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This paper is concerned with a study of women in mathematics. It includes an examination of the role of women in mathematics historically; a brief investigation into the factors and obstacles encountered which have kept women out of mathematics. There is a section devoted to several specific women mathematicians through brief biographical sketches. Other features include an extensive bibliography as well as an index of women mathematicians referenced to this bibliography.

Marion P. Emerson

Approved for the Major Department

Harold E. Dunst

Approved for the Graduate Council

A COMPENDIUM: THE WOMEN OF MATHEMATICS

A Thesis

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by

Ruth E. Channell

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PREFACE

"Compendium" - a brief treatment of an extensive subject; a full list or inventory. Since the purpose of this paper is to provide both brief biographical sketches of a number of women mathematicians and an extensive bibliography as well as general information about women and mathematics, the title "A Compendium: The Women of Mathematics" seems singularly appropriate.

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A COMPENDIUM: THE WOMEN OF MATHEMATICS

Introduction and Background

While studying the history of mathematics, the researcher finds that it is a history dominated by men. Indeed, from antiquity until relatively modern times, there are but a handful of women whose names can be readily found linked with the field of mathematics. A natural consequence of this fact is the question: Why have there been so few women in mathematics? Other questions which arise while contemplating women and mathematics are: Who were the women mathematicians; what were their contributions to mathematics; and where can information about these women be found? These are the basic questions to be researched when studying the women of mathematics. Furthermore, these are questions to which the answers are not easily found. While the study of women mathematicians as well as women and mathematics is rapidly becoming a popular field of research, it is still in a neophyte state. Information is scattered and often contradictory. There simply does not exist at this time a good, extensive central source of information about the women of mathematics. This lack of conveniently available references has been a prime motivator for this paper, along with a basic curiosity for the apparently obscure, coupled with an obsession for the orderly assimilation and organi-

zation of subject matter. Consequently, it is the purpose of this paper to serve as a handbook or reference about the women of mathematics. Perhaps the appropriate nomenclature to be used for this paper would be that of digest - a body of information condensed, arranged and classified. As such, the features of this paper include explanations for the scarcity of females in the history of mathematics, an historical overview of general survey, brief biographical sketches of the more prominent women mathematicians, general resource information, and an extensive bibliography with a reference system for the specific women mathematicians.

When doing any research on mathematicians, there are a few basic problems encountered, regardless of the gender of interest. For example, which people are given the label "mathematician"? In particular, which persons are titled "physicist" or "astronomer" rather than "mathematician" and why? In answer to the latter part of this question, there are no clear lines of demarcation between these titles, nor are there any apparent, tangible criteria for the distinctions. A classic example of this nebulous state is the case of Einstein. Clearly, he was a genius at both mathematics and science. Yet, most historians treat him as a man of science. Moreover, relatively few surveys of the history of mathematics even refer to

Einstein. Yet, if specifically questioned: Was Einstein a mathematician?, surely all learned people would give an affirmative answer. The entire issue of appropriate nomenclature regarding the title "mathematician" versus "scientist" is complicated by a premise that mathematics is essential to, if not the essence of, all science. This premise, if accepted, carries with it the implication that all scientists must first be mathematicians as well as the subsequent implication that perhaps all who are considered great scientists must also be viewed as famous mathematicians. This idea is a moot point. Nevertheless, it is a point of particular concern to this paper. That is, if all female scientists who are acknowledged as significant figures in their fields, especially physicists and astronomers, were considered to be famous women mathematicians, then the scope of this paper would more than double. Furthermore, since the guidelines for classification as scientist versus mathematician are either vague, subtle, or perhaps nonexistent, some criteria for the distinctions must be chosen. Therefore, for the purposes of this paper, custom shall dictate. That is, those women physicists and astronomers who are cast in the resource material as noteworthy mathematicians shall be treated as such. However, it should be noted that there are women scientists who may have greater achievements in

their respective fields who are omitted while others are included.

Another prominent controversy encountered when researching the women mathematicians concerns the quality of their work as well as the significance of their contributions to the field. For instance, several famous women mathematicians are known primarily by the characteristic of being "first" with little notice of their work, i.e. first woman mathematician, first woman mathematician granted a Ph.D., first woman admitted to John Hopkins University, etc. Indeed, when researching, these non-mathematical descriptions seem to dominate and, in some instances, replace references to the mathematical works of these women. There are also several women mathematicians with various other overshadowing claims to fame. That is, they simply are not known primarily for quality of their mathematical endeavors. For instance, Lord Byron's daughter is one of the historical female figures in the study of mathematics. Another is well known as the "Witch" in mathematical circles, but there is little common knowledge of the woman herself or of her mathematical contributions. In addition to these women, are some females with colorful histories that attract attention. Consequently, the question arises of whether they are famous mathematicians, or just plain infamous. The most

notorious illustration of such figures, was Voltaire's mistress. She died shortly after childbirth in the presence of three men; her husband, the child's father, and Voltaire.

There is also a controversy revolving around an issue of women receiving the credit they are due. For instance, while it was at one time a common practice among male mathematicians to enter contests and publish papers under aliases, this was a necessity for women. A work known to have been authored by a female would not have been given proper credence. This raises the question of how much women's work was published in men's names? There are several known instances of women who were perhaps not given the credit to which they were due as their work was tied to that of another. Among these are members of brother/sister astronomy teams and husband/wife mathematicians who worked together. Most such couplings published in the man's name alone so that the work would be more readily accepted and fairly treated. The question of how much of the work was done by the women involved is still unanswered. Currently, historians and mathematicians are reviewing the writings and papers involved thereby changing the status of several women mathematicians. However, in many instances, the credit due the women can never really be ascertained. It becomes a question answerable

only by opinions, and these opinions vary greatly among the researchers.

There is another interesting example which illustrates the necessity of women disguising their gender. A woman applied for and was awarded a fellowship to study mathematics at Johns Hopkins University sight unseen. The application bore only the first initial. Accordingly, she was presumed to be a man. Had her sex been known, she would not have been accepted.

After the distractions from actual mathematics have been discharged, there is still another issue to be dealt with. There is still the question of the actual merit of the mathematics of these women. That is, does the work done by women mathematicians compare with the mathematics done by men, or is the work of these women given credit merely because it is the outstanding work among that which has been authored by females? There are a variety of possible responses to this question. For instance, it would be generally conceded that there would be no women representative on a list of the top ten mathematicians throughout history. However, when considering the ratio of women mathematicians to men historically, it would not be expected to find women ranked very highly. This reflects the attitude that the famous women mathematicians do compare with men. There is also historical evidence to support this

thesis. For instance, if Voltaire is to be considered a mathematician of merit, so also must his mistress. They both once entered a contest independently. Although neither won the highest awards, she was ranked above Voltaire. [281] Another example involves Weierstrass. No one will question the merit of Weierstrass. Consequently, his opinion should be valued. He once credited his favorite student, a woman, with having mathematical ability superior to his own. [41]

Nevertheless, these arguments represent but one side of the issue. There are many mathematicians today, both men and women, who promote the belief that there simply are no female mathematicians of significance. One of the arguments supporting this opinion is that many of the "famous" women have not done any original work. The most appropriate rebuttal to this is the fact that Euclid probably did little original work. Yet, no one begrudges him the title of famous mathematician. Aside from the basic argument regarding the lack of originality, the attempt to downgrade the merit of the mathematical works of females becomes a matter of an opinion poll. Furthermore, it is one in which a valid opinion is difficult to objectively form as the actual works of the women are not easily found and studied. Regardless of the quality and importance of the work done by women mathematicians, his-

torians have tended to downplay their mathematics and emphazie the "juicier" aspects of their lives. Moreover, this paper does little to remedy this situation as little effort has been made to collect or to present the mathematical works of the women mathematicians. Such an endeavor would be a monumental undertaking. Moreover, it would yield a product comprehensible to and appreciated by only mathematicians. At this point, it should perhaps be mentioned that this paper is intended to be readable as well as of interest and use to a more general audience.

