these applied statisticians in the 1952 survey mentioned above were found in larger numbers in Federal, State, or local governments, where 45 percent of the total were employed (*21*). In 1954–55, only about 9 percent of the women and 11 percent of the men registered mathematicians were in government work, which may, of course, be somewhat underrepresented among the registered group. It is also likely that among statisticians with the doctor's degree, a higher percentage are employed in education. Even among this group, however, a 1948 survey, which reached a relatively greater proportion of recipients of higher degrees, found 27 percent of the statisticians in government employment with an additional 4 percent combining government work with education (*19*).

Most straight mathematics positions in government are found at the Federal level. Of the women mathematicians included in the National Register in 1954–55 who reported their employment, 40 were in Federal work and only one in other government employment. All States and most of the larger cities have some statistical positions, as well as some other jobs for those with mathematical training, but very few of these positions are of the mathematical research type (*9*). These have been mainly in connection with unemployment insurance programs.

On August 31, 1954, the Federal Government employed 1,306 women in mathematical and statistical work. Table 6 lists the occupational groups and shows the distribution by agency. Only 35 percent of the Federal mathematicians were women, but women comprised 81 percent of the mathematics aids. The National Advisory Committee for Aeronautics takes a large segment of both groups, most of whom are employed outside the Washington, D. C., area. Women are only 21 percent of all statisticians, who are concentrated in the Departments of Defense, Commerce, and Agriculture.

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Table 6.—Women mathematicians and statisticians among Federal civilian employees, by agency, Aug. 31, 1954

Occupational series	Total women employed		National Advisory Committee for Aeronautics	Executive departments									Veterans Administration	All other agencies
	Number	Percent women are of total		Army	Navy	Air Force	Commerce	Health, Education, and Welfare	Agriculture	Labor	Interior	State		
Total	1, 306	22. 3	370	253	217	104	80	62	52	34	20	16	24	74
Mathematics	450	34. 7	110	150	99	36	37	----	1	----	10	----	----	7
Statistics	416	20. 9	----	57	38	45	42	59	45	34	5	5	21	65
Mathematics aid	414	81. 2	260	46	79	17	1	----	6	----	5	----	----	----
Cryptography	12	0. 8	----	----	----	3	----	----	----	----	----	8	----	1
Cryptanalysis	7	1. 4	----	----	1	3	----	----	----	----	----	3	----	----
Actuary	7	13. 2	----	----	----	----	----	3	----	----	----	----	3	1

Source: U. S. Civil Service Commission, Occupations of Federal White-Collar Workers, Aug. 31, 1954, 1955; and U. S. Department of Labor, Women's Bureau, Women White-Collar Employees of the Federal Government: A Study of Their Salaries and Positions in 1954. Processed, 1957.

They form an even smaller percentage of cryptographers and cryptanalysts (code writers and decipherers), about 1 percent in each case. In both code groups, it is the Army, with 1,936 men and no women in this work, which accounts for the small proportion of women. The 7 women actuaries comprise about 13 percent of the Federal actuaries. They deal with problems that involve the setting up or administering of benefits and payments programs and the appraisal of long-range expenditures. Especially the Veterans Administration and the Department of Health, Education, and Welfare in its Old Age and Survivors Insurance program are interested in such problems.

Figure 4.—A mathematician at the National Bureau of Standards checks the work of a computing machine against the table in her book.

Among women mathematicians employed in government who were in the National Register of Scientific and Technical Personnel in 1954–55, applied mathematics was the leading specialty, with mathematical statistics ranking next.

The influence of the Federal Government in mathematics is greater than the proportion of workers directly employed by it would indicate. According to a 1954 report of the National Research Council: "The Federal Government in 1954 provided \$3¼ million for sponsored research in mathematics, about \$2½ million of which maintained applied mathematics activities. With negligible exceptions, all work units in the field receive a substantial fraction of their funds from

Government contracts" (*12*). The impetus given by defense needs and Government financing has certainly accelerated the rate of growth of the demand for mathematicians in private industry as well. Although the Federal Government's most striking contribution may be in the applied field, basic research is not neglected. In fiscal year 1954, the National Science Foundation awarded 21 grants totaling $173,950 to institutions for basic research in mathematics (*24*). In each of the years since the inception of the National Science Foundation fellowship program in 1952–53, one or two women have been awarded fellowships for graduate study in mathematics. Summer institutes for teachers of mathematics have also been financed by the National Science Foundation. In 1956, such institutes for high-school and college mathematics teachers were scheduled at 3 institutions, with stipends for an average of 50 teachers at each institute (*26*).

State and local governments employ statisticians largely in employment statistics, social insurance, and public health programs. On January 1, 1953, 404 analysts and statisticians were full-time employees of State and local health departments (*16*). The public health statistician defines the health problem of an area in quantitative terms, develops records and analytical procedures for the administration of programs designed to meet these problems, and measures the effectiveness of the public health programs. Roughly 700 or more statisticians working mainly in labor statistics and social insurance were estimated by the Bureau of Labor Statistics to be employed in 1954 by State and local governments (*20*). Among them were a few women who served as senior or chief statisticians in State departments of industrial relations or of labor or who headed divisions of research and statistics in such departments. Statisticians are needed, too, in the administration of social insurance systems set up during the past 20 years.

Actuaries employed by State governments are primarily concerned with supervising the examination and valuation of insurance companies doing business in the State, and seeing that they comply with legal requirements. Some have participated in research in connection with unemployment insurance programs. In addition to Federal, State, and local governments, international agencies—like the United Nations—employ some statisticians. Quotas, however, restrict the number employed from any one country by these agencies.

In industry

Although industry is a massive user of mathematics, the number of mathematicians employed there is relatively small, but increasing rapidly. Most of the extensive mathematical work required is done by scientists and by engineers with a knowledge of the theoretical aspects of their field. Engineers, whose basic professional training includes higher mathematics, comprise the largest of all professional groups in private industry. A recent report estimated their number in a large segment of industry at 409,000 as compared with some 6,400 mathematicians (*27*). Nevertheless, the demand for mathematicians in industry has increased at a tremendous rate. Although the mathematicians in the National Register of Scientific and Technical Personnel in 1954–55 cannot be compared exactly with those registered in 1951, the proportion in private industry was five times that in the earlier one, indicating a sizable increase. Of the women mathematicians in 1954–55, the proportion in private industry was three times that in 1951.

