Prominent Women Biologists

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The perception that scientists are intelligent white men who are socially inept, absent-minded nerds seems to prevail among students at all levels, from elementary school to college (Schibeci & Sorensen, 1983; Fort & Varney, 1989; Evans, 1992; Rahm & Charbonneau, 1997; Barman, 1999). While media may, by chance or choice, promote this image, it is unfortunately a realistic one. For example, while women constituted 46% of the general workforce of the U.S. in 1997, they represented only 19% of the science, engineering, and technology (SET) workforce (National Science Foundation, 2000). This stereotypical image of scientists as white men has, in part, discouraged many women from pursuing any interest they may have in a science career because they do not want to (and cannot) be the people so often portrayed in the media.

We did a survey on a group of 42 pre-service biology teachers recently, requiring them to name prominent female and male biologists. The survey revealed that most could name only one female, but well over 20 male biologists. Such a finding is in line with studies reported by Rahm and Charbonneau (1997) and McDuffie (2001). They used the “Draw-A-Scientist Test” (Chambers, 1983) to determine pre-service teachers’ impression of scientists, and reported that a vast majority perceive scientists as men. We predict that problems will ensue if teachers carry this stereotype with them to the classrooms.

Fortunately, research has shown that strategies such as presentation of female role models, distribution of career information, examination of sex-equitable materials, and participation in hands-on science investigations are effective in dispelling the stereotypical image of scientists (Smith & Erb, 1986; Flick, 1990; Mason et al., 1991; Huber & Burton, 1995). Research has also pointed to the presence of female role models in the sciences as the single most important factor in sustaining girls’ interest in the sciences (Advocates for Women in Science, Engineering and Mathematics, 2000).

This article was, in part, prompted by the report of the Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development (2000). The Commission was established by Congress in 1998 to examine how the U.S. could increase its pool of skilled workforce capable of competing in the technology-driven economy of the 21st century, and also to examine factors contributing to the under-representation of women and other minorities in SET education and employment. This was worthy of attention as the nation has failed to optimize the use of the talent of its entire population — women formed 51% of the population in 1997, but earned just 37% of all science and engineering degrees awarded that year, and represented only 19% of the SET workforce. The report cited the lack of exposure to female role models in science as among the critical factors preventing girls from continuing science education.

This paper aims to sensitize teachers to their perception of scientists. The paper also highlights the lives and contributions of four female Nobel Prize winners: continued on page 585

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WOMEN BIOLOGISTS 583
Prominent Women Biologists
continuation from page 583

Gerty Radnitz Cori, Gertrude Belle Elion, Barbara McClintock, and Rosalyn Sussman Yalow; and summarizes the contributions of other prominent female biologists. Teachers can use these outstanding female biologists to inspire their students.

Gerty Radnitz Cori

Gerty Radnitz Cori and her husband, Carl Cori, were awarded the Nobel Prize in Physiology or Medicine in 1947 for their discovery of the enzymatic breakdown and synthesis of glycogen (Cori & Cori, 1947; Brody, 1996). Although both graduated from medical school, both were sure they wanted to be researchers rather than physicians.

Since the work done by the Coris was dated before the 1950s, it may be pertinent to consider the “state of the art” at that time. Very little was known about enzymes then, and physiological studies were made using whole animals. In the 1920s, the Coris discovered what is today known as the “Cori Cycle.” In the 1930s, the Coris elucidated in great detail the extremely complicated mechanisms involved in the breakdown and synthesis of glycogen. Initially, they used whole animals for their studies but later progressed to tissue extracts. While conducting research, Gerty demanded perfection in all experiments. She devised methods for purifying the enzymes and other biochemicals used in experiments, and supervised all aspects of their production. She knew that in the type of biochemical studies they were conducting, any impurity could give a false result, ruining the experiment. In 1939, the Coris accomplished the astounding feat of synthesizing glycogen in a test tube with the aid of a number of enzymes they had prepared in a pure state, and whose mode of action they had revealed. This was, beyond doubt, one of the most brilliant achievements in modern biochemistry.

Although biochemistry research was advancing rapidly in the U.S. in the 1930s, acceptance of women scientists was not. Even though Gerty was in many respects the leader of the husband-wife research team, she was not granted academic recognition for many years. At that time, the Coris had already published many papers on carbohydrate metabolism and established their scientific reputations. As a result, job offers began to come in — for Carl, but not for Gerty. In 1931, Washington University in St. Louis, Missouri, offered jobs to both Coris. Carl became the head of the Pharmacology Department, while Gerty was hired merely as a research assistant.

The Coris studied how hormones regulate the hexokinase reaction, and this discovery may have led to a new conception of how hormones and enzymes interact. The Coris also contributed to the understanding of glycogen storage diseases, elucidating the enzyme defect in von Gierke disease. This was the first demonstration of an inherited deficiency of a liver enzyme.