While the question of the quality of the work done by women mathematicians remains unresolved, it is only fair to present both sides of the issue. Here, then, is the opinion of a reputable woman mathematician of today: "Emmy Noether is literally the only first class one woman mathematician either living or dead." (personal correspondence from Mary Ellen Rudin)

Obviously, the question of merit, although unresolved, is a valid consideration in the interests of objectivity when discussing famous women mathematicians. Nevertheless, for whatever their worth, there are and have been mathematicians of the feminine gender.

Most of the discussion thus far has been geared to the consideration of women and mathematics of the past. While women of the past and their work stand in scrutiny, their place in history being constantly questioned, the women of

today are undeniably competitive with today's men of mathematics. The sex barriers of yesteryear are disappearing, if not extinct. Today's mathematical works are precisely that, mathematical works. No one questions, unless from curiosity, the sex of an author. The novelty of female mathematicians has worn off among contemporary mathematicians. Nevertheless, those sex distinctions shall be reestablished to permit the inclusion of some contemporary women mathematicians in this paper. However, when examining modern mathematics and mathematicians, it is quite uncertain which names will be remembered in the future. Consequently, those twentieth century women who are included in this paper are there by virtue of the availability of biographical information about them and/or by suggestion of one or more of the many mathematicians with whom the author has corresponded while working on this paper. However, in the final analysis, it will be the history books of several decades from now which will render the verdict concerning the significance of the women mathematicians of the twentieth century.

Indeed, it is readily evident from the study of the history of mathematics that the field of mathematics has been dominated by men. In fact, unless the reader is specifically seeking out women mathematicians, it is unlikely that a female will be encountered. Moreover, even when

deliberately hunting for the feminine figures in the history of mathematics, it is sometimes difficult to make progress. One of the reasons for this is that there are not many female mathematicians throughout the ages. Indeed, the history of mathematics from ancient times through the nineteenth century is colored only slightly by the presence of women mathematicians. Moreover, the few names that are found are often challenged as mathematicians since the stigma of novelty by virtue of sex exists. As the number of women mathematicians has increased, this novelty of being a women mathematician has begun to dissipate. There has also been an accompanying de-emphasis on sex as a distinguishing characteristic between mathematicians as well as an establishment of equity in the evaluation of mathematicians. After all, a first rate mathematician should be just that, a first rate mathematician. Women, like men, should earn that distinction. Perhaps at some point in the future, the study of women mathematicians will be simply a study of first rate mathematicians who just happen to be women.

Mathematics, Women, and Social Structures

Why have there been so few women mathematicians throughout history? Why are there relatively few today? The former question has simplistic answers. The latter is the source of extensive contemporary research resulting in many suggested explanations as well as complicated schemes to alter the situation.

"Women do not do such things," historically speaking, that is, women simply did not participate in the study of mathematics, science, and technology. Lower class women were simply unconcerned with such matters, instead concentrating their efforts on day to day survival. Refined women studied the arts, music, and languages - not such unfeminine subjects as mathematics. Even those things which women did study were studied at home, not in structured institutions. Education stereotypically throughout the ages as well as throughout the various cultures has been geared to, if not restricted to, the education of men. Formal education has generally been begrudged those of the female sex until relatively modern times (post 1850). Of the handful of women mathematicians who did exist before that time, nearly all were able to do so as the daughters, wives, lovers, and/or sisters of mathematicians. The remainder were self-taught.

Furthermore, the women who did master various aspects of mathematics encountered great ridicule from their contemporaries as well as nearly universal lack of acceptance. This non-acceptance carried over into the modern era of mathematics. For instance, women who had succeeded in obtaining Ph.D.'s were denied the right to be faculty members at the great universities. Job discrimination is still a common complaint among women mathematicians.[114, 227, 317, 329] However, current trends in this country are to hire the woman.

While women throughout the ages have been overtly discouraged, if not restrained, in their pursuit of mathematical endeavors, this is no longer typical. Why, then, are there not more women mathematicians today? There are dozens of plausible, probable social explanations. However, before proceeding, there is one rather misguided belief concerning the issue which ought to be refuted. That is, the premise that women are biologically not suited to intensive intellectual activities. One of the contentions to support this idea is that women's brains are literally smaller than those of comparably sized men. This is a physiologically unsound statement. Another suggestion to support this thesis of intellectual inferiority is that women have less abstracting ability. This is also unproven. However, abstracting ability is a function of use, and

women in general are socially inclined not to use it. Women simply are not born mechanically uninclined! It is an achieved state which might be corrected if girls at early stages were encouraged to play with mechanical toys as are boys. Another argument advanced by proponents of women's mathematical ineptitude is that women cannot cope because they are emotionally unstable. It is true that sex hormones do enter the brain and that the edema associated with menstruation may cause slight pressure on the brain for a few days a month, but no correlation between these facts and mental capacity has ever been established. [329] Moreover, "coping" with mathematics to many would be far preferable to "coping" with the trials and tribulations of the domestic engineer (housewife); yet women are considered well suited for that task. Furthermore, how well do men cope? Consider the higher incidence of ulcers, high blood pressure and heart disease among men than women. Another contention is that girls are simply dumber than boys - also unproven. Of studies done involving I.Q. tests, an equal number favor girls as boys as the brighter sex, but the majority show no significant difference.[114] The mind of a child is sexless until society instills its attitudes and nature later renders boys and girls, men and women. Thus we see that the thesis that males are more efficient in the hemispherical cortical functions dealing

with abstract and visual space [329], that is, the thesis that men are more adept biologically to the study of mathematics, is simply unjustifiable.

Social conditioning, rather than overt repression or biology, is without question the most significant factor in and explanation for the lack of numbers of females in mathematical curricula today. From the moment a child is conceived, society begins conditioning its destiny. The parents ponder, plan and dream of the things they will teach it, the stereotypically boy things or girl things. From the moment a child enters the world, it is branded either pink or blue - labeled with color-coded wrist bracelets, gazed upon by visitors only upon the presentation of color-coded passes, and dressed in the traditional colors. As children grow, girls are geared to believing that they are "sugar and spice and everything nice" while boys, well, "Boys will be boys," without any apparent need for explanation nor justification of the presumed roles. Girls cook and clean and sew. Boys catch snakes, toads, and lizards. Girls are neat, weak and easily frightened. Boys are messy, strong and brave. Girls grow up, get married and have children. Boys grow up, get married, and support the family. The illustrations of sexist societal conditioning are unending. Many girls growing up do not fit their sexual stereotype; many con-

sciously fight the conditioning, becoming tom-boys. But the multitude of ways in which women are assaulted by sexual classification is reflected by the low percentage of women in mathematics classes. Higher level mathematics is simply one of those areas which has been traditionally colored blue - it is a boy's thing; it is not feminine to be good at mathematics; mathematics is too hard for girls.