Forty-two industrial firms interviewed in a Women's Bureau survey (*22*) in 1946–47 had expanded their employment of women mathematicians from 166 at that time to 335 in 1953. The gain was 102 percent. *Moreover, these increases took place during a period when fewer women were added to the supply from the colleges, as noted later, and they were not equaled in other scientific specializations.*

By far the largest number of women mathematicians in private industry are employed by electrical manufacturing firms, with transportation equipment ranking next. The aircraft industry leads as an employer within this transportation group. Table 7 shows the industry distribution of women employed in professional mathematics

Table 7.—Women mathematicians employed in private industry, by type of industry, 1953

Industry	Number	Percent
All industries reporting	588	100. 0
Manufacturing	493	83. 8
Electrical machinery, equipment, and supplies	252	42. 8
Transportation equipment	135	23. 0
Chemicals and allied products	45	7. 7
Professional, scientific, and controlling instruments	22	3. 7
Products of petroleum and coal	20	3. 4
Food and kindred products	7	1. 2
Other manufacturing	12	2. 0
Insurance carriers	48	8. 2
Miscellaneous business services	23	3. 9
Miscellaneous services	13	2. 2
Utilities and sanitary services	6	1. 0
All other industries	5	. 9

Source: Scientific Manpower Commission (unpublished data).

work according to a 1953 survey of 991 industrial firms conducted by the Scientific Manpower Commission. These women comprised 18 percent of all mathematicians employed by these firms.

The women mathematicians in industry in 1955 were engaged mainly in research and development. Those in consulting, administrative, and inspection work combined were fewer than those in research. A few were engaged in technical writing or selling or in production. Numerical analysis was the field of highest competence claimed by most of the women mathematicians in private industry.

Especially since the war, operations-research teams have called for mathematicians and statisticians. Operations research is a relatively new occupational field concerned with providing the military or industrial executive with analytical studies of the operations under his control as a basis for more intelligent decisions. In application, operations research usually involves the use of teams of research workers who, depending upon the nature of the problem, may draw upon such diverse fields as physics, economics, mathematics, psychology, and statistics. Operations research places heavy reliance on the use of probability theory and statistics, with increasing emphasis on the use of high-speed computing machines. Chemical, petroleum, and food companies are among those who have added such programs, with scientists and statisticians to administer them, to their research departments. Private consulting firms specializing in operations research are beginning to appear, and private research bureaus which offer these and other services on a fee basis are not new.

Statisticians with background in business administration are also employed in administrative and business research positions. With training in corporation finance and accounting, they find jobs with banks or investment and brokerage firms, where they analyze corporation reports or study the stock and bond market as financial statisticians. In department stores, traditionally a good employment field for women, statisticians set up and use statistical methods of inventory control; in factories, they devise methods of controlling the quality of goods manufactured.

Twenty-seven percent of all statisticians included in a 1952 survey reported employment in private industry (*21*).

Private industry is the leading employer of actuaries. Most actuaries work in life insurance companies, with the second largest group in other types of insurance companies—casualty and fire, for example (*28*). Small insurance firms that cannot afford a full-time actuary hire actuaries in independent practice on a consulting basis. In recent years, business firms—other than insurance—have employed actuaries to consult on or administer their pension and retirement plans, prompting the organization of the Conference of Actuaries in Public Practice in 1950.

Prospective actuaries employed by an insurance company very early in their experience learn to derive formulas and compute premiums and values for life insurance and annuity policies. They make computations in connection with changes in existing policies. Their duties may involve computations of requested settlement options not printed in the policy and of amortized bond values. In a mutual company they may compute dividends. They usually prepare replies to requests which require computations. Advancement to actuarial assistant may come fairly early. There is a tendency for some of those who start training as actuaries to move to other spheres of activity in insurance offices, to investment, administrative, accounting, and high executive positions. There are occasional calls from Latin America and other foreign countries for actuaries trained in the United States.

Among women members of the Society of Actuaries in 1956, two are chief executive officer and actuary, respectively, of a large fraternal organization; one is a consulting actuary; five are associate actuaries of medium-sized insurance companies or consulting firms; seven are assistant actuaries of very large companies or of a consulting firm; one is a mathematician and two are assistant mathematicians in very large companies. Another is a university instructor in actuarial mathematics.

In other employment

The few mathematicians and statisticians not employed by educational institutions, by government, or in private industry are in nonprofit organizations. In 1954–55, less than 4 percent of both the registered women and men mathematicians were employed by nonprofit foundations or organizations. Six percent of the statisticians reported in the 1952 study were employed by nonprofit organizations (*21*). Many labor and trade organizations hire statisticians for their research departments. Directors of research and statistics in such organizations generally have graduate training in the social sciences, especially economics.

Future Demand

For mathematicians

"The computer era represents a second industrial revolution" (*5*). "The effect of electronic equipment on our economic life is of the same magnitude as the effect of the H-bomb on our military strategy"

(*15*). "Any estimate of the number of people required to meet future needs in the computer field is almost sure to be an underestimate" (*5*). These predictions are most enthusiastic, but they are substantiated by facts. Even the most guarded appraisal indicates an extremely promising outlook. While the advent of the high-speed computer is only one contributory factor to the current burst of interest in applied mathematics, it is the most recent and probably the most dramatic.

Figure 5.—In a computation laboratory, a college senior learns how the automatic computer MARK IV operates.

The first computer was developed during World War II to solve ordinary differential equations of ballistics. Since then, they have been used by the Federal Government for problems in weather prediction, explosion theory, and many others in the physical sciences as well as for problems connected with the census of population. Some characteristics of digital computers now in operation may be useful in indicating the role of the mathematicians who operate them:

1. The computers will perform multiplication at speeds as fast as 30 millionths of a second.

2. They have "memories" of many thousands of words (either numbers or instructions).
3. They are able to follow instructions in succession and set up automatically the proper connections between machine parts.
4. If at any point in the calculation there are two or more alternative courses for the subsequent operation, they will select and perform the correct one according to specified conditions contained in their instructions (*15*).

