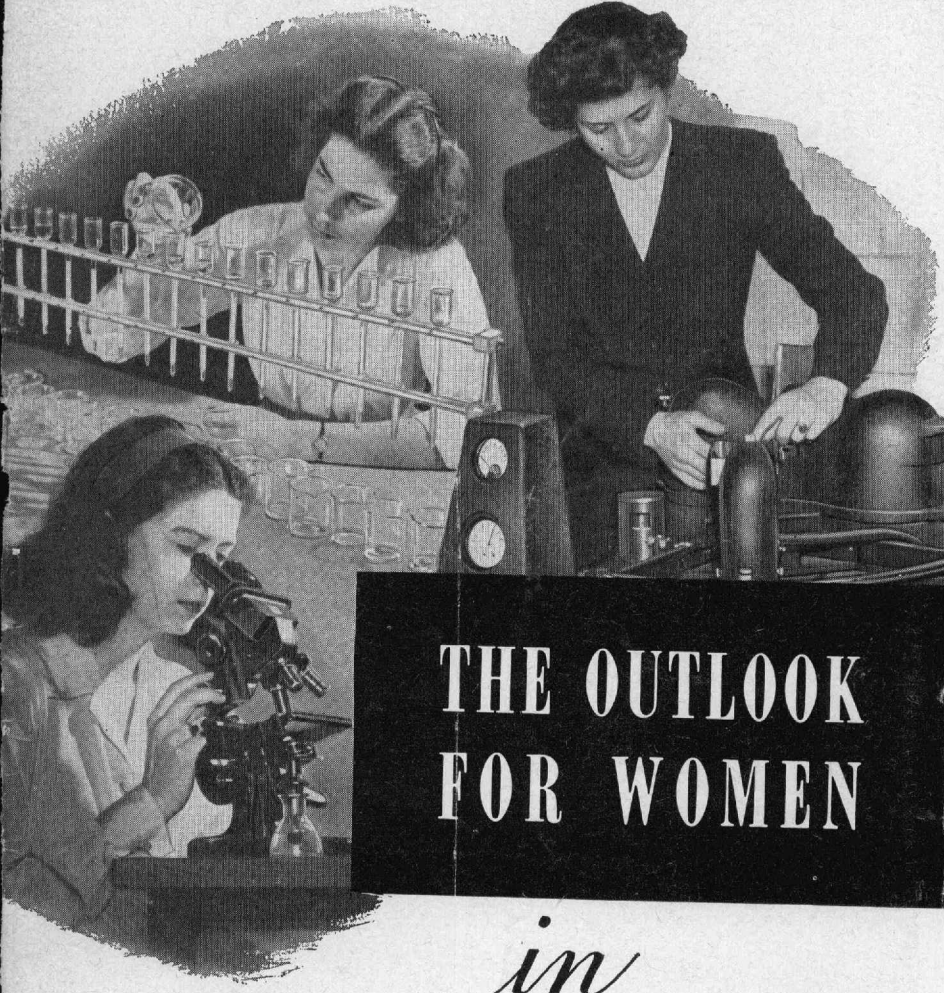

THE OUTLOOK FOR WOMEN

in

MATHEMATICS AND STATISTICS

Bulletin No. 223–4

U. S. DEPARTMENT OF LABOR

WOMEN'S BUREAU

UNITED STATES DEPARTMENT OF LABOR
L. B. SCHWELLENBACH, SECRETARY
WOMEN'S BUREAU
FRIEDA S. MILLER, DIRECTOR

The Outlook for Women in Mathematics and Statistics

Bulletin of the Women's Bureau No. 223–4

U. S. GOVERNMENT PRINTING OEFICE
WASHINGTON : 1948

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 10 cents

This bulletin is No. 223–4 in the following series on

THE OUTLOOK FOR WOMEN IN SCIENCE

No. 223–1 *The Outlook for Women in Science*
No. 223–2 *The Outlook for Women in Chemistry*
No. 223–3 *The Outlook for Women in the Biological Sciences*
No. 223–4 *The Outlook for Women in Mathematics and Statistics*
No. 223–5 *The Outlook for Women in Architecture and Engineering*
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No. 223–8 *The Outlook for Women in Occupations Related to Science*

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LETTER OF TRANSMITTAL

UNITED STATES DEPARTMENT OF LABOR,
WOMEN'S BUREAU,
Washington, December 22, 1947.

SIR: I have the honor of transmitting a description of the outlook for women in mathematics and statistics which has been prepared as a part of a study on the outlook for women in science. The extraordinary demand for women with scientific training during World War II and the resulting questions which came to the Women's Bureau prompted us to undertake this study. The paucity of published information on women in science and the encouragement of the scientists and educators who were consulted in the course of this study confirmed the need for the information here assembled and synthesized. The study was planned and directed by Marguerite Wykoff Zapoleon and completed with the assistance of Elsie Katcher Goodman and Mary H. Brilla of the Employment Opportunities Section of the Bureau's Research Division. Other members of the Bureau staff who helped to broaden the coverage of this study through interviews in the field were regional representatives Margaret Kay Anderson, Martha J. Ziegler, Rebecca G. Smaltz, and another member of the research staff, Jennie Mohr. Corinne LaBarre, research assistant, of the Western Personnel Institute, Pasadena, Calif., furnished the information obtained from western colleges.

The part of the study here transmitted was written by Mary H. Brilla.

Respectfully submitted.

FRIEDA S. MILLER, *Director.*

Hon. L. B. SCHWELLENBACH,
Secretary of Labor.

FOREWORD

Much has been written about science and scientists, but little has been told about the work women trained in science have done and can do in the future.

Although these women are few in number when compared to men in science or to women in such occupations as teaching and nursing, their contribution to the national welfare, so strikingly demonstrated in World War II, goes forward daily in the laboratories, classrooms, offices, and plants in which they work.

The every-day story of where these women work, of what kind of work they are doing, and of what other young women who join their ranks in the future may do has been the subject of this report on the outlook for women in science. Unlike the usual monograph which describes an occupation in detail at a particular point in time, this study, like the Women's Bureau series on occupations in the medical and health services which preceded it, is concerned primarily with changes and trends.