Actually, mathematics is hard for the average person. Therefore, unless gifted or highly motivated to the task, most will not pursue the subject. Boys' motivation, as a function of societal conditioning, exceeds that of girls. Doctor, engineer, scientist - these are boy-type occupations which necessitate mathematics. Consequently, boys prepare for such careers by taking all available high school mathematics. They also work harder to achieve their goals than do girls. This is evidenced by the fact that the majority of matriculating mathematics students in college are women, but the attrition rate for girls is so high that only a small percentage of the women who start in mathematics classes finish the course. [317]

Women and mathematics is an extremely popular research item at the moment. There is a great deal of literature currently being published concerning attitudes of teachers and students towards mathematics at various grade levels. Such studies cover several aspects of mathematics and sex.

Of the published literature, a booklet by John Ernest. Mathematics and Sex,[114] is probably the most comprehensive. It includes an overview of the literature, supplying the results of the various research which has been done. It also contains a good deal of original research. Because of its all inclusive nature as well as its concise structure, it is the single most useful and interesting resource material about sex differences in attitudes, achievement, backgrounds, enrollments, attrition rates, and employment conditions. Consequently, in reporting some of the items of interest which are contained in Ernest's booklet, a good survey of the literature is provided. Here, then, are some of the highlights of Mathematics and Sex.

1. Research has uncovered no sex difference in mathematics preference among students in grades two through twelve. Thus the conclusion is drawn that there is nothing intrinsic in arithmetic or mathematics that makes it more appealing or enjoyable to one sex than the other. However, when mathematics becomes optional at the high school level and in college, far fewer women take it. Consequently, women are more restricted in their career options as they are less prepared.

2. A study of highly creative women mathematicians shows that two-thirds of those surveyed had professional men as fathers and that as a group, these women identified primarily with their fathers. Ernest also reports of another study in which it was found that a child's attitude towards mathematics is strongly influenced by his/her parents.

3. Several other studies reported by Ernest result in the conclusion that society has created the situation where the female self-image can be reflected in the belief: "I'm not good at math."

4. Ernest's studies show no significant sex differences in mathematics performance at the elementary level.

5. "In our small survey, almost half the teachers expect their male students to do better in mathematics while none of them expect the female students to do better."

This has obvious implications in that there is substantial educational research supporting the thesis that parent/teacher expectation greatly influences child behavior and achievement.

6. In a survey administered to prospective elementary education teachers, 26% indicated indifference toward mathematics while 14% indicated that they actually disliked or hated it. The obvious conclusion is that "40% of these prospective teachers are likely to transmit something less than a positive attitude towards mathematics to their students."

This is particularly distressing when examining the other aspects of the research which indicate that students' attitudes towards mathematics are also influenced greatly by their teachers.

It would seem that both mathematical interest and ability among students in general is at the mercy of parents and early childhood teachers. This would suggest that proponents of mathematics - concerned teachers, parents, etc. - should support revamping elementary educa-

tion. Two possible improvements would be greater selectivity for elementary education candidates as well as improvements in degree programs. Alternatively, permit mathematics oriented instructors to teach the subject just as music, art and physical education are taught by specialty teachers.

Even if society's attitudes and educational structures were reformed equalizing a woman's options and opportunities, there probably still would not be equity of numbers of women mathematicians and mathematics dependent career women. While there is no biological inferiority on the part of the female psyche, there probably is a natural or developed inclination in many girls toward a family oriented life style. Granted, mathematics, science, engineering, and medical careers are not mutually exclusive with marriage and family. However, these things are time consuming and demanding to the degree that many women simply do not prefer them as career choices even though they now have the right and privilege to make such a choice.

Why, then, have there been, and why are there so few women mathematicians? The answer can be tersely summarized. It is overwhelmingly a function of the structure and influence of society. Since this is true, perhaps those women who succeeded deserve even more credit. As Gauss said in a letter to Sophie German, "...when a person of

the sex which according to our customs and prejudices must encounter infinitely more difficulties than men to familiarize herself with these thorny researches, succeeds nevertheless in surmounting these obstacles and penetrating the most obscure parts of them, then without doubt, she must have the noblest courage, quite extraordinary talents and superior genius."[41]

Historical Overview

History, from ancient times until modern times, contains the names of only a handful of women mathematicians. The first female encountered is Hypatia (5th century A.D.). She is acclaimed as the first woman mathematician, but her reputed beauty and charm coupled with her gory murder tend to overshadow her mathematical endeavors.

Several centuries pass from Hypatia's time until history mentions another female mathematician, eighteenth century Maria Agnesi (1718-1799). Maria is most commonly referenced as or associated with a curve - "The Witch of Agnesi". Of greater interest is the fact that she was a somnambulist. She would often retire and awaken to discover solutions to problems with no recollection of having done them.[116] In Italian history, besides as a mathematician, Maria is equally well-known for her charitable activities in attempting to improve the social conditions of the poor. The eighteenth century is also the historical niche of the infamous Marquise du Chatelet (Emilie de Breteuil, 1706-1749). Mistress of Voltaire, the Marquise is better known for her escapades than her mathematics. Nevertheless, she was regarded as the most outstanding woman physicist in France during her lifetime. [83]

There is a well-known group of three women who strad-

dled the turn of the century. Caroline Herschel (1750-1848) and Mary Somerville (1780-1872). These women astronomers were the first English women honored by the Royal Astronomical Society. Mary is also considered one of the greatest women scientists England ever produced. [83] A contemporary of these two women was Sophie Germain (1776-1831). Sophie is known as the "Hypatia of the nineteenth century."

Sonya Kovalevsky (1850-1891) is chronologically the next woman mathematician to be discussed. She, like the Marquise, led a colorful life. She was also enamored of literature as a career alternative. This interest in literature coupled with her social activities distracted from her mathematics and frustrated her mentor, Weierstrass. There is more material printed by Sonya and about her than any other woman mathematician. However, a good portion of these writings are in Russian. Consequently, there is a continuous re-evaluation of her worth and merit as more is learned about her work. Furthermore, in spite of the language barriers, Sonya Kovalevsky is generally considered the most significant and important woman mathematician of all time with perhaps the exception of Emmy Noether (1882-1935). The peers of Emmy Noether, Albert Einstein among them, considered her one of the world's greatest mathematicians - without a sex qualification. [108]

These eight women are those which by general consensus are considered the most famous women mathematicians - only eight from ancient times until 1935. While many mathematicians have heard of but a few of these eight names, it is of interest to note that these women studied under, worked with, critiqued the work of and/or were highly regarded by their respective contemporaries. These contemporaries comprise an impressive list of names familiar to today's mathematicians: Diophantus, Appolonius, Ptolemy, Lagrange Voltaire, Newton, Laplace, Poisson, LaCroix, DeMorgan, Weierstrass, Cayley, Carton, Klein, Hilbert, Hasse, vander Waerde, Alexandroff, Weyl, von Neumann, Einstein, Pierce, and Whitehead.

While there are only eight women mathematicians whose names stand out in history, this does not imply that there were only eight female mathematicians. Moreover, with the current trend in women's studies, more women's names are coming to light. Furthermore, the status of many women is being reconsidered and upgraded. One of these women is Lady Lovelace (1815-1852) who is sometimes referred to as the "mother of computers" as well as "the first computer programmer". [17] Another is Christine Ladd-Franklin (1847-1930). She gained admission to Johns Hopkins University by the use of a minor deception. That is, the university presumed her to be a man. Though not the first woman

student at Johns Hopkins, Christine was the first female survivor. She was also the first woman to be awarded a Ph.D. from Johns Hopkins. However, this was not done until forty-four years after she completed her studies when Christine was seventy-eight. Another woman of this time period is Dorothy Klumpke (Roberts) (1861-1942). Dorothy was the first American to receive a French "docteur des sciences mathematiques", as well as the first woman ever to be awarded this degree at Paris.[69] Dorothy was also the first woman to be elected to the Astronomical Society of France.[260] A comtemporary of Dorothy's, Mary Hegeler Carus (1861-1936), was a pioneer in the publishing world as well as an avid promotor of mathematics. Maria Cibrario was an assistant to Peano.[202] Grace Chisholm Young (1868-1944) was the first woman in this country to be granted a Ph.D. in mathematics by the standard matriculation technique. Rudin Grace Murray Hopper (1906-) was the head of the committee which developed the Cobol language for computers.[14] Maria Goeppert Mayer (1906-1972) won a Nobel Prize in Physics in 1963. Maria also developed the shell theory of the atomic nucleus. Lise Meitner (1878-1968) was the first woman to receive the Fermi award, 1966, from the atomic energy commission. Lise helped split the nucleus of uranium.