It should be evident from this description that computing machines are not giant brains. The mathematician must decide exactly what operations are to be done to yield an answer, then break down the problem to elementary operations of which the machine is capable. This is the function of the coder and programer. The operator puts the problem on the computer through "input" devices, causes it to commence operation through a signal to the control unit, and receives the result from the "output" devices.

Due largely to electronic computing, the demand for mathematicians has been multiplying very rapidly—in mathematical terminology, "growing exponentially"—for the past 7 years. Although one expert predicts that the rate of increase will level off after 5 or 6 years, due to the availability of standard codes, others advise those interested in the training of personnel to count on an even more rapid rate of increase in the next decade (*5*). The Division of Applied Mathematics at the National Bureau of Standards concerned, among other things, with these machines and ways in which they can be used, was set up in 1947. There are now 66 mathematicians in the Division, including 24 women.

Although business is rapidly adopting operations-research techniques, the Federal Government is still the vital factor behind applied mathematics. Inasmuch as the reasons which originally gave rise to the Federal subsidies have neither weakened nor shown signs of doing so, this source of strength appears to be assured for the foreseeable future. The growing interest of private industry will likewise further the continued expansion of mathematics in the applied field.

Although the emphasis on future demand here—and in most currently published material—is on applied mathematics, and in spite of the comment in a popularly written career guide that "pure mathematics offers few job opportunities, save to a relatively few wizards" (*2*), pure mathematics is also an active field. Although each selects more courses in the area of his special interest, the basic mathematical training of the pure mathematician, the applied mathematician, and the statistician may be the same. Those working in applied mathematics require a knowledge of the field to which the mathematics is applied. Developments in pure mathematics are still basic to advance in the applied field, as recognized by the National Science Foundation in its program of grants and fellowships for work in this field. Shortages are greatest, however, in the applied field.

For teachers of mathematics

Among the most serious problems besetting the conduct of applied mathematics programs, according to the National Research Council, is the difficulty of finding applied mathematicians qualified and interested to accept faculty appointments. The program director for mathematical sciences at the National Science Foundation suggests that the most critical shortage is in the teaching of mathematics. If industry took only 5,000 mathematicians now from college teaching, where the 1950 census found only 5,600, the future supply would be cut off at its source. It has been suggested that mathematicians from industrial and government projects be invited to teach at universities and take part in their research activities on a temporary basis (*12*). This program would accomplish the double purpose of alleviating the teacher scarcity and of giving mathematicians the opportunity to combine academic work with their industrial or government duties. It would also enable them to contribute to a supply upon which their own work depends.

Women, even more than men, have seen the range of jobs outside teaching widening greatly in recent years, encouraging the trend from teaching to industry (*10*). Nevertheless, many find certain advantages in teaching. Not the least of these is the fact that it is possible to go back to teaching, at least below the university level, after leaving it for a time without the loss of status incurred by periods of inactivity in many other professions. It offers good possibilities not only for full-time work, but also for part-time and substitute teaching. Successful teachers, of course, emphasize the satisfactions of working with young people and watching them mature mathematically. The need for mathematics teachers in high schools is already severe, as noted earlier, and, as enrollments in the lower schools make their resulting impact on the colleges a few years hence, the additional faculty needed will make the current demand at the college level seem slight. There will be a growing demand for mathematics teachers for the next decade on the basis of population increases and enrollments alone.

It is also possible that the proportion of all students who will enroll in mathematics may increase as a result of efforts stemming from current dissatisfaction with the so-called recent neglect of mathematics in high school, in the face of growing needs for natural scientists and engineers.

In 1954, according to the United States Office of Education, one-third of the public high schools did not offer trigonometry, solid geometry, or advanced algebra. These schools have about one-tenth of the students enrolled in the last two grades of high school where these subjects are normally offered. One-tenth of the high schools in the country did not offer elementary algebra, but only a small fraction of the ninth-grade students are enrolled in these schools. Enrollments in elementary algebra equal about two-thirds of the students enrolled in the ninth grade. About one-fourth of the high schools do not offer plane geometry; these high schools have about 7 percent of the pupils who would be in the grade where they would normally take the subject. Actual enrollments in plane geometry amount to about one-third of these students. The chairman of the Physical Sciences Council at Brown University reported that about 80 percent of the applicants in 1955 for enrollment in the undergraduate applied mathematics division failed to meet admission requirements, because they had not taken the necessary high-school courses in mathematics and the sciences or had scored poorly in these subjects in the College Board tests. Engineering schools make similar observations. As more opportunities for scholarships in engineering, science, and mathematics are made available to qualified students, the need for high-school courses to prepare them for college work in mathematics will be even more keenly felt.

For statisticians

Although the first system of statistical quality-control methods was initiated about 25 years ago, statistics, like applied mathematics, proved its value on a larger scale than ever before in World War II. For instance, statistical studies were made of merchant ship losses as a function of convoy size and of aircraft losses as a function of time since overhaul. Techniques for inventory control were developed to estimate tires and other supplies. In 1951, there were 1,458 statisticians in civil-service positions in Washington, D. C.; in 1931, there were only 79 (*20*). In private industry, the organization of economic research departments in large corporations indicates the growing emphasis on statistical studies and research. Of 42 such departments on which date of establishment was available in a recent study, more than half were organized during the 1940's. These departments ordinarily hire not only economists but also statisticians with second specialties in economics. They do market research and conduct commercial sample and other surveys. A slow but steady increase in opportunities over the long run is predicted.

Some other fields accounting for an increasing utilization of statistical methods are the biological and medical sciences, psychological testing, education, and public health. For instance, when the major problems of public health departments concerned acute diseases of high incidence or prevalence, the statistician's job was limited to computing relatively crude health indices based on records collected routinely, such as death certificates and physicians' reports of communicable diseases. With the conquest of major communicable diseases and the transfer of attention to chronic-disease control, hospitalization, and medical care, the need arose for more complicated statistical studies. In Federal agencies which have substantial health activities, e. g., Public Health Service, Children's Bureau, Defense Department, the demand for specially trained statisticians exceeds the supply (*1*). The limited facilities for training in the past decade have built up a backlog of demand by existing units that alone would last for the next several years. The Federal Government's need for sampling experts is particularly acute.