Although more than 800 books, articles, or pamphlets were culled for background information, the principal raw material for the entire study of which this bulletin is a part came from such primary sources as scientific organizations, employers and trainers of women scientists, and men and women scientists themselves. Principal sources were as follows:

Scientific organizations: The National Research Council supplied useful directories of scientific laboratories and organizations. Helpful criticism and direction to other authorities were obtained from its Office of Scientific Personnel. Sixty separate organizations of scientists supplied information on their women members, by interview or correspondence.

Federal agencies: Unpublished information on personnel in scientific fields was supplied by:

The United States Bureau of Labor Statistics,
The National Roster of Scientific and Specialized Personnel,
The United States Office of Education,
The United States Civil Service Commission, and
The United States Public Health Service.

In addition, 52 separate bureaus, offices, or other operating units of the Federal Government known to employ scientists were solicited for information regarding the number of women employed on jobs requiring scientific training and the type of work

they were doing. Detailed statistics over a period of years were available from some agencies, while only fragmentary data were obtained from others. The women's military services likewise supplied information on the wartime use of women trained in science in the WAC, WAVES, and the Marine Corps.

Private industry: One hundred industrial firms were visited in 1945 and 1946 to obtain information, usually by interview with the director of research or the personnel director, on the women employed by any part of the organization in any capacity requiring scientific training of college level. Prewar, wartime, and postwar statistics were obtained where available, as well as suggestions and comments. In many instances, some of the women in scientific work were interviewed on the job. The firms visited included:

Seventy-eight firms listed in the National Research Council's 1946 directory of 2,443 firms having research laboratories. The firms visited are listed in the directory as employing 24,816 persons as scientific or technical personnel in their laboratories. This number represented 28 percent of the total personnel of this type estimated as employed in all the laboratories listed. In addition to this numerical coverage, an attempt was made to include among the 78 firms visited small as well as large firms, plants in all parts of the United States, and a variety of industries. However, the intricate industrial organization, interrelationships, and variety of research revealed in the directory, added to the fact that some firms did not report personnel statistics and none reported women separately, made the selection of a true sample complicated beyond its value for this purpose. The firms visited were chosen rather as a clue to industrial firms most likely to be engaged in the type of work in which women trained in science are used. In all firms, information was requested for the entire organization rather than for the research laboratory only.

Eighteen commercial testing laboratories which offer testing services to industry and individuals and which employed women were also visited. Seven others contacted did not employ women. These 25 laboratories represented 10 percent of the 244 commercial testing laboratories listed in the National Bureau of Standard's 1942 Directory of Commercial Testing and College Research Laboratories. Since personnel is not reported in the directory, there is no clue to the coverage of workers.

Three large additional industrial firms which employed women in laboratory work but were not listed as having research laboratories were visited, as was one biological supply house.

Research institutions: Eight research institutions or centers, some of them identified with a particular college or university, also supplied information on women members of the scientific staff.

Colleges and universities: Statistical information on the number of women graduated with degrees in science, mathematics, and engineering over a period of years from 1939–40 to 1946 was obtained from 30 colleges and universities and from 9 engineering schools. Again an attempt was made to obtain wide geographical coverage and to cover different types of institutions, such as women's colleges, State universities, and small liberal arts colleges. The information available from these sources, too, varied. Placement bureaus and heads of science departments as well as deans of women at these institutions and at six other colleges contributed reports on the demand for women trained in the sciences. The Western Personnel Institute made possible the inclusion of data which it collected for the Bureau from its affiliated colleges and universities in the far West.

Since no recent data were available on the number of women teaching science in the colleges, a count was made in 1947 of the women identifiable by name who were listed on science faculties in the catalogs of 330 institutions of higher learning which were then available in the United States Office of Education Library. These institutions were selected because they are believed by the United States Office of Education to be representative in their enrollments of the 1,749 institutions of higher education in the United States and, therefore, are likely to have faculties equally representative.

Other sources: In addition, 97 individuals not included in the afore-mentioned sources, most of them women scientists, contributed information, suggestions, or helpful criticisms of the preliminary manuscripts circulated before revision for publication.

While every effort has been made to obtain wide coverage, there remain some dark corners still unexplored because of the range and variety of these fields and the difficulty of obtaining information from widely scattered sources. Perhaps this beginning will result in further additions to our so-little knowledge.

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Courtesy National Bureau of Standards

Figure 1.—A mathematician at the National Bureau of Standards works on a sampling problem as part of a research program conducted by the Statistical Engineering Laboratory at the Bureau.

CONTENTS

Mathematician as Defined in the Dictionary of Occupational Titles (*13*)

A term applied to a worker who has attained eminence in some field of mathematics and is a recognized authority in that field.

Mathematical Statistician as Defined by the National Research Council's Committee on Applied Mathematical Statistics (*10*)

"The mathematical statistician is a mathematical expert who concerns himself primarily with critical mathematical investigations of statistical problems which arise in * * * various fields, and with the development of methodology for dealing routinely with them."

Statistician and Actuary as Defined in the Dictionary of Occupational Titles (*13*)

"Statistician (profess. and kin.) 0–28–10. Plans procedure and technique for solution of statistical problems and devises formulas for reduction of data; must possess a thorough knowledge of mathematics; analyzes quantitative statistical data, such as money, labor problems, marketing, and agricultural problems; adjusts standard methods of mathematical analyses to type of data used; devises or develops new methods of analysis; selects methods of presenting information, such as charts, diagrams, graphs; searches out and corrects inconsistent data. May write reports and summaries presenting the findings."

"Statistician, actuarial; actuary (insurance). A statistician (profess. and kin.) who calculates the rates to be charged for different types of insurance (annuity, life, fire), basing his calculations on scientific investigations and analyses of natural laws affecting human life, theft hazards, and other conditions which affect insurance."