Of lesser importance historically are Charlotte Angas Scott (1858-1931), Elizabeth Leonard Scott (1917-), and Lao Genevra Simons (1870-1949).

It is difficult to add contemporary women to a list of famous mathematicians as the passage of time is a necessity to the accurate generation of that list. Consequently, most of the other women who are included in this paper are listed by virtue of peer recognition. That is, their names were suggested in personal correspondence with living mathematicians. Prominent among those named were Hanna Neumann (1914-1971), Mary Weiss (1930-1966), and Dame Mary Cartwright (1900-). Based on the previously mentioned correspondence, if the list of the eight most famous women mathematicians were to be expanded, these three would be the first to be added. Names of living mathematicians suggested in the correspondence for inclusion in this paper include Olga Taussky Todd, Mary Ellen Rudin, Barbara Osofsky, Julia Robinson, and Sophie Piccard.

In the book, Women in Mathematics, Lynn M. Osen cites two additional names not yet mentioned who she thinks will stand out in future histories, Mina Rees, and Dorothy Maharam Stone. Mina is believed by many to be the most outstanding woman mathematician of this century.[178] Other women included but not previously mentioned are Jacqueline Lelong-Ferraud, Paulette Libermann, and Maria

Pastoria. Jacqueline is credited with originating the concept of preholomorphic functions.[202]

The following chapter will consist of brief biographical sketches of these thirty-three women who are generally recognized as the most notable women in mathematics.

Biographical Sketches

An examination of the literature reveals various inconsistencies in the biographical details about women mathematicians. Foremost among these are spelling variations. Consequently, preference has been given those forms which appear most commonly. A minor deviation which is noticed is a discrepancy in birth dates and/or death dates. In these, as in all such incongruencies which are found, the following biographical sketches incorporate that information which seems to be most generally accepted and/or best documented.

Maria Gaetana Agnesi (1718-1799)

Maria Agnesi is sometimes regarded as one of the most extraordinary women scholars of all time. Perhaps her first outstanding feat was the mastery of eight different languages as a child. By the age of only eleven, she spoke French, Latin, Greek, German, Hebrew as well as others; she had also by this age published articles which she had written. One of twenty-three children and daughter of an Italian mathematician, Maria Agnesi became a mathematician in her own right. She was more than just the first woman mathematician since Hypatia.

Maria's most important work was a treatise on differential and integral calculus called Analytical Institutions.

Her motivation for this work was the belief that mathematics was progressing so rapidly that it was difficult for the beginner to assimilate the broad mass of knowledge. She, therefore, constructed this text so that the reader could be abreast of the mathematics advancements of her time. Maria's text deals with analysis of finite quantities, construction of loci, conic sections as well as problems of maxima/minima, tangents and inflections (Book I); Book II covers infinitesimals: "It is astonishing that differences which are variables tending to zero, and fluxions which are finite rates of change should be treated as essentially the same thing."[83] Book III deals with integral calculus and touches on the expressions of function as a power series; Book IV discusses inverse methods of tangents and simple differential equations.

The equation: $xy^2 = a^2(a - x)$ was earlier studied by Fermat as well as Guido Grandi. However, this is the equation which is more commonly known as the "Witch of Agnesi." This nomenclature in no way reflects upon Maria herself whose primary concerns were religious. (Maria's father had early in her life denied her permission to become a nun.) Maria's life as a mathematician virtually terminated in 1852 although she lived until 1799. She preferred the role of doer of charitable deeds over that of mathematician. This is best illustrated by the fact

that in 1762, at the age of only forty-four, Maria refused to comment on the work of Lagrange on the calculus of variations when asked to do so by the University of Turin. The reason given for her refusal was that such matters no longer concerned her; mathematics no longer occupied her thoughts.

Dame Mary Cartwright (1900 -)

Mary Lucy Cartwright is an English mathematician. She has extensive research publications on integral calculus, theory of complex variables, theory of ordinary differential equations, and topological aspects of theory. She earned her Ph.D. at Oxford and for thirty years was on the staff of the University of Cambridge as a pure mathematician. She is presently in the Division of Applied Mathematics at Brown University.

Miss Cartwright has received many honors. She is a Fellow of the Royal Society, has honorary degrees from Cambridge, Edinburgh, Leeds, Hull, Wales, and Oxford. She was awarded the Sylvester Medal of the Royal Society in 1964 and the DeMorgan Medal of the London Mathematical Society in 1968. In 1969 she was made a Dame Commander of the British Empire for her services to mathematics.

Mary Hegeler Carus (1861-1936)

Mary is less of a mathematician and more of a promoter of mathematics although she did graduate from the

University of Michigan having studied primarily mathematics and chemistry. She also did do work in chemistry laboratories and was working with her uncle Clemens Winkler when he discovered the element Germanium. Nevertheless, her primary contribution to mathematics lies in the field of publishing. She both financed and arranged financing of such serials as the Carus Mathematical Monographs. This was initiated upon the cessation of European publications because of WWII. Mrs. Carus, her husband, and her father were associate editors of the Open Court Publishing Company. Mary Carus' attitude was such that the Open Court published a good many articles and a number of books on mathematics.

The Marquise du Chatelet (Emilie de Breteuil) (1706-1749)

French-born Emilie is regarded as the number one woman scientist in France during the first half of the eighteenth century. Considered by many to be a physicist, by some as merely a translator, Emilie's claim to mathematics lies primarily in her writings on the works of first Leibniz, then Newton. Emilie's most important contribution was her translation of Newton's Principia from English into French. (Emilie had had Voltaire teach her English solely for the purpose of being able to read the work of Newton.)

Emilie was friend, lover, and peer of Voltaire. Jointly they established and worked in a research laboratory.

Among the accomplishments of Emilie the scientist were her belief that light and heat had the same modes of motion and her discovery that different colored rays of light do not give off an equal degree of heat. Although Emilie and Voltaire worked as a team, they once had differing opinions regarding the direction that their research should take. Subsequently, Emilie did her own research unbeknownst to Voltaire. They both entered their respective results independently in the same contest. Neither won, but Emilie out-ranked Voltaire.

Emilie is said to have died in childbirth, although it was actually several days after the birth of the child that her death occurred. (The child itself died a few days after her mother.) At the time of her death, Emilie's husband, the Marquis, Voltaire, and Jean Francois de Saint-Lambert, the father of the child, all were present.

Maria Cibrario

Maria Cibrario, wife of mathematician Silvio Cinquini, was an assistant to Peano. Her work in various branches of infinitesimal analysis is said to have gone far beyond that of her predecessor Sonya Kovalevsky. This included research on the theory of partial differential equations. In fact, Maria is credited with classification of linear partial differential equations of the second order of mixed type as well as existence and uniqueness theorems for many

of these. Maria solved the Goursat problem for the hyperbolic and non-linear equation of the second order. She has also solved the Cauchy problem for quasi-linear and non-linear hyperbolic systems.