In view of the demand for statisticians and the currently limited supply, there are also very good employment prospects in teaching. Rising demand in business administration, engineering, and the natural sciences, as well as in the social sciences, in which statistics is becoming increasingly applied, has already resulted in an increase in the number of institutions offering courses in statistics, and further expansion is likely. Although there were only about 750 professors and instructors of statistics reported in the 1950 census, including less than 70 women, the demand for specialists in this faculty area is bound to grow. Mathematical statistics has received a great deal of attention in this country during the past 25 years, and according to an authority at the American Statistical Association, mathematical statisticians are "always in demand."

Many more actuaries are needed, with no prospect of the actuarial profession becoming overcrowded for many years. Life insurance, health insurance, and insurance pension and retirement plans are expected to continue to expand, as are casualty and fire insurance (*28*) (*4*). The new demand for actuaries in the consulting field has already been noted and is expected to continue as smaller companies set up pension, retirement, and other insurance plans.

Although the actuarial profession has not been closed to women, it is apparent that most jobs are filled by men. Standards set by the professional organization are very high and require years to complete, so that only women of persistence as well as of outstanding ability can succeed in meeting them. In 1955, the Society of Actuaries had only 21 women among its 890 fellows and 19 women among its 684 associates. The greatest limitation on opportunities arises from the reluctance of most life insurance companies to assign women to executive duties and to positions requiring frequent contacts outside their own department or company (*9*). Nevertheless, the unusual demand favors opportunities for the well-prepared woman actuary. The fact that the number of women in this field has been increasing in recent years in all probability indicates a continuing trend, at least so far as employment is concerned.

Future Supply

Meanwhile, as the demand for women mathematicians has been growing, the supply has fallen behind. Table 8 shows the number of degrees conferred in mathematics from 1947–48 to 1954–55. The

Table 8.—Earned degrees conferred by higher educational institutions in mathematics, 1947–48 to 1954–55

Year	Bachelor's and first professional			Master's and second professional			Doctor's		
	Number		Percent women	Number		Percent women	Number		Percent women
	Total	Women		Total	Women		Total	Women	
1947–48	4, 266	1, 647	39	711	148	21	128	10	8
1948–49	5, 040	1, 527	30	893	181	20	126	10	8
1949–50	6, 392	1, 446	23	974	190	20	160	9	6
1950–51	5, 753	1, 442	25	1, 109	180	16	184	9	5
1951–52	4, 721	1, 332	28	802	139	17	206	11	5
1952–53	4, 396	1, 274	29	677	112	17	241	14	6
1953–54	4, 090	1, 368	33	706	127	18	227	14	6
1954–55	4, 034	1, 310	32	761	148	19	250	11	4

Source: Department of Health, Education, and Welfare. Office of Education. Earned Degrees Conferred by Higher Educational Institutions, published annually.

decrease since 1950–51 may be attributed to the lower birthrate in the 1930's, the results of which are now being felt at the college level. The increase in the number of women in 1953–54 reversed the downward trend, but the gain did not continue the following year.

New graduates, men and women, prepared to teach high-school mathematics have also been declining in number, although 1956 saw the first reversal of the alarming downward trend. In 1955–56, 2,600 were graduated, 44 percent below the 1950 number but 21 percent above the number graduated the preceding year (*14*). The fact that mathematics had been adversely affected by additional factors as well as by the low birthrate of the 1930's is indicated by the lesser decline of 34 percent in the number of all college graduates prepared to teach in high schools during the same 6-year period. However, mathematics appears to have recovered more quickly from the decline since the rate of increase of all graduates prepared to teach high school was only 15 percent, from 1955 to 1956.

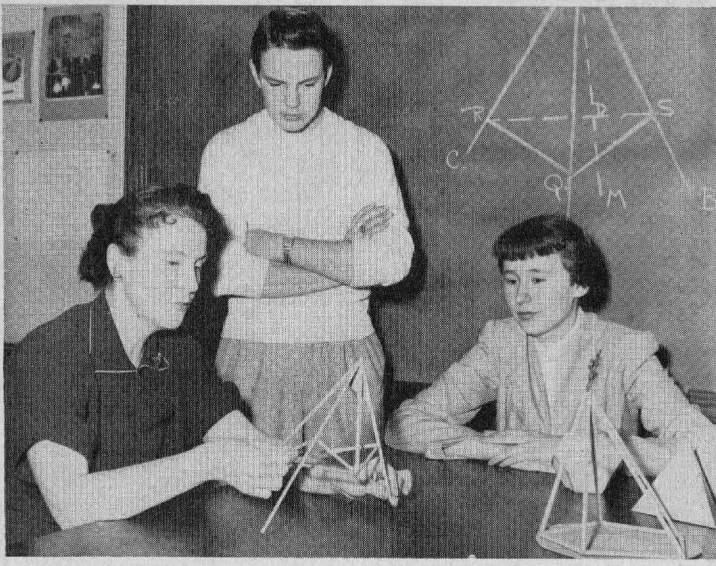

Figure 6.—A high-school mathematics teacher explains the intricacies of solid geometry to two students and encourages their interest in the field of mathematics.

These figures on new graduates are larger than the numbers which become available for employment from this source. Losses occur, among men, for military service and other employment; among the women, for full-time homemaking and other employment. The National Education Association found that only seventy-seven percent of the women and seventy-four percent of the men who had prepared for mathematics teaching in the academic year 1954–55 were either teaching, seeking teaching jobs, or continuing formal study (*14*).

Although a few mathematicians come from related fields, not many can be expected from these sources. More than 9 out of 10 of the mathematicians registered in 1951 had received their highest degree in mathematics (*25*). The largest group derived from other specializations came from the physical sciences and engineering, fields which are also facing shortages and are unlikely to provide many additional mathematicians.