THE OUTLOOK FOR WOMEN IN MATHEMATICS AND STATISTICS

The term "mathematician" is usually reserved for those who have a Ph. D. or its equivalent in mathematics and are engaged almost exclusively in research or in college teaching.[1] Engineers and those engaged in the physical sciences also need preparation in higher mathematics, which they apply to specific problems within their fields. This discussion, however, is confined to the mathematician, the mathematical and applied statistician, and others whose principal preparation for their occupation is college-level training in mathematics or statistics. Among them are actuaries, teachers of high-school mathematics, statistical clerks, computers, mathematical aids and assistants. Engineering aids and engineering draftsmen, similar in their requirement and use of mathematics, are discussed in the bulletin on engineering. (See Bull. 223–5.)

Although the exact number of mathematicians and of others engaged in mathematical occupations is unknown, some idea of the size of the total group may be gained from the maximum number registered with the National Roster of Scientific and Specialized Personnel during the war, in April 1944: those in the field of mathematics numbered 17,357; in statistics, 3,737; and in actuarial science, 839. Only 3 percent of the latter were women, while 12 percent of those in mathematics and 14 percent of those in statistics were women (*15*). Since registration with the Roster is voluntary, there is no way of knowing how complete or how representative these figures are. But these percentages of women members correspond to those in the principal mathematical societies. About 15 percent of the members of the Mathematical Association of America and about 13 percent of those of the American Mathematical Society are women. Approximately 10 percent of the members of the American Statistical Association are women, and 3 percent of the fellows and associates of the two actuarial societies are women (*8*). However, among high-school teachers of mathematics, estimated at some 40,000 in 1947, women are in the majority, and they predominate in the National Council of Teachers of Mathematics. Many of these are trained principally in education, rather than in mathematics, and they are probably not among those on the National Roster list.

[1] In civil service and very occasionally in industry, however, the term is used also for the beginning professional level which requires the bachelor's degree with a major in mathematics.

Prewar Distribution

In 1940, according to an American Council on Education study, there were 695 living recipients of Ph. D. degrees in mathematics conferred in the preceding decade. Of the 647 who reported their occupation, 85 percent were teaching, and an additional 4 percent combined teaching and research. Less than 6 percent were engaged solely in research, and no other single type of work claimed as much as 2 percent of the group (*6*).

The exact number of mathematics teachers before the war is not known. But the first Roster count in December 1942 revealed that there were 3,483 mathematics teachers in institutions of higher learning; and 686, nearly one-fifth, of these were women (*14*). Mathematics was taught in some 28,000 high schools in the country (*7*). In many of these, there was only one mathematics teacher, who also taught one or more other subjects; in others, there were several full-time mathematics teachers on the faculty, sometimes as many as 25 or even more.

The relatively small number of mathematicians in industrial research before the war is indicated by Thornton C. Fry's estimate that in 1940 there were about 150 mathematicians doing consultative work on mathematical problems in industry (*4*). The largest prewar demand for women trained in mathematics was reported consistently by college placement bureaus to be in teaching or as statistical clerks in insurance or other business firms. Mathematics majors with special training in mathematical statistics or such applied courses as mathematics of finance, for example, were especially in demand. A few women, however, were employed even before the war in calculating or computing jobs with firms manufacturing such products as instruments and electrical equipment.

Some of this work was only arithmetical, and some women saw little difference, except in location, between their work as computers in an engineering department and that of cost clerks or calculating machine operators in the office. Several employers reported that they hired college mathematics majors not because of the need for higher mathematics on the job but because such training indicated accuracy and a liking for computing. However, even before the war, there were some exceptional women who were doing responsible mathematical work in industry. For example, one woman with a Ph. D. in mathematics from a large women's college has been engaged in research in the mathematical research department of a utility company for about 15 years. Although such cases are unusual, they indicate that opportunities do exist for the woman with ability.

In 1938, only 85 women mathematicians and statisticians were employed by the Federal Government (*16*). The Civil Service Commission reported that the demand for women mathematicians before the war was never great.

Annual Addition to the Supply

A small but steadily increasing number of persons took doctorates in mathematics before the war, and in 1940, 103 persons obtained Ph. D.'s in mathematics, the largest number in any one year up to that time (*5*). In the relatively new field of mathematical statistics, only 5 or 6 doctor's degrees were awarded annually before the war, according to recent estimates (*10*).

No figures are available on the number of persons receiving first degrees in mathematics in 1940. But the United States Office of Education reports the combined number of graduates with majors in mathematics and in physical science in 1941–42 as 3,053, of whom one-third were women (*19*). In the same year, almost 1,000 people prepared to teach mathematics were graduated from colleges and universities, and about 45 percent of these graduates were women (*19*). For the most part, their degrees were from schools of education.

Wartime Changes

During the war there was a tremendous increase in the demand for women trained in mathematics in industry, in Government, and in research institutions working on Government projects. One women's college reported that every mathematics major had her choice of 25 jobs in industry or Government, and that the demand was overwhelming in research work. A coeducational university, which before the war had few outlets for mathematics majors except in routine calculating jobs, found many attractive jobs available to mathematics majors during the war, mostly in Government-sponsored research. This same story was repeated in a number of college placement bureaus throughout the country. There was a definite shift from the usual type of employment for mathematics majors in teaching and in clerical jobs in business firms to computing work in industry and on Government war projects.

Of 81 industrial firms visited by Bureau representatives near the end of the war or after its close, only 15, less than one-fifth, had employed college women in mathematical occupations during the war either in the research laboratory or in the plant, usually in the engineering department. Among them were gas and electric power companies, and manufacturers of transportation equipment, communications and

other electrical equipment, instruments, metal and metal products. The foods, paper products, and chemical industries were also represented, but the principal employment of women mathematical aids or assistants, computers, and calculators (as they were variously called), like that of engineering aids, was found in the industries in which engineering and physical problems rather than chemical problems were paramount. None were found in the 18 commercial laboratories visited.