Sophie Germain (1776-1831)

Sophie Germain, known as the "Hypatia of the nineteenth century," is also called one of the founders of mathematical physics. Sophie, a student of Lagrange, was an active correspondent with Gauss under the pseudonym M. le Blanc. Sophie's early interests and work were in number theory. However, she became engrossed in the study of mathematical theory of the vibrations of elastic surfaces and did extensive work in that field. Nevertheless, Sophie is best known for her work in number theory. In this area, of significance, is her proof that Fermat's last theorem is not soluble for $n < 100$. That is, if x, y, and z are not divisible by an odd prime n, and if $n < 100$, then $x^n + y^n = z^n$ is not soluble.

Although Gauss and Sophie never actually met, it was upon his recommendation that she was to be granted an honorary doctor's degree by the University of Gottingen. However, Sophie died of breast cancer before the degree could be awarded.

Caroline Herschel (1750-1848)

German-born Caroline Lucretia Herschel is best known

as an English astronomer. (She emigrated to England with her brother William in 1772.) Primarily, her role was regarded as that of her brother's assistant. She performed all of William's calculations errorlessly. Nevertheless, Caroline is considered to be the first woman astronomer and did function as an astronomer, not just her brother's helper. Between the years of 1786 and 1797, Caroline discovered eight comets. (William was the discoverer of the planet Uranius.)

Caroline had devoted all of her energies to her brother and his work. Perhaps she was motivated to do so because her father had told her that she was too unattractive to ever find a husband. Consequently, she was extremely distraught when William married, and ten years after the event, she destroyed their journals. In spite of this, she continued her own work as well as that of William. At the age of eighty-five, Caroline was elected honorary member of the Royal Astronomical Society. She and Mary Somerville were the first English women to have their scientific achievements honored by this society.

Grace Murray Hopper (1906-)

Grace Hopper received her bachelor's degree from Vassar, her master's degree and her doctorate from Yale. Grace was on the staff of Vassar from 1931-1946. She then did research in engineering science and applied physics as well

as computer science. Grace did subsequent work with computers in the business world. Grace was, as of 1972, a Professor at George Washington University and the Head of the Programming Language Section, Department of the Navy. She is most noted for heading the group in the late 1950's that developed Cobol (COmmon Business Oriented Language).

Hypatia (370A.D. - 415A.D.)

Hypatia is believed to have been the first woman mathematician. She is also perhaps the most famous of women philosophers (Encyclopedia Americana). Hypatia was the daughter of Theon, himself a mathematician. Theon's affiliation with the Museum, the intellectual center of Alexandria, afforded Hypatia a great many opportunities academically. However, little is definitely known about her work. She is believed to have lectured on the Arithmetica Of Diophantus. Hypatia is also believed to have written several treatises on mathematics as subsequent Greek writers and mathematicians have attributed many titles to her. A portion of Hypatia's original commentary On the Astronomical Canon of Diophantus, has been found.[281] Hypatia is credited with popularizing the work of Appolonius by writing a treatise, On the Conics of Appolonius. Similarly, she is credited with writing on Ptolemy's Almagest.

Hypatia, who was renowned for her beauty, modesty, learning and eloquence was probably the most important

figure in the Neoplantonic School in Alexandria. Because of her position as well as her friendship with Orestes, the pagan prefect in Egypt, Hypatia was barbarously murdered, physically dismembered and burned in the streets by the Christians.

Dorothy Klumpke (Roberts) (1861-1942)

Dorothy Klumpke's German father encouraged her to study extensively in Germany, Switzerland, and France. She was the first woman to obtain a Ph.D. in mathematics from the Sorbonne, the first woman student at the Paris Observatory, and also the first woman to be elected a member of the Astronomical Society of France. She married Isaac Roberts, a noted Welsh astronomer in 1901, but was widowed three years later. In 1899, she made two balloon ascents at night to better observe the heavens. Early in her career, Dorothy completed the work begun by Sonya Kovalevsky on the rings of Saturn, using this as a topic for her doctoral thesis. Later in her career, she directed the project of cataloguing stars up to the fourteenth magnitude. She also published Celestial Atlas. In 1934, the French government awarded Dorothy the Cross of the Legion of Honor for forty-eight years of service to French astronomy. Dorothy died in 1942 in San Francisco.[15]

Sonya Kovalevsky (1850-1891)

"Perhaps the most dazzling mathematical genius to sur-

face among women during the past two centuries . . ." [281]

Russian universities were closed to women. Consequently, Sonya Corvin-Krukosky found it necessary to devise a marriage of convenience as wives were free to study at foreign universities. Subsequently, Sonya and Vladimir Kovalevsky went to Heidleberg where Sonya studied at the university. She became determined to study under Weierstrass. However, the University of Berlin, too, was closed to women. She therefore convinced Weierstrass to give her private lessons which he did for the next four years. Sonya became his best and favorite student. Weierstrass himself attempted to find Sonya a position worthy of her talents, but was unable to do so because of her sex. Cayley, too, had been unsuccessful at opening the mathematics department to women as faculty. Because of these and similar barriers, Sonya eventually found herself in a more enlightened Sweden.

Sonya's work includes:"On the Reduction of a Definite Class of Abelian Integrals of the Third Range;" "On the Theory of Partial Differential Equations;" - both of which build on the work done by Weierstrass; "Supplementary Research and Observations on Laplace's Research on the Form of the Ring of Saturn;" "On the Property of a System of Equation." Sonya also did work on the

refraction of light in a crystalline medium.

Christine Ladd-Franklin (1847-1930)

Christine was an American psychologist and logician. She studied logic at Johns Hopkins under Charles Sanders Pierce after being admitted to the university by a ruse. When the school announced its fellowship program in 1876, one of the first applications received was signed "C. Ladd." The accompanying credentials were outstanding, and the student was awarded a fellowship. When the board discovered that "C. Ladd" was a woman, it tried to revoke the fellowship and deny her admittance. However, Professor James J. Sylvester, who had been named the "world's greatest living mathematician" by the Encyclopedia Britannica, prevailed in his insistence that Christine be permitted to remain. She was admitted in 1878 as a full-time graduate student, maintained her fellowship for three years, and in 1882 had her dissertation, "The Algebra of Logic," both accepted and termed brilliant. However, the trustees refused to grant her degree. Following this, Christine and her husband, Fabian Franklin, an associate professor of mathematics at the university, left for study at Gottingen. After her marriage, Miss Ladd added her husband's name to hers and was thereafter known as "Ladd-Franklin."

When the Franklins returned to the United States,

Christine was a lecturer in psychology and logic at Johns Hopkins, and from 1914-1927 she held a similar position at Columbia University. She did original work on color theory and published a book, Color and Color Theories. She also contributed the highly-acclaimed doctrine of anti-logism to logic. Finally, in 1926, only four years before her death at eighty-two, Johns Hopkins University awarded Christine Ladd-Franklin her long overdue Ph.D. She was proud of being a pioneer in gaining university education for women. [173]

Jacqueline Lelong-Ferraud (1918-)

Jacqueline is a Professor at the University of Paris. She, like many other women mathematicians, is married to a mathematician. Jacqueline's work includes research on the behavior of conformal transformations and representations (Her doctoral thesis was on conformal transformation in the neighborhood of a boundary point.); Reimann manifolds and harmonic forms; and potential theory. Jacqueline is also credited with originating the concept of preholomorphic functions.

