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WOMEN IN SCIENCE

Time to Recognize the Obvious

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Time to Recognize the Obvious

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Ladies and Gentlemen,

It is important that scientists everywhere address the issues confronted by women in the practice of science.

My remarks are structured around three main themes:

- First, why we should be concerned about the status of women in the sciences
- Second, what can we learn from the history of struggle of women in the sciences
- Third, what we should be doing today to remedy the situation

Allow me to say a few words about each.

1. AN UNACCEPTABLE SITUATION

Why should we be concerned by the inadequacy of the representation of women among practicing scientists? For two separate and distinct reasons.

First, it is one more domain where the obstacles to women's advancement are manifesting themselves, and should be overcome, as part of the ongoing struggle to get the rights of women recognized as inalienable human rights.

Second, science itself and the practice of science, is ill served by biases of any kind, and this pernicious discrimination is one that must be ended.

Is there a problem?

Some may not consider that there is a problem. We must be wary of the harmful inadequacy of the current state of affairs that we observe all around us.

Women are half the population, but only a very small percentage of the scientists.

This is certainly not due to lack of ability. That old canard about women not being suited to science is a much heard argument resting on the practice of cultural pressures against girls going for science. There is certainly *no lack of innate ability*: from Marie Curie[1], the first person ever to win two Nobel Prizes[*], to Maria Goeppert-Mayer[2],

to Rita Levi–Montalcini[3] to Rosalyn Yates[4] to Barbara McClintock[5] to Linda Buck[6] ... the honor roll of women scientists winning the Nobel prize is clear testimony that such biases are not only unfounded—they are insulting.

So why do we not see that there is bias in the inadequate representation of women in the sciences yesterday and today? Scientists who know about statistics know better than to try to argue these facts away… Luckily, the statistics are changing and tomorrow will be different. Many more women are now registering in science in universities and graduate schools all over the world. But more will have to be done.

It is always amazing to me how people can avoid looking at the obvious discrimination against women. Recall the famous paper by Amartya Sen: *100 million women are missing*[**]. The statistics were there for all to see. If the age sex specific mortality rates of girls in the Indian sub-continent were similar to the developing world average, there would have been about 100 million more women in the population. The systematic discrimination against the girl child was not easy to acknowledge.

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* Besides Marie Curie, the first person to be awarded two Nobel Prizes (1903, Physics; and 1911, Chemistry); other Nobel Laureates are: Irène Joliot–Curie (1935, Chemistry); Maria Goeppert–Mayer (1963, Physics); and Laureates in Physiology or Medicine are: Rosalyn Sussman Yalow (1977); Barbara McClinktock (1983); Rita Levi–Montalcini (1986); and Linda B. Buck (2004).

** The New York Review of Books, 1990, Volume 37, Number 20.

It is not easy to acknowledge the biases against women scientists today. But we must address that too. Redressing this situation is part of the overall struggle of women everywhere for dignity and equality. A recognition of their common humanity.

There is no doubt that women everywhere are discriminated against. In primary and basic education, the gender gap is systematically against girls wherever it exists. In employment, there are many disparities in many parts of the world. Traditional societies tend to be overwhelmingly patriarchal. In many parts of sub-Saharan Africa, women farmers produce 80% of the food and yet receive about 10% of the wage income and own about 1% of the land.

Worse, women are frequently still legislated against in many countries … From personal status law to inheritance to political participation. There are still some countries where so-called "Honor killings" are allowed to go almost unpunished.

Let us recognize that the claims of cultural specificity that would deprive women of their basic human rights, or mutilate girls in the name of convention, should not be given sanction, especially by those who, like myself, are proud of their Muslim and Arab identity and do not want to see the essence of that tradition debased by such claims.

Let us recognize that no society has progressed without making a major effort at empowering its women, through education and the end of discrimination.

Why we should be concerned…

In the world of science, do women scientists bring special talents or outlooks that men do not have? Do women bring a special perspective to science? An intuitive rather than a inductive approach? Do they have special talents, by virtue of being women?

Some would argue yes. That they are more intuitive, more cooperative, or more patient or, or … Louis Leakey used to think that women are better suited for certain scientific tasks, such as the patient work of studying animal behavior, and thus encouraged such luminaries as Diane Fossey[7] and Jane Goodall[8]. Also Francine (Penny) Patterson[9] taught American Sign Language (AMESLAN) to Koko the ape.

Whatever the merits of this line of reasoning, it is a partial argument at best, for it is a "means" argument, a utilitarian argument.

I prefer a more direct approach. We should be concerned because it is fundamentally wrong. Discrimination is never right, in any context. Prejudice does not serve society well, neither by its existence (which is corrosive), nor by its results (loss of output and waste of talent).