Since their work consisted primarily of assisting engineers or research personnel with calculations or of performing inspecting or checking operations involving computations, their duties varied from purely routine arithmetical work to the solution of difficult problems requiring the use of calculus and other forms of higher mathematics. Graph and chart making was sometimes involved. In an aircraft plant, for example, beginning "computers" read blueprints and made weight calculations on simple parts, using slide rules and calculating machines. More experienced computers employed in the same plant were working under the supervision of test engineers and assisted them by working out solutions of differential and integral equations, by plotting test data, and by preparing data sheets and charts. The only industrial establishment visited in which women were called mathematicians was another aircraft plant. The requisite training was 2 years of advanced college mathematics, or, for "senior" mathematicians, 4 years of training and experience. More routine work was done by technical computers, who were required to have at least 1 year of college mathematics.

On Government-sponsored projects farmed out to university and other private research laboratories during the war, like those carried on at the Radiation Laboratory at Massachusetts Institute of Technology and the Manhattan project work at the University of Chicago, women mathematicians, especially those who combined physics with their mathematical training, were employed in relatively small numbers, along with a larger number of computers with only the bachelor's degree. Because such demand was virtually nonexistent before the war, it made a sizable impression. Some women transferred from college teaching to this type of work during the war period.

The women's military services, especially the WAVES, in the early expanding phase of their programs, were particularly eager to recruit college graduates with training in mathematics and science. Approximately 1,500 college graduates, most of them with mathematics or science majors, became WAVES officers who were trained for technical work in communications, air navigation, and aerology, often by other WAVES, whose earlier scientific training and teaching experience had resulted in their selection for such work.

A large group of the women became aerological officers and were engaged in meteorological work. (See Bull. 223–7, on Meteorology.) Others were assigned to such jobs as instruction in air navigation and work in ordnance. One woman supervised naval personnel assigned to a ballistics laboratory; another worked on computations of ballistic range tables and bomb tables, making computations from penetration charts and of various problems of exterior ballistics. A few others were assigned to survey work in radio, radar, and electronics, checking specifications and obtaining information from radio companies for complete identification of radio parts.

Mathematician, computer, geodetic computer, and cryptographer were among the job titles of a small group of WAC personnel who had the needed mathematical background for such work. Those who had some statistical training worked as statistical clerks, financial clerks, and financial technical clerks (*23*).

In the Federal Civil Service, women trained in mathematics were sought for many jobs, beginning at the junior professional level, which required only the bachelor's degree with a major in mathematics. They were employed not only in the War Department (Ordnance, Signal Corps, Engineer Corps) and in the Navy Department, including the Naval Research Laboratory, but also in the National Advisory Committee for Aeronautics, the Bureau of Reclamation, the Federal Bureau of Investigation (as cryptographers), the National Bureau of Standards, and the Coast and Geodetic Survey. Special courses in mathematics were given in the Engineer Corps, Ordnance, and the Signal Corps, all in the War Department, to train needed personnel (*22*).

In Government, as in industry, the work varied from simple calculations to more complex assignments. Much of it was routine, but, as one research man long in Government service puts it, most mathematical work, no matter the degree of difficulty, involves routine. However, the difference between the mathematician and the routine computer, according to a well-known woman mathematician, "is precisely in handling the nonroutine aspects of the problem * * *. The distinctive contribution of the mathematician is either in clarifying the structure of a problem which has confused the engineer or physical scientist, and formulating it in mathematical language; or in creating a new mathematical theory, or extending a branch of an old one."

The increased Government and industrial demand, plus the drafting of men into military service, resulted in shortages of qualified teachers. Early in the war, on the basis of reports from 1,060 colleges and universities in the fall of 1942, the United States Office of Education stated that mathematics was one of the subject fields in which there

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was a great number of vacancies, 57, on these college and university faculties (*17*).

The demand for statisticians and statistical clerks increased tremendously during the war. In 1944, the American Statistical Association had requests for more statisticians than it could supply, at salaries of $2,000 to $6,000 annually (*12*). College placement bureaus reported that women mathematics majors had their choice of a wide variety of jobs as statistical clerks or computers. The War and Navy Departments, medical centers, public health departments and agencies and other medical groups, as well as insurance companies, and at least one Federal Reserve bank were among the employers of recently trained statisticians.

A study of the employment of the members of the American Statistical Association in 1945 showed that the largest proportion of them, nearly two-fifths, were in Government, most of them in the Federal Government. Almost one-fifth were in colleges and universities, and another one-fifth were in manufacturing industries and financial institutions. About half of the members lived in two areas, the Washington, D. C., area and New York State, chiefly New York City. There was an approximately equal number in each of these areas (*8*). In the Institute of Mathematical Statistics the proportion of members in academic positions was much higher; more than one-half of them were so employed (*10*).

The lack of teaching personnel made it necessary for some schools to curtail their course offerings in mathematics. This was especially serious for those who wanted to go on with advanced training, but who found that only standard mathematics courses were being offered (*3*).

The number of doctorates awarded in mathematics, never large, declined sharply during the war as prospective students were withdrawn into military service. More than 100 were earned in 1940; only 41 in 1944 (*5*). The number of persons receiving first degrees in mathematics and science also declined from 3,053 in 1941–42 to 2,709 in 1943–44. The number of women in the group, however, increased from 1,012 to 1,141 (*19*).

Under the special Engineering, Science, and Management War Training programs, a number of women were given special training in mathematics to equip them for war jobs in industry and Government, according to the United States Office of Education. Among these courses were: engineering mathematics and calculus, as well as such specialized applied courses as mathematics for aircraft workers, for high-school teachers, for engineering aids (*18*). In addition, approximately 3,500 production and inspection engineers and other industrial personnel, from over 800 of the larger industrial corpora-

tions, were trained in the use of some of the simpler statistical methods of quality control, in short intensive courses given throughout the country (*10*).

The wartime emphasis on sciences, particularly the physical sciences and mathematics, stimulated enrollments in regular college mathematics classes. Prof. G. B. Price, in a study of enrollments in mathematics courses for the Mathematical Association of America, found substantial increases in enrollments between 1941–42 and 1942–43. The increase was usually 30 percent for men's colleges and ranged from 25 to 40 percent in eastern women's colleges (*3*). But coeducational schools, with few exceptions, reported little or no increase in the number of students taking mathematics. Despite the higher enrollment of women in mathematics courses, the number of women majoring in this field remained very small. Reports from 24 colleges and universities on women graduating with majors in mathematics indicated no abnormal fluctuation in the number of such graduates during the war period.