Paulette Libermann

Paulette, Professor at the University of Renes, has done work in the fields of algebraic topology, infinitesimal pseudogroups, differentiable fiber spaces. She was student and protege of Elie Cartan. She also studied

under A.N. Whitehead at Oxford University.

Ada Augusta, Countess of Lovelace (1815-1852)

Lady Lovelace, born Augusta Ada Byron, was the issue of well-known Lord Byron. When Ada was in her late teens, she was taken by Sophie DeMorgan to a party at the house of Charles Babbage. He kept a small model of his Difference Engine, a calculating machine, at his home to be exhibited to guests. During the succeeding years, Ada became a frequent visitor in the Babbage household, usually accompanied by Mrs. DeMorgan or Mary Somerville. Meanwhile, during her nineteenth year, Ada married William, eighth baron king, later to become Lord Lovelace. By the year 1843, Ada had translated the "Sketch of the Analytical Engine invented by Charles Babbage" into English and had begun annotating it. "The Notes," as her work was called, grew to be longer than the original text. As it was unladylike for women to attach their names to literary works, Ada refused to publish The Notes. However, she did permit them to be included with publishings of male writers using only her initials, A.A.L. [17]

DeMorgan once wrote in a letter to Lady Byron that Ada had the makings of "an original mathematical investigator, perhaps of first-rate eminence." However, her primary concern was with the Analytical Engine. This was a machine that Babbage believed would be able to do work directed by

means of punched cards, that would store partial answers to be used in later operations, and that would print results. In short, he thought out all the basic principles that guide modern computers. However, Babbage failed in his attempts to build the machine because the precision needed to make the parts did not exist at that time. It was Lady Lovelace's description of the machine as well as her records of Babbage's concept that has preserved the knowledge of this work for posterity. Babbage is known as "The Grandfather of the Modern Computer," while Lady Lovelace is considered the "Mother of Computers." [31]

Lady Lovelace's health had always been precarious. The strains of work and of heavy gambling debts took its toll. She developed some kind of "internal cancer." The last years of her life were painful. She had also been compelled to confess her secret betting to her husband, Lord Lovelace. In the end, she was estranged from both her husband, and her mother, Lady Byron, who had frequently loaned her money for her gambling debts.[17]

Ada died in 1852, at the age of thirty-six; she was buried next to her father, Lord Byron, whom she had never known.

Maria Goeppert Mayer (1906-)

Maria, born in Poland, received her doctorate from the University of Gottingen before migrating from Europe

to the United States. Maria had studied physics, mathematics, and chemistry. She held teaching positions at Columbia University, the Institute for Nuclear Studies at the University of Chicago, and the University of California at San Diego. Maria and her husband, American physicist Joseph E. Mayer, coauthored a book called Statistical Mechanics. Maria was also a joint winner in 1963 for the Nobel Prize in physics for research done on the nuclear shell structure. (She was the first woman to receive a Nobel Prize in theoretical physics.) Maria developed the shell theory of the atomic nucleus with protons and neutrons arranged in shells just as the electrons are arranged in shells in the outer atom.

Lise Meitner (1878-1968)

Lise was "one of the leading mathematical physicists of this century."[281] Furthermore, E.E. Kramer, in 1955, considered her the foremost living successor of Kovalevsky.[202] Lise was an Austrian-born Jew. She studied and received her doctorate at the University of Vienna. During the twenties, she was a physics professor at the University of Berlin. As the situation in Germany became more unstable as well as unhealthy for Jews, Lise went first to the Netherlands, then Sweden, Britain and finally the United States.

Lise, doing research on radioactive materials, became

forerunner in the atomic energy field. She is said to have coined the term, fission.[324] Lise published her first paper on uranium fission in 1939 while still in Stockholm. With Hahm, she discovered Thorium-C in 1908 and proactinium in 1917. She studied nuclear isomerism; found four radioactive elements resulting from neutron bombardment of uranium; with Frisch, she helped split the nucleus of uranium. Lise also predicted chain reaction which contributed to the development of the atomic bomb. Lise was the first woman to receive the Fermi Award from the Atomic Energy Commission, 1966.

Hanna Caemmerer Neumann (1914-1971)

Hanna von Caemmerer attended the University of Berlin where she met Bernhard H. Neumann. Because of the situation in Germany, Bernhard left for London; and because of Hanna's criticism of the Nazis, Hanna herself was not permitted to obtain a doctorate in Germany. In 1938, Hanna and Bernhard were married and moved to Oxford. Here Hanna's research supervisor was Olga Taussky Todd. After the war, both Hanna and Bernhard held positions in England as members of mathematics faculties. When in 1960, Bernhard was offered an opportunity to set up a research department of mathematics at the Australian National University, the family moved to Australia. Hanna died unexpectedly in 1971. Hanna's work is primarily in group

theory: group amalgrams, generalized free products, near rings, and free groups. She also did work on finite non-desarguesian planes.[329]

Amalie (Emmy) Noether (1882-1935)

The peers of Emmy Noether considered her one of the world's greatest mathematicians. Among the people who have worked with her or studied with her are: Klein, Hilbert, Hasse, Van der Waerde, Alexandroff, Weyl, and John von Neumann. When the great migration of intellect from Germany took place, Emmy went to Byrn Mawr, while her brother, an applied mathematician went to Siberia. Emmy's doctoral dissertation was: "On Complete Systems of Invariants for Ternary Biquadratic Forms." Emmy worked on the mathematical formulation of the theory of relativity. She was instrumental in the axiomatic development of abstract algebra. She also investigated the structure of noncommutative algebras, their representations by linear transformations and their application to the study of commutative number fields and their arithmetics. Emmy worked with Hasse and Brauer on several papers concerning non-commutative algebras, the hypercomplex quantities and the theory of class fields, norm rests, and the principle genus theorem. The three proved that every simple algebra over an ordinary algebraic number field is cyclic.

Barbara Osofsky (1937-)

Ms. Osofsky is a professor at Rutgers University; she has held that position since 1971. Her undergraduate work was done at Cornell University, from which she also received her M.A. She was granted her Ph.D. from Rutgers in 1964. Her dissertation topic was "Homological Properties of Rings and Modules." Her fields of study include algebra and theory of numbers as well as logic and foundations.

Maria Pastori

Maria Pastori, Professor at the Institutio Matematico of the University of Milan, has worked principally in the fields of tensor analysis and relativity. In 1949, Maria published Calcolo tensoriale ed applicazione, and in 1953, a text on differential geometry in which she discusses the space of Einstein's unified field theory.

Sophie Piccard (1904-)

Sophie Piccard was born in St. Petersburg. She was coerced by her mother into the study of theoretical mathematics. Sophie herself preferred the study of applied physics. Sophie left Russia during the 1920's. In 1936, she became a part of the faculty at the University of Neuchatel (Switzerland). Sophie later occupied the chair of higher geometry and probability theory. She has done work in set theory, group theory, function theory, theory

of relations, and actuarial science. She has written two original books in which special attention is given to certain perfect sets on the real line. These arise from a closed interval by a process generalized from the construction of the Cantor ternary set. Sophie has also written a biography of Lobachevsky.

Mina S. Rees (1902-)

"Probably the most outstanding woman mathematician of today (1957) is Mina S. Rees."[178] At the very least, she has a lengthy list of credits to her name: King's Medal in England - 1948; President's Certificate of Merit - 1958; Distinguished Service to Mathematics Award (Mathematics Association of America) - 1962; Achievement Award (American Association of University Women) - 1965.

Mina received her bachelor's degree from Hunter College, her master's from Columbia University, and her doctorate from the University of Chicago. Her work has been in abstract algebras, division algebras, linear algebras, and numerical analysis.