College enrollments are now increasing, so the future potential supply is more encouraging than it has been for some years. However, unless a much larger proportion of high-school students prepare themselves to study college mathematics, and unless a much larger proportion of college students specialize in mathematics, we shall have not only a continuing shortage in this key group but also a bottleneck effect on engineering, the physical sciences, statistics, and many other fields dependent on mathematics instruction. The scarcity of students is less felt in pure mathematics, however, than in applied fields. In 1953, the great centers of pure mathematics reported a gratifying number of really gifted students, while some of the outstanding schools of applied mathematics already had difficulty in filling their funded graduate-student positions with qualified candidates (*12*).

Preparation Needed

For mathematicians

There are employment opportunities at all levels of education in mathematics although they become greater at the high levels. In programing work, the problems encountered vary from those which can be handled by high-school students unusually proficient in mathematics to those requiring a doctorate level of education in mathematics. Only slightly exaggerated was the statement made at a 1954 conference on training personnel for the computing machine field, where the programer's qualifications were noted by one of the participants "as anything from those of an 8-year-old up to a finished Ph. D. in mathematics" (*5*). The variations in the uses to which electronic computers are put result in a demand for programers at the bachelor's and master's levels as well as at the Ph. D. level.

As background for the 6 to 12 weeks of on-the-job training given for programing preparation, most employers presently seem to look for a "good, solid classical background in mathematics." While suggesting that course work include numerical analysis, most authorities stress that it is more important than ever that college courses avoid excessive development of specialized techniques and aim rather at breadth of mathematical background. One electronics manufacturer explained that emphasis in university courses on programing preparation is not so crucial, inasmuch as a capable person with good mathematical background has no difficulty in learning this on the job. Nevertheless, in 1954, training with respect to electronic computers existed as regular courses in some 30 universities scattered over most of the United States. More of these were in electrical engineering than in mathematics departments (*5*). Among these computing centers are those at Columbia, Purdue, New York, Wayne Universities and the Universities of Illinois and Michigan, and Georgia Institute of Technology.

In one 4-year curriculum leading to a bachelor of science in applied mathematics, students take 8 semester courses in mathematics, 4 in applied mathematics, and 8 in engineering, physics, and chemistry (an economics option may be added soon). This type of program offers the kind of background needed by young women seeking work in industry who may or may not use electronic calculators, but who will assist research chemists, physicists, engineers, and others in the mathematical phases of their work. Since the graduate with a mathematics major who enters industry usually operates a calculating machine and has occasion to use a slide rule, it is desirable for her to pick up these skills in school. For work in research departments of all large industrial concerns, a college background in physics and drafting is helpful. As was common during World War II, a few large industries are hiring promising young women with mathematics and science backgrounds whom they send on for further schooling while working.

For a beginning professional position as a mathematician in the Federal Civil Service, college graduates without experience must have not only their bachelor's degree but courses in mathematics totaling at least 24 semester hours. For some types of positions, additional courses in the physical sciences or engineering may be required up to 12 semester hours.

The emphasis on courses outside mathematics—for instance, in the physical sciences—is a trend everywhere being promoted for applied mathematicians. Some type of formal study in physics, chemistry, engineering, biology, psychology, statistics, or economics is usually necessary to make the mathematician effective in applied work. A committee of the Social Science Research Council warns that until more mathematicians and mathematical statisticians select a minor in social sciences, as many now do in physics, their communication with social scientists will continue to be handicapped.

For teachers of mathematics

To teach mathematics in college, it is usually necessary to have a Ph. D. degree or be working toward one. Professorships almost invariably indicate advanced graduate training and the equivalent of post-Ph. D. research experience. For college instructors of applied mathematics, it is desirable to have had first-hand experience with computing machines. Formal requirements for secondary-school teachers vary widely according to State certification standards and in times of severe shortage are sacrificed frequently for the sake of filling positions.

A study published in 1950 polled 263 high-school mathematics teachers, 107 heads of college mathematics departments, and 83 heads of college education departments in the Middle West to determine college courses desirable in training secondary-school teachers. The first 10 subjects were college algebra, trigonometry, methods in high-school mathematics, solid geometry, educational psychology, supervised teaching, analytical geometry, general high-school methods, college geometry, and advanced college algebra. High-school mathematics teachers favored professional courses in education to a greater extent than did college education department heads. Another survey produced evidence to support the following courses and experiences in training secondary-school mathematics teachers: statistics, applied mathematics, mathematics of finance, history of mathematics, field work in mathematics, audiovisual aids, and social problems (*7*). The Mathematical Association of America considers calculus and differential equations essential, and would include as much work as possible in the sciences (*9*).

To an increasing extent, high schools provide, beside the traditional college preparatory courses, such mathematics courses as general mathematics, shop mathematics, consumer mathematics, business arithmetic. High-school teachers should be prepared to give both types of instruction.

For statisticians

Mathematical statisticians almost invariably have a doctorate in their specialty. Very few universities give adequate training in mathematical statistics at the present time (*9*). Among those that do are Columbia, Princeton, and Stanford Universities, the Universities of California, Chicago, and North Carolina, and Iowa State College. A high-school background for statisticians should include as much mathematics as possible and the natural and social sciences, and should develop the ability to write clear, concise English. In college, algebra, plane trigonometry, analytical geometry, differential and integral calculus, plus courses in statistical method, are essential (*20*). Original work in statistics demands an understanding of matrix algebra, *n*-dimensional Euclidean geometry, the theory of measure and integration, the Fourier integral, and the theory of complex variables (*6*).

Students intending to be applied statisticians often take degrees in fields where they intend to apply their statistical training. A study made in 1950 of members of the American Statistical Association showed that 27 percent had taken their highest degrees in economics; 20 percent in statistics; and 12 percent in mathematics. Other major subjects were business, psychology, and sociology (*8*). A 1952 survey which reached statisticians through organizations in the social sciences and humanities, found that more than 40 percent had majored in mathematics or statistics (*21*). Almost half of those found in business and management in the 1952 survey had only the bachelor's degree (*21*). To qualify for a beginning position with the Federal Government as a professional statistician, the candidate must take the Federal Service Entrance Examination, which is open to all graduates of a 4-year college course leading to the bachelor's degree. For certain openings in statistics, a minimum number of academic credits in a related area of study may be required of those who have no professional experience.