Earnings and Advancement

The earnings of a college graduate with a degree in mathematics depend upon the type of work that she does. They are low in the largest field, that of teaching, although they have been increasing recently. According to scattered college placement bureau reports, most of the beginning jobs in teaching and in business pay less than $2,000 per year; during the war, many beginning jobs in industry paid $2,000 or more per year, and this was the beginning rate for mathematicians in Government. In 1947 the entrance salary in the Federal Civil Service for mathematicians and statisticians was $2,644 per year.

Teachers' salaries vary considerably, not only in different sections of the country but also in cities of different size. In 1940–41, the median salary of $2,768 paid to high-school teachers in cities having a population over 100,000 was nearly twice as large as the $1,428 received by those in cities of 2,500 to 5,000 population. By 1946–47, the median salary of teachers in the largest cities had increased to $3,593. For those who taught in cities whose population was 2,500 to 5,000, the median salary in that year was $2,274. Although the difference between the earnings of teachers in the largest cities and those in the smallest cities was less in 1946–47 than in 1940–41, nevertheless it remained a substantial one (*9*). According to the United States Office of Education: "The median salaries of professors in different types of publicly controlled institutions ranged in 1939–40 from $2,900 to $5,000, and in different types of privately controlled insti-

tutions, from $1,800 to $5,000. Associate and assistant professors, and instructors, on an average, received less" (*20*).

Statisticians, at the Ph. D. level, are paid somewhat higher salaries than are mathematicians. This is partly a result of their scarcity. Only about 50 Ph. D.'s in mathematical statistics have been awarded so far, according to a recent estimate (*10*). It is also due in part to a difference in type of employment. Most persons who have the Ph. D. in mathematics teach in colleges and universities, where salaries are relatively low. On the other hand, professional statisticians are more likely to be employed in industry or in Government, often at higher salaries. This is particularly true of actuaries. At the bachelor's level, salaries are more nearly equal to those in mathematics, although the opportunities are broader for the graduate trained in mathematical and applied statistics.

Women mathematics majors with the bachelor's degree sometimes become statistical clerks, whose jobs usually pay about the same as those of computers. Although salaries for statistical clerks with college background were as low as $1,000 per year before the war, in 1946 placement bureaus reported that mathematics majors were being hired as statistical clerks by State agencies and private industry at $140 and $150 per month, or about $1,680 to $1,800 per year.

Except for Ph. D.'s, women trained in mathematics tend to be employed at the assistant level. In the industrial establishments and in the Government agencies visited in connection with this study, only a few women mathematicians were found in high-level jobs, and they usually had also specialized in one of the physical sciences. However, one woman in industry was supervising a large group of women computers; another was found on independent research work of a Government research project. In the teaching field, women are appointed to college faculties, but only a few reach the professorship level. They seldom become heads of departments, either in colleges or in secondary schools, except in colleges and schools for women. That it is possible for competent, well-trained women to attain positions of responsibility is indicated by the achievements of a few. Listed in the 1938 edition of American Men of Science, among the 80 mathematicians who have made outstanding contributions to scientific progress, were 4 women (*2*).

Because there are many more outlets for statisticians and because there is a shortage in this field, advancement is usually more rapid for qualified women in statistics than in mathematics. The possession of the Ph. D. is important for recognition in this field, too. Because of their background and understanding of the insurance business, men actuaries frequently move into high executive positions in insurance firms (*1*), but this is seldom true of women.

Organizations

Among the largest professional mathematical societies are the Mathematical Association of America, the American Mathematical Society, and the National Council of Teachers of Mathematics. Each of the first two groups has more than 3,000 members. The teachers' group has about 6,000 members, most of whom are women. Most of these have mathematical training, although there may be some who do not, since the only requirement for membership in all of these groups is an interest in mathematics.

There are a number of professional societies for statisticians, some of them confined to the special fields in which statistics is applied. In addition to the Institute of Mathematical Statistics, which includes statisticians interested in statistical theory and technique, there are, for example, an Econometric Society and a Psychometric Society, whose members have specialized in statistical measurements in the field of economics and psychology respectively. All of these are of comparatively recent origin and have had a great increase in membership in a relatively short time. The American Statistical Association is an all-inclusive group, which in 1946 had some 4,000 members, about 10 percent of them women. The Institute of Mathematical Statistics, organized in 1935, had about 900 members in 1946; interest in statistics is the only requirement for membership in the Institute as well as in the American Statistical Association (*10*). Membership in the principal organizations of actuaries, the Actuarial Society of America and the American Institute of Actuaries, on the other hand, is restricted to those passing a series of examinations given jointly by the two societies. Candidates become associate members upon passing five examinations and full members or fellows after passing 3 more. In these two groups combined, in which the membership is largely duplicating, there are only about 565 fellows, including actuaries in the United States and Canada. There are 562 fellows and 301 associates of the Actuarial Society, of whom 12 fellows and 11 associates are women.

The Outlook

Although, during the war, production firms and Government projects were important outlets for women trained in mathematics, the emphasis, following the end of hostilities, shifted back to the more usual channels. Teaching and employment with insurance and other business firms again became the principal outlets for women college graduates with mathematical training. The wartime shortage of high-school teachers has continued, particularly in mathematics and certain other fields (*20*). Placement officers in colleges throughout the coun-

try in 1947 noted a continuing demand at the wartime level for women mathematics teachers in secondary schools. At least 40,000 teachers of mathematics were teaching in junior and senior high schools in 1947, according to the chairman of the Commission on Postwar Plans of the National Council of Teachers of Mathematics. The preponderance of women in this organization is indicative of their numerical importance in high-school teaching. Because men appear to be leaving this field, it will become increasingly important for women.