Mina has served the government in a variety of capacities: Technical Aide and Executive Assistant to the Chief of the Applied Mathematics Panel, National Defense Research Committee, Office of Science Research and Defense, 1943-1946; Director of the Navy's Mathematical Sciences Division, 1949-1952; Director of the Department of Science, 1952-

1953; Member of the Mathematics Division, National Research Council, 1953-1956, serving on the Executive Committee, 1954-1956; Survey Committee of Mathematics in the United States, 1954-1957; Chairman of the Advisory Committee on Mathematics, 1954-1957; Advisory Panel of Mathematics, National Science Foundation, 1955-1958; National Science Board, 1964-1970. Since 1973, Mina has been a member of: Board of Directors of the National Manpower Advisory Committee, the SIAM Institute of Mathematics Society, and served as a subcommittee professor, Science and Technological Manpower.

Meanwhile, Mina has been active academically: Faculty Dean, 1953-1961; Graduate Dean, 1961-1968; Provost, Graduate Division, 1968-1969; and President, 1969-1972 -- Hunter's College. Since 1972, Mina has been concurrently Emeritus Professor of Mathematics and Emeritus President of the Graduate School of the City University, New York.

Julia Bowman Robinson (1919-)

Julia Robinson received her B.A. in 1940; M.A. in 1941; and her Ph.D. in 1948 - all from Berkley. Her fields of study are mathematical logic and number theory. She has done research in number theory decision problems and recursion functions. Osen [281] cites Dr. Robinson's contribution to Hilbert's tenth problem. Julia was recently the first woman elected to the Mathematics Section of the

National Academy of Sciences. She is a pure amateur - she has no job at all.

Mary Ellen Rudin (nee Estill) (1924 -)

Dr. Rudin is a professor of mathematics at the University of Wisconsin. She received her Ph.D. from the University of Texas in 1949. Her thesis topic was "Concerning Abstract Spaces." She has done research in theoretic topology, especially the construction of counter examples.

Charlotte Angas Scott (1858-1931)

Charlotte Angas Scott was educated at Girton College, Cambridge University. However, at that time, women were not permitted to receive degrees from Cambridge. Nevertheless, Charlotte was a resident lecturer on mathematics while she attended the University of London from which she received her doctorate in 1885. Before the turn of the century, Charlotte migrated to America where she was on the staff of Bryn Mawr. Her work is concerned primarily with the analysis of singularities for algebraic curves. Charlotte was a very active member of mathematical societies and organizations. She also wrote numerous papers which have been published.[124]

Elizabeth Leonard Scott (1917-)

Oklahoma-born Elizabeth Scott is considered both an astronomer and a statistical mathematician. Elizabeth received her Ph.D. in mathematical statistics and astronomy in 1949. She has served with the National Defense Re-

search Committee, Office of Science Research and Development during the war years. Since 1962, she has been a professor of statistics at Berkley, and in 1973, became the co-head of a group studying biostatistics. Elizabeth has applied statistics to astronomy, physics, medicine, biology, and meteorology. She has experimented with methodology of evaluation cloud seeding, worked with binary systems, and studied the distribution of the galaxies in space as well as the expansion of clusters. Further included in her studies is work in carcinogenesis.

Lao Genevra Simons (1870-1949)

Lao Genevra Simons' specialty was the study of the history of American mathematics. She was a professor of mathematics at Hunter College and eventually the head of the mathematics department there. Lao was also the book review editor of Scripta Mathematica for several years.

Mary Fairfax Somerville (1780-1872)

Mary Fairfax, one of the greatest scientists England ever produced, was born in Scotland. She married her cousin, Samuel Greig, and was subsequently widowed in 1807. At this time, Mary began the serious study of mathematics. In 1812, she married another cousin, Dr. William Somerville, a surgeon. William was very supportive of Mary's mathematical endeavors in spite of the harsh criticism which they received from relatives about

Mary's unladylike activities - studying mathematics. Because of the social position of Dr. Somerville, Mary had the opportunity to become friends with Cuvier and Pentland (explorers), Laplace, the Napiers, the Herschels, and Sir Edward Perry. Sir Edward was an astronomer and explorer. He named an Artic island after Mary. Mary also became acquainted with Poisson and La-Croix. Mary Somerville is usually cited as having done little original work. Nevertheless, she presented a paper on "The Magnetic Properties of the Violet Rays of the Solar Spectrum." Her most famous work is a translation of Laplace's Mecanique Celeste. Mary also produced a work, The Mechanisms of the Heavens - an assimilation of translations and commentaries on the physical principles of the universe. Other publications include: The Connection of the Physical Sciences; Physical Geography; Form and Rotation of the Earth; The Tides of the Ocean and Atmosphere; and Molecular and Microscopic Science.

Dorothy Maharam Stone (1917-)

Dorothy received her Ph.D. in mathematics from Bryn Mawr in 1940. In 1961, she accepted a position as professor at the University of Rochester. Her work has been in the areas of measure theory, ergodic theory, probability, and linear operations.

Olga Taussky Todd (1906-)

Olga was born in Czechoslovakia. She received her Ph.D. in Vienna. She has held positions at Bryn Mawr, Cambridge, Gottingen, Vienna, and London. From 1943-1946, she worked for Ministry Aircraft Production, England; and subsequently with the Department of Science and Industrial Research. She was a mathematics consultant for the National Bureau of Standards, and is currently at the California Institute of Technology, Pasadena. Olga has done work in algebra, algebraic number theory, matrix theory, and numerical analysis. She has published approximately one hundred and forty papers.

Mary Catherine Weiss (1930-1966)

Mary Bishop was born in Wichita, Kansas. Her father, Colonel Albert Bishop, was a university mathematics teacher after his retirement from the army. However, he died when Mary was only two. Upon completion of grade school, Mary moved to Chicago with her mother and brother, Errett. In Chicago, Mary first attended the Laboratory School at the University of Chicago. Mary met and married Guido Weiss while they were both undergraduates at the University. Mary later received her Ph.D. from the University of Chicago.

After completion of work for her degrees, Mary held teaching positions at DePaul University in Chicago, Wash-

ington University in St. Louis, the University of Chicago, and Stanford University. She also was a National Science Foundation senior post-doctoral fellow at Cambridge. From there, she went to the post of professor of mathematics at the University of Illinois, Chicago Circle. She held this position for only a few weeks when she died in 1966 at the age of thirty-five.

Mary's thesis topic was "The Law of the Iterated Logarithm for Lacunary Series and its Application to the Hardy-Littlewood Series." Mary was most interested in classical analysis, especially real variable and harmonic analysis. [399]

Grace Chisholm Young (1868-1944)

As a child, Grace Chisholm was educated at home by her mother and a governess because schools were not available for women in America at that time. However, at age seventeen, in 1885, she managed to pass the Cambridge Senior Examination and in 1889 was admitted to Girton College. This school was affiliated with Cambridge and was the first English institution devoted to educating women at the university level. In 1892, Grace scored the equivalent of a first class on her examinations. Since there were obstacles to her further education in England, she went to Germany where she studied under Felix Klein. She is said to have been his favorite student. Grace received her Ph.D.

magna cum laude from Gottingen in 1895 at age twenty-seven. After she finished her studies at Gottingen, she married William Henry Young who had been her tutor at Girton.

Although Grace received her degree in mathematics, she was also greatly interested in medicine, languages, and music. She completed all the requirements for a medical degree except the internship. Grace knew six languages and taught them to their six children. Each of the children was also taught to play a musical instrument skillfully enough that the family gave informal concerts.