In 1947, both Gerty and Carl were awarded the Nobel Prize in Physiology or Medicine, and subsequently, Gerty was appointed full professor at Washington University. Although 1947 brought joy, it also brought sadness. Gerty was stricken with myelofibrosis, a rare disease of the bone marrow. For ten years she continued her work, suffering with pain and refusing to stop her laboratory activities until mid-1957. She died on October 26, 1957.

Gertrude Belle Elion

Gertrude Belle Elion developed some of the most revolutionary drugs of the 20th century, including drugs for leukemia and gout, a drug that made organ transplants between non-related donors and recipients possible, and acyclovir for treating herpes virus infections (Elion, 1988). Her methods were used to synthesize Azidothymidine (AZT), the first drug for treating AIDS. For her contribution to understanding the metabolism of the natural compounds on which these drugs were based, Gertrude Elion shared the 1988 Nobel Prize in Physiology or Medicine with her mentor and research partner George Hitchings, and with Sir James Black, who developed the first beta-blocker drug.

Elion graduated at the top of her class with a Bachelor’s degree from Hunter College in 1937, but due to the Great Depression and the fact that she was female, she had difficulty finding a job where she could apply her chemistry training. She had temporary and part-time jobs and took courses towards a Master’s degree, but kept hoping for a real research opportunity. World War II (1939-1945) created opportunities for Elion, as men were called to serve in the military. Whatever reservations there were about employing women in laboratories simply evaporated. In 1944, Elion was hired by Burroughs Wellcome (now known as Glaxo Wellcome), where she stayed until she retired in 1983. Here, she was able to broaden her horizons into biochemistry, pharmacology, immunology, and eventually virology.

At Burroughs Wellcome, Elion and Hitchings synthesized a wide array of drugs that few scientists could match. Elion and Hitchings worked out a new way to develop drugs by imitating natural compounds, instead of using trial-and-error methods. Hitchings theorized that it should be possible to synthesize artificial compounds similar to the natural ones that cells needed for growth and division. By fooling certain cells into taking in these compounds, Hitchings hypothesized that
defective cells or harmful organisms would be killed. As a result, these drugs should block the division of cancer cells. In 1950, Elion developed two drugs to fight leukemia, thioguanine and 6-mercaptopurine.

Elion and Hitchings also developed a drug called Imuran, which suppresses the immune system, making organ transplants possible. In 1962, the first successful human kidney transplant from an unrelated donor was performed. Since then, many kidney transplant patients have owed their survival to Imuran. In 1963, Elion synthesized another important drug, allopurinol, which prevents the build-up of uric acid, a condition that causes the severe pain of gout.

In 1968, after becoming head of the experimental therapy department, Elion turned her attention to viruses. She put her team to work on a drug to battle herpes virus infections. These viruses are responsible for chicken pox, shingles, cold sores, and genital sores. Elion and her team developed acyclovir, a compound similar to one the virus needs to reproduce itself. The drug does not harm other cells but when the virus takes it in, an enzyme converts acyclovir into a form that destroys the virus.

Altogether, Elion was named on 45 patents. Elion was often asked whether she encountered the proverbial "glass ceiling" in her career, which was dominated by male scientists. She replied that confidence, persistence, and passion for her work enabled her to break the "glass ceiling." She was one of only ten women to win a Nobel Prize in the sciences, and one of the very few recipients to earn a science Nobel Prize without a doctorate.

Barbara McClintock

Barbara McClintock was awarded the Nobel Prize in Physiology or Medicine in 1983 for her discovery of mobile genetic elements (Keller, 1983; McClintock, 1984). In her earlier work on cytogenetics, she identified each of maize's ten chromosome pairs by carefully looking for their distinct features under a microscope. Her studies also associated each of the ten chromosomes with specific genes that each carries.

McClintock did her landmark experiments in the late 1940s at Cold Spring Harbor Laboratory, New York. Her work on the cytogenetics of maize led her to theorize that genes could move from one position to another within a chromosome, and between chromosomes. She drew this inference by observing changing patterns of coloration in maize kernels over generations of controlled crosses. When McClintock presented her findings at a major genetics symposium in 1951, it was met largely with silence and indifference. The idea that genes could move did not seem to fit with what was then known about genes — that their positions on chromosomes were fixed and unchanging. It is pertinent to mention that McClintock made this discovery before the structure of DNA and genetic code were known.