Most high-school teachers give instruction in more than one subject, and existing teaching vacancies can often be filled only by persons proficient in several related fields. Certain subjects tend to be grouped together. Since mathematics teaching is usually combined with that of the physical sciences, the woman who plans to teach high-school mathematics will have wider opportunity if she is also able to teach high-school science, particularly physics or chemistry.

In colleges and universities, too, opportunities for women mathematics teachers continued. The secretary of the American Mathematical Society stated in 1946 that there were not enough well-trained women to fill all the first-class mathematical positions available to them in colleges and universities. Some graduate work is practically essential for appointment to college faculties, and, before the war a Ph. D. was considered necessary to attain professorial rank. However, the Women's Bureau found, in 1947, that of a sample of women with the rank of assistant professor or above in mathematics, less than one-half had the Ph. D. Shortages will probably continue in this field for several years; but as more persons with the Ph. D. become available it will become more difficult to attain professorial rank without it. A report to the President in 1945 predicted that there will be, due to the war, a total deficit of 1,200 Ph. D.'s in mathematics by 1955 (*21*).

Most of the wartime research projects sponsored by the Government were dropped after VJ-day. In the few that continued, the small number of mathematical jobs were filled by the staffs of the institutions at which the research was being done and by men with mathematical skills who were being released from military service. The women's military services, which utilized women with mathematical training during the war, were reduced to very small staffs. One, the SPARS, ceased to exist, and the continuance of the others will depend upon the passage of special legislation. In any case, only a few mathematical jobs will be found in peacetime in these agencies.

Federal civil-service demand for women mathematicians continued after the war. In 1947 a few women mathematicians were still employed in such agencies as Ordnance in the War Department, the Naval Research Laboratory, the Coast and Geodetic Survey, the National

Bureau of Standards, the National Advisory Committee for Aeronautics, and the Tennessee Valley Authority. It appeared that the demand from the Federal agencies would continue for some time to outstrip the supply of those qualified. At the National Bureau of Standards there were almost as many women mathematicians employed in 1947 as there were during the war. On the other hand, at the Coast and Geodetic Survey, women were being displaced as men veterans returned. The Federal Bureau of Investigation, also, had already dropped many of the women who had been hired for cryptographic work during the war.

Women mathematicians and computers in 1947 were working on the National Bureau of Standards mathematical tables project, located in New York. In the spring of 1947, this project employed seven mathematicians, excluding the Director; three of them were women, two of whom contributed work on a research level. There were also 24 women computers, about two-thirds of all the computers on the project. However, in 1946, most of the vacancies on the computing staff had been filled by male veterans. Turn-over is low, and it is not expected that there will be many openings for men or women computers there in the near future.

In industry, 14 of the 15 establishments covered in this study that had women mathematical workers on the pay roll during the war continued to employ some of them following the war. The number of women in mathematical occupations in these firms even during the war was small, seldom over 25, although one very large corporation employed about 100 women in mathematical work. These were computers doing calculations for the technical staff; some of them have been employed in these same jobs for many years.

Most of the industrial jobs available to women will continue to be in computing, but this demand is almost negligible as compared with that during wartime. Calls from industry for women trained in mathematics were reported to be rare in 1947. A large aircraft company, for example, which during the war asked one college for 100 or more women at a time, was asking for groups of only a half dozen after the war's end.

Some of the employers expressed a preference for men, although they planned to retain the women mathematical workers they had hired during the war. As the women leave, however, men will be hired to replace them. College placement officers also reported that some well-qualified graduates had been dropped from industrial research jobs held during the war. Although many women are continuing on their wartime mathematical jobs, it is difficult to say how much of the gain will be in terms of permanent opportunities for

women. Much depends on the success of those who remain on the jobs which opened up during the war.

From 1940, when there were in industry about 150 mathematicians trained to or nearly to the Ph. D. level, to 1947, there was an appreciable increase in such personnel, according to the statement of a prominent research mathematician in the communications industry. Not only is normal industrial research going forward, but a considerable amount of postwar military research is continuing, partly in industry, partly in Government laboratories, and partly in universities. Many of the mathematical questions raised in this type of research are akin to those raised in normal industrial research. A substantial number of mathematicians are engaged in this work, although few of them are women.

Although the demand for highly trained mathematicians in industry will increase, scientists seem to agree that it will never be comparable in volume to that for engineers, chemists, or physicists (*4*). Opportunities for the woman Ph. D. in industry are few compared with those on college faculties. However, entrance into industrial research will be easier for women Ph. D.'s in the next few years than it is likely to be later when a greater supply of men with the doctorate will be available.

Employers complain frequently that men as well as women with degrees in mathematics enter industry with no knowledge of applied mathematics or of the problems and the terminology of the industry (*24*). Women who want a career in mathematical research in industry can increase their opportunities by taking some engineering or other applied courses that will increase their understanding of the practical problems requiring mathematical solutions in industry. For consulting or research work in industry, a Ph. D. degree and a knowledge of the industry are essential.

Although the United States assumed world leadership in pure mathematics between World War I and World War II, mathematicians in this country have tended to ignore applied mathematics, and not much emphasis has been placed upon it by institutions of higher learning. But the wartime situation emphasized the importance of applied mathematics, which was used in the solution of problems relating to aircraft design, explosion theory, exterior ballistics, and nuclear physics, among others. Partly as a result of its prominence during the war, universities are giving somewhat more attention to applied mathematics than formerly. There is a School of Applied Mathematics at Brown University and an Institute of Mathematics and Mechanics at New York University; and other universities are offering courses in this field. In addition, it has been proposed that a unit, to be known as the National Applied Mathematics Laboratories, be

established as part of the National Bureau of Standards. The purpose of the unit is described by the Bureau as follows: "It will specialize in numerical and statistical analysis, and will undertake to offer various services in these fields, and carry on a broad program of research and training. Particular emphasis will be placed on the development of high-speed automatic computing machinery and the mathematical theory needed for its effective use." The projected program for the laboratories also includes a training program, to consist of instruction and work experience, for graduate students in applied mathematics.