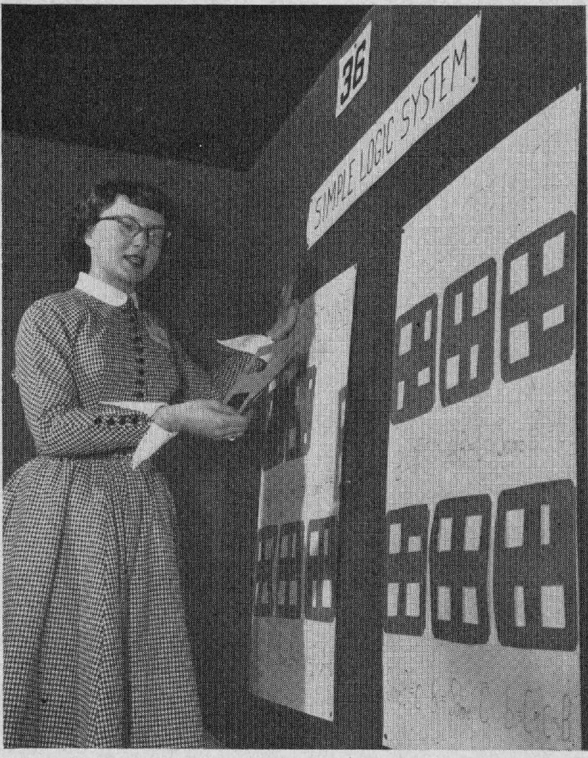

Figure 7.—A high-school senior, finalist in the 1956 Science Talent Search, displays her statistical study of what has happened for both high-average and low-average students of her school, since their graduation.

For statistical quality-control work, the use of sampling to inspect materials or products, it is desirable to have one or two courses in engineering statistics and to be a graduate of a chemical, electrical, or mechanical engineering curriculum. For the prospective public health statistician, professional study should include substantial courses in anatomy, physiology, and pathology, along with epidemiology, public health administration, microbiology, and environmental hygiene. Industrial hygiene, medical care, and hospital administration are desirable. Graduate study in a school of public health accredited by the American Public Health Association is a prerequisite for career advancement. There were, in 1950, 11 such schools (*1*).

For actuaries, the generally recognized mark of professional status is successful completion of a series of examinations given by the Society of Actuaries, in the life insurance field; or by the Casualty Actuarial Society, in the casualty insurance field. There are eight examinations in each series. A candidate becomes an associate member after passing five examinations given by the Society of Actuaries or four given by the Casualty Actuarial Society. After passing all eight, which requires between 5 and 10 years on the average, the actuary is a fellow or full member. However, associates as well as fellows are regarded as having professional status as actuaries.

In the Society of Actuaries series, it is desirable to take the first three examinations while still in college. These test language aptitude, general mathematics, and special mathematics (on finite differences and probability and statistics). The Casualty Actuarial Society, in the first three examinations, tests statistics, probability, elementary life-insurance mathematics, general principles of insurance, insurance law, and social insurance. The remaining examinations require practical experience and home study and are taken while employed in actuarial work at a lower level than that of the actuary.

Basic requirements for a beginning actuarial position in the Federal Civil Service specify the completion of a 4-year college course leading to a bachelor's degree. A minimum of 24 semester hours of mathematics must be included in the study of those candidates who have no professional experience, although 6 hours of statistical theory and method may be substituted for 6 of the mathematics credits. As of 1955, five universities in the United States offered specialization in actuarial science. Besides the required mathematics, a college program preparing for actuarial work might include English composition, speech, economics, banking and finance, accounting, business administration, and business law.

Personal Characteristics Needed

Mathematicians in the electronics computing field have been described as bright people, with mathematical aptitude and interests, plus perseverance and motivation. These qualities are characteristic of professional workers in mathematics and statistics generally. Success in the programing and coding field requires in addition, according to two women mathematicians at the National Bureau of Standards, a special aptitude—like that for music. Seeking a preprofessional indication of this talent, it was noted that most of the Bureau programers and coders like puzzles.

Fundamental qualities in a statistician are a liking for numbers, strict mathematical accuracy, ability to manipulate figures and power to draw general conclusions from them; a logical mind, a certain amount of imagination, and patience to check and recheck are likewise indicated (*11*).

The actuary has been described as more of a businessman than a mathematician. He must have administrative and executive ability, the ability to work well with many types of people, good command of the English language, and good health to permit 5 to 10 years of combined study and employment.

Trying Out for the Field

After a certain level of education has been reached, the student mathematician may be able to obtain short periods of employment where he can apply his training on the lower levels while observing professional workers. In the Federal Civil Service there are positions for student trainees in mathematics. Some of these positions may provide summer employment for college students majoring in mathematics and others may provide scheduled periods of employment for students in college cooperative courses. A written test is required, consisting of a scientific aptitude test which includes spatial visualization, mathematical formulation, table reading, and form perception. Salary levels increase as students acquire more education. Junior students taking the examination may qualify for the highest salary level available to students by taking an additional test in mathematics.

The Mathematics Student Journal, published for high-school students by the National Council of Mathematics Teachers with the cooperation of the Mathematical Association of America, will help to test interest in mathematics as well as to supply information. Students interested in statistical work may work as statistical clerks or student assistants on research projects using statistical techniques. Preliminary actuarial examinations taken while still in college may indicate the likelihood of future success in actuarial work, and advance the opportunity for employment.