The lack of recognition did not seem to affect McClintock. She continued with her research throughout the 1950s and 1960s, recording her results in her personal notebooks. It took the scientific community almost 30 years to catch up with McClintock, and to accept her reports of mobile genetic elements. The development of molecular biological techniques in the late 1970s allowed researchers to confirm her discovery of "jumping genes" and to detect them in other organisms as well. Consequently, McClintock was hailed a scientific visionary and was awarded the 1983 Nobel Prize in Physiology or Medicine at the age of 81. This made her the first American woman to win an unshared Nobel Prize. Despite her rise to fame, she maintained a busy schedule and worked 12-hour days in her laboratory and on maize fields throughout her 80s. She continued her maize research until she died on September 2, 1992 at the age of 90.

Even though McClintock's work was done over half a century ago, it is still highly esteemed. Mobile genetic elements are now considered a general phenomenon, and have profound biological and medical significance. They were demonstrated in bacteria and shown to play a role in the transmission of resistance to antibiotics from one bacterium to another. In trypanosomes, a type of parasite that causes African Sleeping Sickness, mobile genetic elements cause changes in the surface molecules of the parasite, making it possible for the parasite to evade the immune response of the host organism. In another example of the importance of "jumping genes," recombination of genetic elements proved to be an essential factor in the ability of lymphoid cells to produce a seemingly infinite number of different antibodies to foreign substances. In recent years, it has also been shown that mobile genes help transform normal cells into cancer cells.

A comment to a reporter just after McClintock had won the Nobel Prize sums up the wonderful independent spirit that saw her through difficult times in her professional life. When asked by the reporter if she was bitter about all the years she had been ignored, she answered, "If you know you're right, you don't care. You know that sooner or later, it will all come out in the wash."

Rosalyn Sussman Yalow

Rosalyn Yalow was awarded the Nobel Prize in Physiology or Medicine in 1977 for the development of radioimmunoassays (RIA) of peptide hormones (Yalow 1978). Yalow graduated with honors in physics and chemistry in 1941 from Hunter College in New York,
but her application to pursue a higher degree at Purdue University was rejected because she was a Jewish woman. Fortunately for her, the U.S. was about to enter World War II, and men were diverted into the military. Graduate schools suffered a shortage of students, so they began accepting women rather than close. The University of Illinois accepted Yalow, and she graduated with a Ph.D. in nuclear physics in 1945.

The contributions of Yalow have to be regarded in light of the following context. In the mid-1950s, chemical methods for quantitative analysis of hormones in blood were common, but specific analytical procedures were not available for peptide hormones. The main reason for this was their occurrence in blood in extremely low concentrations. For example, the molar concentration of pituitary ACTH under basal conditions is $1 \times 10^{-12}$. To measure such a small amount of ACTH with prevailing biological methods, as much as 250 ml of blood was necessary!

The lack of specific procedures to measure peptide hormones in blood with some degree of accuracy brought about stagnation within a large section of biological and medical research. Worse, on the basis of unreliable determinations of peptide hormones, hypotheses on physiological mechanisms and pathological events were advanced which led research astray.

Yalow, together with her coworker Solomon Berson, developed RIA in 1959. RIA was so sensitive that it could detect as little as 10 pg of insulin per ml body fluid. RIA represented a spectacular merging of immunology, isotope research, mathematics, and physics. After Berson died in 1972, Yalow was awarded the Nobel Prize in Physiology or Medicine in 1977. At Yalow's request, their laboratory was renamed the Solomon Berson Research Laboratory so that his name would continue to be on her publications and his contributions to RIA would be commemorated. Yalow and Berson did not patent RIA procedures, so that they are available to all users, and Yalow refused to consult for any drug company, so that she could speak out on how RIA should be used.

RIA brought about a revolution in biological and medical research. We have today at our disposal a large number of RIA-like procedures for detecting and quantifying peptide hormones, hormones that are not peptides, peptides that are not hormones, enzymes, viruses, antibodies and different kinds of drugs. RIA allows doctors and investigators to diagnose conditions caused by minute changes in hormone levels, to screen blood for hepatitis viruses, to determine effective dosage levels of drugs, to detect foreign substances in blood, and to test and correct hormone levels in infertile couples.

Yalow's contributions were not limited to RIA. With the aid of RIA, she and others were able to elucidate the mechanisms of peptide hormones such as insulin, ACTH, and growth hormone, and also to throw light upon the pathogenesis of diseases associated with abnormal secretion of these hormones. Thus, Yalow has brought about the birth of a new era in endocrinology. This was pioneering work at the highest level!