The industrial demand for statisticians, which increased tremendously within recent years, especially in the last decade (*10*), appears to be continuing. This growth was further stimulated by the wartime use of statistics in statistical control work and in planning. Sampling methods, for example, developed by mathematical statisticians, made it possible and safe to substitute inspection of only one of a number of units produced in a war plant for the inspection of every unit. The saving of time and manpower was tremendous. This is only one of the many applications of statistics that has resulted in accelerating the demand for statisticians.

The National Roster of Scientific and Specialized Personnel reported that, in a 9-month period in 1945–46, for every 1,000 persons registered in statistics, there were 30.7 vacancies reported to the Roster, as compared with 4.4 vacancies per 1,000 registrants in mathematics and 23.9 in physics. The openings in statistics were divided about equally between industry and Government; there were none from colleges, which usually recruit directly (*10*).

The postwar demand for statistically trained personnel was studied by the National Research Council's Committee on Applied Mathematical Statistics, which in April 1946 made an inquiry concerning requests for statisticians received by 30 leading authorities in this field. Although undoubtedly some of the requests were duplicating, their number and type illustrate the demand. About 140 requests were received from business and industry, most of them to fill positions in industrial quality control and in engineering, but there were also many for sampling experts in market research organizations. The educational requirements ranged from the bachelor's degree to the doctorate (*10*).

Almost as many requests, 135 in all, came from academic institutions for persons with Ph. D.'s in mathematical statistics, or in such fields as agronomy, biology, economics, or psychology, if combined with a minor in statistics. The positions offered ranged from instructorships to full professorships. One of the 30 authorities reported 12 requests for men trained in agronomy and statistics;

another had received requests for mathematical statisticians from 21 colleges and universities (*10*).

Women mathematics teachers in 1947 numbered 355 in 330 colleges and universities which comprise a United States Office of Education enrollment sample of the 1,749 institutions of this type in the United States. Most of them, 304, were teaching mathematics only; the others were instructing in some other subject as well. If these institutions are as representative of the faculties of all institutions of higher education as they are of enrollments, 1,710 women college teachers of mathematics were employed in 1947, 85 percent of whom taught mathematics only. The others usually taught a science, such as physics or chemistry, but sometimes a language, or economics, or some other subject was combined with mathematics in the teaching schedule. A very few combined the duties of counselor or dean with mathematics teaching. Two women included in the sample headed mathematics departments. Unlike women teachers in some of the sciences, women mathematics teachers were found in all types of institutions, in larger universities as well as in women's colleges.

Government was also represented among the requests for statisticians reported by selected authorities to the National Research Council's Committee on Applied Mathematical Statistics. Approximately 90 requests for statisticians came from Federal and State government agencies in a 6-month period. Most of these were from the Federal Government (*10*).

In the fall of 1944, David M. Schneider made a survey of 164 governmental agencies in 23 States, representing all areas of the country. He estimated that State agencies needed, at that time, a total of over 600 statisticians and nearly 1,100 statistical clerks. This included both currently employed personnel and vacancies. Since there has been a trend toward greater utilization of statistical personnel, it is likely that the total need in State agencies is at least as great as it was in 1944. State departments of labor employ the largest number of statistical clerks; public welfare departments and health departments rank second and third in employment of statistical personnel, who are also employed in State departments of highways, agriculture, taxation, education, banking and insurance. Comments from the States indicated that, although practically all municipal governments perform some statistical functions, few technically trained statisticians are employed for such activities (*11*).

According to the National Research Council, in recent years the growth in statistical opportunities has been especially great in the fields of: (*a*) industrial statistics (quality control, research, and development); (*b*) research in the biological sciences; (*c*) collection and

analysis of government statistics; (*d*) market research and commercial sample surveys; and (*e*) psychological testing (*10*). However, there are jobs for statisticians in many and varied fields, including that of teaching to prepare additional needed statisticians.

The 1947 count of women faculty members in 330 institutions of higher learning, as mentioned on page 4–14, revealed only 10 women teaching statistics and 3 teaching biostatistics in these schools. This would indicate that there are about 45 women teaching statistics primarily in all colleges and universities, two-thirds of whom are in publicly and privately controlled universities and the others in technical and professional schools. There are probably a great many more who teach statistics courses along with other subjects such as economics or mathematics. These would not show in the count, since such faculty members would be listed as instructors or professors of economics or mathematics.

Courtesy U. S. Department of Labor

Figure 2.—A mathematical statistician in the Bureau of Labor Statistics, U. S. Department of Labor.

For at least a few years to come, then, there will be ample opportunity for statistically trained women, who will not encounter as much discrimination in this relatively new and growing field as women in many other professional fields have had to combat.

The inadequacy of present facilities and teaching personnel for the training of statisticians has received attention in a special study of the Committee on Applied Mathematical Statistics of the National Research Council. In 1946, only 10 colleges and universities were reported to have programs in mathematical statistics adequate for the training of Ph. D's (*10*). Among the schools at which outstanding work is being done in this field are Princeton, the University of California, Columbia, and Iowa State College. Another school which has recently emphasized this field is the University of North Carolina, where an Institute of Statistics is directed by Prof. Gertrude Cox. Only 14 institutions, including most of the 10 that were prepared to offer the Ph. D. in mathematical statistics, were equipped also for advanced training in applied statistics (*10*).

For Government workers and others living in Washington, D. C., a variety of courses in statistics are offered at the Graduate School of the United States Department of Agriculture. Evening classes are held, and in addition to classwork, students can get experience in sampling at the Bureau of Census and other agencies.

A specialized group of statisticians are the actuaries, whose opportunities are limited chiefly to insurance companies, although there are expanding opportunities for them in business and industry, because of the increasing trend toward pension and retirement plans. In addition, there are jobs in many State insurance departments, which supervise and regulate the insurance business, and in such Federal agencies as the Bureau of the Census, the Social Security Administration, and the Railroad Retirement Board. There are also occasional calls from Latin-American and other foreign countries for American-trained actuaries. In spite of the limited number of organizations which employ actuaries, this field is not overcrowded. There are over 350 life insurance companies in the United States and Canada; most of them are growing in size, and their business is becoming more complex. There are only about 565 fellows of the Actuarial Society of America and the American Institute of Actuaries, and many more are needed (*1*). "In the next few years the 350 insurance companies in the United States will require several hundred more actuaries than they now have," according to the Committee on Applied Statistics of the National Research Council (*10*).