Even more, it speaks poorly of scientists and the manner in which they practice science if they do not address biases and fight the inherent discrimination in their midst. The practice of science requires the adoption of certain values that I will call "the values of science", and such values cannot co-exist with sexism or bigotry.

The values of science

These are the same values of science that were so eloquently described by Jacob Bronowski in his classic on *Science and Human Values* over a generation ago. Such values cannot coexist with discrimination.

Truth: No scientist would ever be forgiven the reporting of false data. Mistakes in interpretation are one thing, but falsifying data is unforgiven in the community of scientists. Sir Cyril Burt was struck down from the annals of cognitive psychology posthumously when this was discovered about his work.

Honor: The second most heinous crime is plagiarism. An elaborate system of footnotes and reference citation is maintained in the arsenal of scholarship. Giving due honor where honor is due is fundamental.

A constructive subversiveness: Science advances by having a new paradigm overthrow the old, or at least expand its applicability in new ways. Thus inherent in the scientific outlook is a willingness to overthrow the

established order of thinking, or else there will be no progress. Frequently, those who come up with the new insights are remarkably young. Einstein was 26 when he wrote his five papers in 1905, and Dirac was 27 when he hypothesized anti-matter, and so on. This means that seniority cannot rule unchallenged.

Tolerance plus engagement: The very openness of science to the new means that there is a tolerance of the contrarian view—provided that it can be backed up by evidence, subjected to the rigorous test of replication and meet the Popperian falsifiability criterion. This means that scientists must remain tolerant and engaged. In that sense the tolerance based on the adoption of the values of science is different from the tolerance of political liberalism, which may mask indifference to the behavior of others, dismissing them without engaging them. Tolerance among scientists requires respect for the contrarian view and a willingness to test unusual ideas against the rigor of proof.

An established method to settle disputes: scientists everywhere are willing to accept the arbitration of disputes by the testing of hypothesis and accumulation of evidence. The larger the claim, the more compelling the evidence must be. But the appeal to reason, to debate and to the rational interpretation of evidence is overwhelming in the scientific community.

Imagination: We value the imagination of those who break the mold, and open new vistas, not just those

who add at the margin. Thus the ability to pursue the new, to respect the contrarian view, are important parts of the scientific enterprise. Science values originality as a mark of great achievement. But originality is a corollary of independence, of dissent against the received wisdom. It requires the challenge of the established order, the right to be heard however outlandish the assertion, subject only to the test of rigorous method.

As Bronowski observed, independence, originality and therefore dissent—these are the hallmarks of the progress of contemporary science and contemporary civilization.

In parallel, the scientific community has learned to be wary of bias for its corrosive effects on the practice of science. Scientists now rightly decry the racial biases of even eminent scientists such as were manifested by Paul Broca in his brain studies, or of anti-Semitism in all its guises. Yet, we still have to recognize the inadequacy of the scientific community's response to gender bias.

Recognizing the presence of gender bias is the hardest one of all. It touches every single one of us. It is easier to be dispassionate about events far way, but gender touches us in the privacy of our homes and in the deepest recesses of our minds. It is very much about relations between wife/husband, mother/son, daughter/father, sister/brother. No one can address gender bias in the abstract and escape holding up a mirror to themselves and look hard at how they have responded to the gender bias in their own lives.

And so, to the members of the scientific community I say: look at the facts, hold up a mirror to yourselves—you cannot allow the talents of 50% of the population to be impeded and still claim to serve the interests of science.

2. HISTORY OF WOMEN IN SCIENCE

Let us look back at the history of women in science. It is a history of dogged determination against all odds.

2.1 Few Examples

Women in science go back a long way … To antiquity ... to the most ancient history…

The first human being, whose name is honored for his intellectual achievement, not because he was a king or a conqueror, was a man who lived some 5000 years ago. Imhotep, builder of the stepped pyramid of Saqqarra and founder of the oldest medical school that applied science and not magic to diagnosis and healing. He, a commoner, was to become deified as the Ancient Egyptian god of medicine. However, women were not far behind.

There are some who see in Merit Ptah[10], the first woman scientist. She flourished shortly after Imhotep, *c*. 2700 BCE, and is said to have been a physician. However, if not the first, then one of the earliest known women in science would have to be En Hedu' Anna[11], who lived in Babylon around 2350 BCE. Her father was

Sargon who created the Sargonian Dynasty of Babylon, and she was the chief priestess of the Moon Goddess of the city of Babylon. The priests and priestesses of the time were involved in astronomy and mathematics, as they organized the calendar. In addition, she wrote poems.

Thus women were making a mark by the power of their intellect from the third millennium BCE. But the record of gender discrimination is almost as old.