Grace's dissertation topic was "The Algebraic Groups of Spherical Trigonometry." Together she and her husband published two hundred mathematics articles and several books. In 1906, they published the book, Theory of Sets of Points. It was the first text of its kind and was highly praised by Cantor and others.[384]

As was the case with many mathematical pairs throughout history, the work done by Grace and William together was usually published in his name alone. Therefore, Grace Chisholm Young is one of those women whose true merit as a mathematician has been disguised by her partner's name. In fact, Mary Ellen Rudin has said that she suspects that Grace is second only to Emmy Noether of those women mathe-

aticians born before 1900 (personal correspondence).

Perhaps William best summarizes the situation himself in a letter he wrote to Grace:

> The fact is that our papers ought to be published under our joint names, but if this were done neither of us get the benefit of it. No. Mine the laurels now and the knowledge. Yours the knowledge only. Everything under my name now, and later when the loaves and fishes are no more procurable in that way, everything or much under your name.[384]

Resource Information

Where to begin researching the women of mathematics is a pertinent question. Moreover, it is sometimes difficult to find the answer to this query. The primary reason for this situation is the general lack of common knowledge regarding female mathematicians. However, as with all women's studies, the study of the women of mathematics is a rapidly growing research field, but it is not a new one. There is a vast amount of resource material in existence even though the assimilation and coordination of this information is in a neophyte stage. Therefore, in accordance with the intents of this paper, this section is devoted to possible answers to the question posed, as well as helpful research suggestions.

One of the most important discoveries to be made when delving into the literature is the existence of the Association for Women in Mathematics. The Association encourages greater participation of women in mathematics, provides a speakers bureau which lists available speakers and topics, and publishes a bi-monthly newsletter. The newsletter is a particularly useful resource carrying historical articles, items of current interest, and a job directory. The mailing address is: AWM, c/o Department of Mathematics, Wellesley College, Wellesley, MA, 02181.

Another useful research tool is the Directory of Women Mathematicians, compiled by the American Mathematical Society, P.O. Box 6248, Providence, RI, 02940.

Perhaps the single most significant resource for the study of the history of mathematics in general is: Bibliography and Research Manual of the History of Mathematics, Kenneth O. May. Kenneth May is also the editor of a quarterly publication entitled Historia Mathematica, International Journal of History of Mathematics, University of Toronto, Toronto, Canada M5S 1A1.

Good bibliographies are probably the best beginning for any research endeavor. Consequently, the reference section of this paper is the most important, as well as the most difficult and time consuming to construct. It consists of all relevant references which this author has located and is intended to be as comprehensive as possible in order that it be useful to a wide audience. This is why non-English entries have been included. The bibliographical list has been generated in part from reference to authors, mathematicians, and publications which were mentioned in readings. Other entries were gathered from personal correspondence with prominent mathematicians and the integration of entries from other bibliographies. Also included are entries based on unpublished material received through the previous mentioned correspondence.

While the references accompanying this paper are extensive, they do not include entries about specific women not included in the paper. Other bibliographies which should be consulted are: Campbell and Grinstein [68], Campbell [69], Grinstein [145], and May [240]. Even though these bibliographies duplicate many entries, those researchers interested in a thorough study should consult all the bibliographies because each contains a number of unique entries.

Additional resource materials include Lynn. M. Osen's Women in Mathematics.[281] This is an interesting readable text containing useful resource material. While this book is primarily a collection of biographical sketches on only eight women, it includes a good deal of additional information of various aspects about the lives of many women mathematicians. This work is also frequently quoted in the current literature.

Mathematicians from Antiquity to Today, Fang [119], is probably a very good resource. However, it is incomplete, and the one volume which is finished is not commonplace in libraries.

Another resource which is often overlooked as it is difficult to find is Poole's Index to Periodicals [301]. Volumes one through six cover the years 1802-1881.

Another source to consider is the standard reference

works and encyclopedias which may contain information about some of the women.

Not to be neglected in research activities are such references as American Men of Science, American Men and Women of Science, Asimov's Biographical Encyclopedia of Science and Technology, Biographical Cyclopaedia of American Women, Dictionary of American Biography, Dictionary of National Biography, Dictionary of Scientific Biography, Leaders in American Science, National Cyclopedia of American Biography, New Catholic Encyclopedia. Then of course, there are the various Who books: Who's Who, Who's Who in America, Who Was Who, Who Was Who in America with World Notables, World Who's Who in Science, Who's Who in Science in Europe, and World Who's Who of Women.

Index to Women Mathematicians

A listing of those women previously mentioned in this paper follows. All are included in the biographical sketches. The numbers after each name correspond with appropriate reference numbers and constitute individual bibliographies. With regard to the references themselves, those preceded by * are those which have actually been read and/or consulted for this paper. That is, * items would represent the traditional end-of-the-paper bibliography entries.

Following this first list of women mathematicians, is a second list. This one contains the names of those women found in at least one of the four previously mentioned bibliographies but not included in this paper per se.

Mary Clerke Agnes (1842-1907)
Clara Latimer Bacon (1866-1948)
Nina Karlova Bari (1901-1961)
Anna Lavinia Van Benschote (1866-1927)
Alicia Boole-Stott (1860-1940)
Evgenija Aleksandrovna Bredihana (1922-1974)
Sophie Willock Bryant (-1922)
May Ayres Burgess (1888-1953)
Evelyn Teresa Carroll-Rusk (1900-1964)
Anna Philippa Cobbe (1920-1971)
Marguerite Cook (1900-1965)
Elizabeth Morgan Cooper (1890-1967)
Lennie Phoebe Copeland (1870-1947)
Florence Nightengale David (-)
Mary Patricia Colciani (-)
Marie Louise Dubreil-Jacotin (1905-1972)
Ethel Mary Elderton (1878-1954)
Cornelia Fabri (1869-)
Hilda Geiringer-von Mises (-)
Ruth Gentry (1862-1917)
Harriet Eudora Glazier (1870-1955)
Christine Mary Hamill (1923-1956)
Frances Hardcastle (1866-1941)
Ellen Amanda Hayes (1851-1930)
Cora Barbara Hennel (-1947)
Ruby Usher Hightower (1880-1959)
Hilda Phoeba Hudson (1881-)
Sof' ja Aleksandrovna Janovskaja (1896-1966)
Carol Ruth Karp (1926-1972)
Claribel Kendall (1889-1965)
Cecelia Krieger-Donaj (-1974)
Klavdiya Yakolevna Latysheva (1897-1964)
Emma Lehmer (-)
Florence Parthenia Lewis (1877-1964)
Marie Litzinger (1899-1952)
Mayme Irwin Logsdon (1881-1967)
Anna Louise Mackinnon-Fitch (-1940)
Isabel Maddison (-1950)
Emilie Norton Martin (1869-1936)
Helen Abbot Merrill (1864-1949)
Bessie Irving Miller (1884-1931)
Mary Winston Newson (1869-1959)
Anna Johnson Pell-Wheeler (-)
Rozsa Peter (-)
Lia Predella (-)
Mildred Lenora Sanderson (1889-1914)
Vera Sanford (1891-1971)
Sheila Scott-MacIntyre (1910-1960)
Mary Emily Sinclair (1878-1955)

Clara Eliza Smith (1865-1943)
Pauline Sperry (1885-1967)
Irene Barnes Taeuber (-1974)
Bird Margaret Turner (1896-1962)
Galina Nikolaevna Tyurina (-)
Marie Johanna Weiss (1903-1952)
Agnes Ermina Wells (1876-1959)
Mabel Minerva Young (1872-1963)

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