Those who plan to enter this profession usually major in mathematics but often study economics or business administration in addition. They frequently take the first three of the eight examinations

necessary to qualify themselves as Fellows of the actuarial societies while they are in college, taking the other examinations later while employed, usually with an insurance company (*1*). Only the woman of superior ability should be encouraged to take the very difficult actuarial examinations, which only a small proportion of the candidates pass.

Although women fill most of the clerical jobs in insurance offices and some become actuaries' assistants, they rarely become actuaries. One young woman who worked as an engineering aid for an aircraft company during the war and had excellent recommendations from that company was recently hired by a firm of consulting actuaries and hopes to become an actuary. But insurance companies have traditionally preferred men for these positions, and only the exceptional woman will pass beyond the position of assistant to an actuary. Two women, one of them a Negro, are actuaries of small companies, although others have reached the mid-ranges of associate actuaries and mathematicians in larger companies. This is a field in which women must have unusual ability to succeed. A prominent actuary says that, "A woman can succeed in this field, but she has to be 50 percent better than her nearest male competitor to do it." An outstanding woman who has combined actuarial training with a Ph. D. in economics suggests that the woman actuary's best chance for success lies in doing the unusual, in finding a relatively unexplored area and specializing in it. She attributes her own success to her ability to handle problems which a person trained solely as an actuary or solely as an economist would not be prepared to handle.

Although the shortage of Ph. D's in mathematics and statistics is expected to continue for some time, there appeared in 1947 to be a satisfactory adjustment in the demand for and supply of women with the bachelor's degree in mathematics. According to reports from college placement bureaus, even before the war, the number of women mathematics majors graduating from college each year, although small, was just about enough to meet the demand for people with such training. Recent reports indicate a return to this tendency to equilibrium following the wartime distortion. But the shortage of statisticians, trained at both the bachelor's and the Ph. D. level, will continue for some years to come.

Women as well as men who have the capacity to do doctoral work in mathematics, however, are needed in greater numbers than ever before, and training is readily available in a number of institutions of higher education. Theoretical mathematics is basic to scientific progress, and the ability to contribute to knowledge in this field is so exceedingly rare that an oversupply is almost inconceivable.

APPENDIX

Minimum Education and Experience Requirements for Application for Beginning Federal Civil Service Position as Junior Professional Assistant With Option as Mathematician ($2,644 a year)

(As taken from Civil Service Announcement No. 75, issued October 14, 1947, closed November 4, 1947)[1]

Applicants must have successfully completed one of the following:

A. A full 4-year course, in a college or university of recognized standing, leading to a bachelor's degree in mathematics. This study must have included courses in mathematics consisting of lectures and recitations totaling at least 24 semester hours, and courses in the physical sciences (engineering, physics, geology, astronomy, chemistry, etc.) totaling 12 semester hours; or

B. Courses in mathematics, in a college or university of recognized standing, consisting of lectures and recitations totaling at least 24 semester hours; plus additional appropriate experience or education in scientific fields which, when combined with the 24 semester hours in mathematics, will total 4 years of education and experience and give the applicant the substantial equivalent of the 4-year college course prescribed under A above. The following are types of experience which will be accepted in combination with education to complete the 4-year requirement:

Subprofessional or professional experience in the mathematical or statistical analysis of observational data in the physical or biological sciences which provided a working knowledge of the theory and application of mathematical principles.

Research experience in such fields as physics, chemistry, engineering, biology, etc., which involved the evaluation of reports and the organization of experimental data.

Subprofessional and higher grade laboratory work, production or manufacturing involving technical duties, and similar types of work which provide a means of obtaining a working knowledge of the theory and application of the scientific principles of a physical or natural science or of engineering.

In either A or B above, the courses must have included analytic geometry, differential calculus, integral calculus, and in addition, any four of the following: (*a*) Trigonometry; (*b*) theory of equations; (*c*) vector analysis; (*d*) statistics; (*e*) higher algebra

[1] For more complete and later information, consult latest announcements of the Civil Service Commission posted in first- and second-class post offices.

(beyond elementary college algebra); (*f*) differential equations; (*g*) advanced differential calculus; (*h*) advanced integral calculus.

Minimum Education and Experience Requirements for Application for Beginning Federal Civil Service Position as Junior Professional Assistant With Option as Statistician ($2,644 a year)

(As taken from Civil Service Announcement No. 75, issued October 14, 1947, closed November 4, 1947) [1]

Applicants must have successfully completed one of the following:

A. A full 4-year course leading to a bachelor's degree, in a college or university of recognized standing, with (1) 20 semester hours in statistics; or (2) 30 semester hours of college work consisting of a combination including 6 semester hours in statistics and 24 semester hours in any one or any combination of the following: (*a*) economics; (*b*) agricultural economics; (*c*) sociology; (*d*) political science; (*e*) social service; (*f*) education; (*g*) psychology; (*h*) home economics; (*i*) biology; (*j*) public health; (*k*) agriculture; (*l*) mathematics; (*m*) engineering; (*n*) physics; or

B. Courses as given under A above; plus additional appropriate experience or education which, when combined with these courses, will total 4 years of education and experience and give the applicant the substantial equivalent of a 4-year college course. The following are types of experience which will be accepted in combination with education to complete the 4-year requirement:

Progressively responsible clerical experience in (*a*) use of frequency distributions; (*b*) calculation of measures of central tendency, measures of variation and skewness, or index numbers; (*c*) graphic analysis, time series analysis, or correlation analysis under the direction of a professional statistician.

Progressively responsible experience in planning statistical surveys; processing statistical data, including the collection, compilation, verification, and appraisal for consistency of numerical data; and analyzing statistical data.

[1] For more complete and later information, consult latest announcements of the Civil Service Commission posted in first- and second-class post offices.

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