Late 4th century BCE in Athens: Physician Agnodice[12] was put on trial for pretending to be a man to practice medicine, which was formally illegal. Her women patients (many of whom were wives of important men) saved her and had the law repealed!

Eight-hundred years later, in early 5th century CE, Alexandria, fabled city of learning—where the Ancient Library of Alexandria had been a beacon of learning and education, including girls' education for centuries—Hypatia[13] was killed for her scientific views. She was not even given a trial! A Christian zealot mob hacked her to pieces.

Fourteenth century France—almost a replay of the case of Agnodice, 1800 years later, Jacoba Felicie[14] was tried for impersonating a physician to practice medicine.

Emilie du Chatellet[15], the love of Voltaire's life, was an accomplished scientist who organized at her chateau at

Cirrey a veritable think tank. Even then, society frowned upon her activities.

Even when the law was not prohibiting them from practicing science and medicine, women were still expected to attend to their female societal roles. They are still expected to raise the family as they do their science. Some have done it magnificently. Witness Laura Bassi[16] in 18th century Italy—Europe's first woman Physics professor also raised eight children! Witness Marie Curie, first woman professor at the Sorbonne and the first female Nobel Laureate—widowed mother who wins a second Nobel Prize for herself and also brings up her daughter Irene[17] to become a scientist and the daughter also wins a Nobel Prize!

These are but a few of the many eminent women whose names have been beacons of learning and achievement through the centuries.

2.2 The factors of success

What are the causes of success?

On a *personal level* each of the successful women demonstrated

- Deep commitment to science
- Superhuman determination
- Willingness to fight for what is right

- Mentoring benefits, and
- At least some supportive surroundings

In addition, some circumstances can also be favorable to help them overcome the myriad obstacles that block their way, and these are important to identify. Nurturing these supportive circumstances can help improve the conditions of women in science today. They include both public and private sources of support.

Public support

Public support does play a role.

- Pagan Alexandria and the momentum of the Ancient Library of Alexandria supported Hypatia against Christian Alexandria, until the latter got the upper hand.
- The Church in the middle ages supported some nuns doing research, which is what enabled Hildegard of Bingen[18] to achieve what she did.
- Italy supported women academics more than other parts of Europe, thus we have a proud tradition from Trotula[19] in 11th century Salerno, to Maria Agnesi[20] and Laura Bassi in the 18th century.

Private support

Private Support is also very important. In almost every case of a notable woman scientist defeating the odds to be

recognized for her talent, private and immediate support was important. Father, husband, brother, family and/or friends helped.

Thus Hypatia's father encouraged and helped her.

More recent, but possibly more enduring, it was the "Ladies of Baltimore" who helped make Johns Hopkins fully co-educational in the 19th century. They provided the sustained support that encouraged the early generations of women students at that prestigious university.

2.3 Obstacles to Women in Science

There are many obstacles, but they can be grouped into five broad themes:

- Double standard
- Barriers to access and advancement
- General discrimination
- Social ostracism
- Psychological barriers

2.3.1 Double standard

In all aspects of social behavior today we note a double standard that puts on women an added burden. Science is regretfully not different. Women are assumed to be the assistants to men, not their peers, much less their leaders. This pernicious attitude finds frequent reflection,

from Marie Curie to the present, that when women and men work as a husband and wife team—the husband is assumed to be the "brains of the outfit"!! The old double standard is alive and well even in the dispassionate scientific community. Women have to prove themselves time and again before being assumed to be the equal of men.

2.3.2 Barriers to access

Women suffer from many barriers to access throughout their careers in science. First and foremost, there is a universal discrimination against the girl child in many parts of the developing world, with enrolment and graduation rates lagging boys. Then subtle and not so subtle societal pressures operate to reduce their attendance at science and mathematics courses in higher education facilities.

Consider the enormous difficulties faced by the women who wanted to make a career in science in the 19th century and well into the 20th century. It is interesting to remember that Elizabeth Blackwell[21], (UK/US, 1821–1910) was the first woman to earn an MD degree (on 23 January 1849). She had 29 rejections from colleges until, as a joke, the Geneva NY College accepted her.

Today, in many parts of the developing world and in some parts of the industrialized countries too, early

marriage and abandonment of study and career choices are frequently the lot of talented women who in other societies could have flourished in science.

2.3.3 General discrimination

Barriers to entry are exacerbated by discriminatory practices on the job. We should not be deluded by the many successful careers of women in advanced institutions in the industrialized countries today. Many more suffer and continue to suffer, at entry, then by absence of opportunities, and lack of promotion opportunities or of adequate recognition.