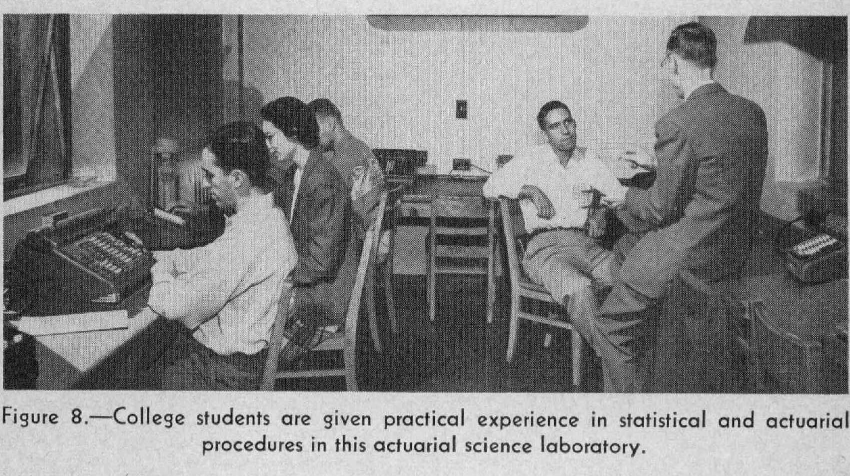

Figure 8.—College students are given practical experience in statistical and actuarial procedures in this actuarial science laboratory.

Obtaining Employment

College teaching positions are mainly found through professors and chairmen of mathematics departments. Many assistant or instructor positions are filled by outstanding present or former graduate students, and most higher positions, by promotion. Both graduate and undergraduate schools should be chosen carefully toward this end if such employment is anticipated.

Joining professional organizations and attending meetings is often fruitful of leads to openings. Some bulletins of professional organizations list employment opportunities. In statistics, the bimonthly news bulletin of the American Statistical Association and the *American Statistician* carry such information.

High-school teaching positions are obtained through college and teacher placement bureaus or often by direct application to school systems. Examinations are sometimes required of nonresidents.

In the Federal Government, mathematical and statistical positions are covered by civil-service examinations. The requirements for beginning positions have been noted previously. Examinations for scientific personnel for higher positions are "unassembled," i. e., based on review of the candidate's experience, education, and training. In State insurance departments, the top actuarial official is often appointed by the governor. For staff actuarial positions, application is made to the commissioner in charge of the insurance program. These and State statistical positions are filled either by examination or appointment, depending on the State.

To find positions in private industry, professors and departmental chairmen and college placement bureaus are helpful, as are the public employment offices operated by State Employment Services. Answering advertisements in professional journals, large metropolitan daily newspapers, and financial journals may be rewarding.

Advancement

In colleges and universities, advancement from the intermediate levels to full professorship is often dependent on length of service and other factors, such as contributions through publications, since all candidates for advancement have presumably reached the Ph. D. level. In public school systems, automatic salary increases are usually given periodically according to a schedule, and sometimes depend on completing additional courses. The head of a department in a high school may receive an additional salary increment. Promotion beyond that is to assistant principal or other administrative work. In the Federal Government, advancement is through civil-service ratings. Although there are automatic, periodic salary increases within a grade, administrative action is required to proceed from one grade to another.

Advancement in industry to supervisory or administrative positions brings an obvious change of rank, often without further education, but this is based more on administrative than on mathematical ability. There are positions, programing, for example, where the title may not change from the B. A. through the Ph. D. level. The level of programing done may vary, of course. Some young women mathematicians after assisting engineers have completed enough experience and training to become junior engineers.

The advancement of actuaries is generally regulated by the examinations they must pass. Exceptions arise in small insurance companies, small consulting firms, and State insurance agencies. Usually an actuary who has passed all the examinations, however, is promoted to officer status when a vacancy as an actuary is available.

Earnings

In 1954–55, the median annual earnings of mathematicians without the Ph. D. who were registered with the National Register of Scientific and Technical Personnel were $5,927; for registered Ph. D. mathematicians, the median was $6,325. Undoubtedly the medians were lower for women mathematicians than for men, although they were not computed in time to be published here. A recent report showed that men graduated at the bachelor's level with a mathematics major in 1951 and employed in 1952 had a median salary of $3,400. The median for women was $2,800 (*23*). However, the median reported for women receiving bachelor's degrees in 1955, followed up by the Women's Bureau and the National Vocational Guidance Association in early 1956, was $3,848 for those employed as mathematicians or statisticians. Obviously, beginning salaries have been increasing.

Professional incomes of mathematicians are generally lowest in educational institutions, intermediate in government, and highest in private industry (*25*). The salaries offered in industry create extraordinary employment problems for the Government, while in education they are offset somewhat by the longer summer vacations and holiday periods, and the less rigidly scheduled nature of academic work. The Federal Government starts mathematicians, like engineers and physical scientists, at a higher salary rate than it does beginners in the same grade in other professional fields. Salaries in colleges and universities vary greatly by institution. Beginning salary of an instructor in mathematics may be as low as $3,000; the maximum salary of a full professor may reach $15,000 or more. Salaries for instructors in mathematical statistics are generally higher.

Professorships in mathematical statistics may pay as high as $18,000 to $20,000 per year (*9*).

High-school teaching is less well paid than work in industry, although long summer vacations, here, too, offer an offsetting attraction. Mathematics teachers, of course, are on the same salary scale as other high-school teachers, and women teachers in most communities are on the same salary scale as men. Women college graduates of the class of 1955 who early in 1956 reported employment in high-school teaching averaged $3,061, according to a survey conducted by the National Vocational Guidance Association in cooperation with the Women's Bureau. Average (median) salaries in 1954–55 for high-school teachers, many of whom have had long years of teaching experience, are given in table 9.

Table 9.—Median annual salaries paid junior high-school and high-school classroom teachers in urban school districts, by population size, 1954–55

Population size of urban district	Junior high school	High school
Over 500,000	$4, 931	$5, 864
100,000 to 500,000	4, 311	4, 650
30,000 to 100,000	4, 382	4, 686
10,000 to 30,000	4, 103	4, 385
5,000 to 10,000	3, 751	4, 021
2,500 to 5,000	3, 579	3, 848

Source: National Education Association. Salaries and Salary Schedules of Urban School Employees, 1954–55. Research Bulletin 33, No. 2, April 1955.