Conclusion

Besides the four women biologists mentioned above, we have included in the curriculum other prominent biologists (both female and male). Appendix 1 contains other prominent women biologists and their contributions. We have selected biologists of diverse backgrounds so that pre-service teachers will begin to view biologists more as individuals, rather than as stereotypes. The biologists excelled in different fields. They represent different ethnic groups (white, African American, and Hispanic) so that pre-service teachers can identify with their role models culturally. Some women and girls eschew science careers because of the perception of difficulty with balancing work and family life. Hence we present pre-service teachers with biologists who were single, as well as those who married and raised large families. This exposure will address the concerns of potential female scientists of whether they...
could balance a career in science with family responsibilities. We also present biologists in a variety of settings, including field studies and other non-laboratory settings, to dispel their stereotypical image of scientists.

In our experience, administering a survey to name female and male biologists to an unsuspecting class is a powerful way to make teachers aware of their stereotypical perception of scientists. Teachers must be aware of their own perceptions before they can correct the misconception among girls that a career in science is not suited for them. Wherever possible, teachers must also assure girls that females can contribute as equally as males in the sciences, as evidenced by the prominent women biologists described in this article. As the economy in the U.S. and the world grows more and more reliant on a technologically literate workforce, the nation cannot afford to overlook the talent and potential contributions of half the population. If it does, societies, nations, and our world will suffer.

References


**APPENDIX 1. Prominent Women Biologists & Their Contributions to Life Sciences.**

<table>
<thead>
<tr>
<th>BIOLOGIST</th>
<th>CONTRIBUTIONS TO LIFE SCIENCES</th>
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<tbody>
<tr>
<td>1  Florence Augusta Merriam Bailey (1863 - 1948)</td>
<td>Ornithologist. She was noted for her ability to observe birds, and published <em>Handbook of Birds of the Western United States</em> in 1902.</td>
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<td>2  Rachel Louise Carson (1907 - 1964)</td>
<td>Marine biologist and science writer. Her writings brought to public attention the destructive effects of pesticides, resulting in curtailment of their use, and in stronger efforts to develop biological controls for harmful insects.</td>
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<td>3  Jewel Plummer Cobb (1924 - )</td>
<td>Cell biologist and educator. Her early research led to discoveries concerning normal and malignant pigment cells. Interested in helping to solve the puzzle of cancer, she undertook many research projects for the National Cancer Institute.</td>
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<td>4  Alice Eastwood (1859 - 1953)</td>
<td>Botanist. A self-educated frontier botanist, she expanded the California Academy of Sciences Botany Collection to more than 340,000 specimens.</td>
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<td>5  Dian Fossey (1932 - 1985)</td>
<td>Zoologist. She studied the rare mountain gorillas in Africa, and prevented their extinction. She wrote a popular book, <em>Gorillas in the Mist</em>, which described her research on gorilla behavior and how human activity threatened their existence.</td>
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<td>6  Rosalind Elsie Franklin (1920 - 1958)</td>
<td>Molecular biologist and X-ray crystallographer. A pioneer of the study of molecular structures including DNA, she discovered adequate information about the structure of DNA to explain the molecular basis of heredity. Her work contributed to the unravelling of the complete structure of DNA.</td>
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<td>7  Jane Goodall (1934 - )</td>
<td>Ethologist. Living for long periods of time in the field, her studies were the first to show that chimpanzees are intelligent, social animals.</td>
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<td>8  Ida Henrietta Hyde (1857 - 1945)</td>
<td>Physiologist. She made major contributions to the understanding of the nervous and respiratory systems.</td>
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<td>9  Rita Levi-Montalcini* (1909 - )</td>
<td>Biochemist. She received the Nobel Prize in Physiology or Medicine in 1986 for her discovery of nerve growth factors, a class of substances that provides a regulatory link between targets in the body and the nerve cells that innervate them.</td>
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<tr>
<td>10 Judith Graham Pool (1919 - 1975)</td>
<td>Physiologist. She researched the clotting of blood, and developed a method to separate blood clotting factor VIII from blood plasma. Factor VIII is used to treat hemophilia.</td>
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<td>11 Estelle Ramey (1917 - )</td>
<td>Endocrinologist. She experimented with numerous hormone systems including insulin and cortisol. Her work with insulin is important for diabetes research, and her work with cortisol is used in the treatment of inflammation, such as that associated with arthritis.</td>
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<td>12 Florence Rena Sabin (1871 - 1953)</td>
<td>Anatomist. She determined the origin of erythrocytes and did important research on tuberculosis.</td>
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<tr>
<td>13 Nettie Maria Stevens (1861 - 1912)</td>
<td>Biologist. She discovered how sex is determined in an organism.</td>
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<tr>
<td>14 Christiane Nusslein-Volhard* (1942 - )</td>
<td>Geneticist. She won the Nobel Prize in Physiology or Medicine in 1995 for deciphering the genetic control of early embryonic development in fruit flies. The work led to a better understanding of early animal development in general.</td>
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*Denotes a Nobel Prize winner.