The latest comprehensive data on salaries of statisticians are for 1952, when the median salary of women statisticians reporting was $5,600 compared with a median of $7,000 for men. The entire group of statisticians was found to have the highest median salary of all groups studied, although it was the youngest of a number of groups in the social sciences and the humanities surveyed through the cooperation of the American Council of Learned Societies. The median annual salary for all statisticians was $6,800; for those with the Ph. D., $7,500. These 1952 salaries exceed those of mathematicians in 1955. The high proportion of statisticians in nonacademic work may explain this in part, since the median salary for statisticians employed by colleges and universities was lower than in government and private industry (*21*).

A 1950 study of statisticians in the American Statistical Association found that the median income of statisticians with independent practice as their primary source of income was $13,300, but the median for salaried employees, excluding teachers, was $7,000 (*8*). Statisticians reporting income from second sources mention most often teaching outside of regular duties. Other common sources of additional income are consulting, royalties, and lectures (*21*).

The salary of a beginning actuary is likely to range between $4,200 and $5,000 per year. In 5 years, it may increase to perhaps $7,500. A number of actuaries in the country make over $30,000, while it is possible for those who head firms to earn $50,000 or more. Separate statistics are not available on the relatively few women in this field.

Working Conditions

The office environment in which much of the work of the mathematician and statistician is done is likely to be modern and well equipped with cafeteria and other employee services. The mathematician usually has regular hours. The applied mathematician or statistician, however, may be required to work after regular office hours on rush projects. Actuaries are seldom required to work overtime except for a short period at the end of the year, and hours in many insurance companies are limited to 35. Depending partly on the work habits of the individual, mathematicians or statisticians in administrative positions may put in extra time in the office or on homework much more than subordinates. In the lower levels, while the hours are regular, the work is often tedious, and the necessary close concentration may be tiring to the eyes and nervous system. As compared with work in some of the sciences, mathematics is usually free of physical hazards encountered in handling dangerous equipment or materials.

Organizations

Some of the professional organizations now existing in mathematics were founded more than a hundred years ago, but the number has risen at an ever-increasing rate since the 1930's. The most recent are the small but fast-growing splinter societies in applied mathematics. The organizations publish journals, transmitting new developments in the field, and subscription to these publications is usually included in the membership fee. Yearbooks, booklets, pamphlets, and reprints describing various aspects of the field are likewise distributed. Frequently the societies obtain reduced prices for their members on pertinent books of other publishers. The organization's offices generally act as a central source of professional information, convening conventions for direct interchange among members, who are reached through publications and special services at all other times.

The American Mathematical Society concentrates on research in mathematics, while the Mathematical Association of America specializes in collegiate mathematics. The National Council of Teachers of Mathematics is open to anyone interested in the teaching of mathematics. Springing up beside these long-established groups are societies representing the newer branches of mathematics: the Society for Industrial and Applied Mathematics, the Industrial Mathematics Society, the Association for Computing Machinery, the Operations Research Society of America, and the Institute of Management Sciences. (*12*).

The American Statistical Association and the Institute of Mathematical Statistics are the overall societies in statistics. Among specialized groups are the Econometric Society and the Psychometric Society founded in the early 1930's for advancement of the theory and application of statistical methods to economics and psychology. The Biometric Society, organized in 1947, is devoted to the mathematical and statistical aspects of biology, and the American Society for Quality Control, interested in the use of statistics in assessing the quality of production in industry, was organized in 1946. Actuarial societies include the Casualty Actuarial Society and the Society of Actuaries, previously mentioned, and the recently founded Conference of Actuaries in Public Practice.

Special Groups of Women

No qualifications other than ability to do the required mathematics and statistics were noted in the review of literature and announcements for positions, or in interviews with employers in the course of this study. The tremendous demand has largely removed barriers that may have existed previously to the employment of women or special groups of women in this field of work. Married women are hired when available, as are older women with the required training. In view of the fact that the content of mathematics has advanced so rapidly in the past years, however, it is unlikely that older women would be prepared to take most positions without additional training. Teaching mathematics at the lower levels is an exception. Most orthopedic or hearing disabilities would not be handicapping in this work, but defective vision, unless corrected, would be a handicap.

Appendix

DEFINITIONS

Mathematician as defined in the Dictionary of Occupational Titles (*18*):

MATHEMATICIAN (profess. & kin.) 0–35.76. Solves and directs the solution of problems in higher mathematics incidental to investigative, developmental, and research work in scientific fields, such as engineering, physics, and astronomy: Determines mathematical principles involved and most efficient methodology for solution of problems. Acts as an adviser or consultant on application of mathematical analysis to scientific problems. May perform research to discover new or improved methods for application of mathematical theory or analysis to new or unexplored areas of scientific investigation.

Statistician as defined in the Dictionary of Occupational Titles (*18*):

STATISTICIAN (profess. & kin.) II. 0–35.75. statistician, physical-science. Discovers facts and solves quantitative problems in the field of physical science by application of statistical methods to a mass of individual observations: Observes scientific phenomena and devises techniques for their tabulation and analysis, varying methods according to nature of subject matter. May specialize in statistical analysis in a specific scientific field, such as physics, chemistry, or biology.

STATISTICIAN (profess. & kin.) I. 0–36.51. statistician, social-sciences. Discovers general facts and interprets quantitative information by application of statistical methods to a mass of related individual observations in the field of social sciences, such as economics, sociology, or psychology: Obtains and devises methods for obtaining basic data, determining character and volume of information necessary for solution of a statistical problem. Reduces and determines most effective techniques for reduction of data according to nature of available information and type of problem under study. . . . Usually has broad training in mathematics. . . .

Actuary as defined in the Dictionary of Occupational Titles (*18*):

ACTUARY (profess. & kin.) 0–36.55. insurance actuary. Deals with statistical, mathematical, and financial calculations involving probability of future payments or contingencies in pension and insurance plans, such as insurance against losses arising from death, disability, sickness, and unemployment: Evaluates risks, calculates premium rates, and constructs tables of probability for such contingencies as mortality, disability, sickness, and accidents. Develops contract provisions of insurance and pension plans. Determines proper basis and methods for valuing liabilities of insurance and pension organizations. Determines equitable bases for distributing surplus earnings under participating insurance and annuity contracts. Is generally concerned with maintaining permanent financial stability of insurance and pension plans.

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