For many reasons, a "glass ceiling" has existed in the world of employment and it is no different in many—though certainly not all—scientific enterprises. Sometimes this discrimination takes the form of not giving women the opportunity to lead the team, and thus perpetually keep them from the visibility and experience that would help them get recognition and promotions. Sometimes it is motivated by a view that women are the secondary wage earner in the family and thus it is "all right" to pass them by in favor of their male colleagues, and sometimes it is because of a fear that they may marry and leave the enterprise after the enterprise has "invested in them" and so on … All the usual efforts at justifying discrimination in one form or another. Yet, most regretfully, it is so pervasive as to be almost unnoticed.

Recognition was denied to many women of distinction.

Ada Lovelace[22] (1815–1852), Daughter of Byron, explained the Babbage computer in a series of remarkable notes that for 30 years had to be signed only AAL because it was inappropriate for a "decent" woman of her rank in society to publish scientific material; while the men could gain fame and honor for so publishing. That attitude carried into the twentieth century, and Arthur Wallace Calhoun could still state in 1918 that "A woman's name should appear in print but twice—when she marries and when she dies."

Cecilia Payne[23] had to endure the sexism rampant at Harvard in the 1920s as she tried to convince astronomers that hydrogen, not iron, was at the heart of the sun.

More recently:

Lise Meitner[24], long-time associate of Otto Hahn, discovered nuclear fission, but did not share the Nobel Prize, although an element was later named after her.

Barbara McLintock[5], who identified the "jumping genes", was ignored for decades—as "that crazy woman"—until after her formal retirement and only when many other researchers confirmed her work. Belatedly, she received the 1983 Nobel Prize.

Rosalind Franklin[25], had she lived longer, would perhaps have shared in the Nobel Prize for the discovery of DNA. I certainly hope so.

2.3.4 Social ostracism

Much of the networking that helps people advance in their chosen careers occurs at social gatherings where women have frequently been denied entry. This has taken the form of formal rules, or unstated practices, at clubs and professional societies. The Cosmos club in Washington did not allow women as full members until 1988, and the Royal Society had no female members till 1945.

We have come a long way since then … Recall that Margaret Peachy Burbidge[26] became first woman to head the Royal Greenwich Observatory and today, Harriet Wallberg Henriksson[27] heads the Karolinska Institute in Sweden, Susan Hockfield[28] is President of MIT, Shirley Ann Jackson[29] is President of Rensselaer Polytechnic Institute (RPI), Rita Colwell[30] headed the NSF and Jane Lubchenko[31] was elected president of ICSU. Mamphela Ramphele[32] was Vice-chancellor of Cape Town University and Managing Director of the World Bank; and so many other remarkable women shine in the realm of science that we might be tempted to ignore the very real difficulties that they encounter.

2.3.5 Psychological obstacles

Prejudice often carries onto the mind of the victim. Thus Mary Somerville[33] in 19th century Britain, wrote that "…genius, that divine spark from heaven, is not granted to the female sex…" despite herself being a scientist of ability, and a great popularizer of science.

But today ...

Mathematician Julia Bowman Robinson[34] (1919–1985), who served as the first woman president of the American Mathematical Association in 1983/84, did not want to be known as the first woman to have done this or that, but to be remembered for the quality of her work.

Indeed we must be grateful to the women pioneers who would not be deterred by these myriad obstacles and who by their determination paved the way for the many young girls entering science all over the world, and who will redress these grievous past imbalances by their achievements in the decades to come.

3. THE TASK AHEAD

We need to empower women in every domain, and science is no exception. We must do so because empowerment of women is the key to all development; because discrimination is wrong in any domain; and because science cannot discriminate against women and

remain true to the values of science, to its own moral code of objectivity.

The task will be difficult, because the remaining issues are not legal boundaries to overcome, they are behavioral issues ... Bringing about behavioral change is infinitely more difficult than changing a law. Although the law is important to help prevent the most egregious behavior, as Martin Luther King Jr. said about civil rights legislation:

> *"Morality cannot be legislated, but behavior can be regulated. Judicial decrees may not change the heart but they can restrain the heartless."*

Frankly, in many places today, it is not legal discrimination that we confront. We are now up against subtle, and not so subtle, discriminatory behavior that needs changing.

We need to create work environments where women are empowered. There are a few simple rules to follow: accept that in all our societies, women have a larger burden in child rearing than men, and thus accommodate that in the work environment: generous maternity leaves, part-time employment and flexible hours are a must. Do not penalize a woman's career because she chooses to work part-time in the most crucial child-rearing years. Ensure the presence of role models and mentors in the organization, and make sure that women receive adequate

public recognition for their achievements, especially when they work as part of a team that includes men. Finally, also involve women in the design of research programs that they may bring to the fore topics that may be of particular interest to them.

That, my friends, is the true revolution. Simple as these steps may sound, they can lead to an inviting nurturing work environment where women are allowed to grow to their full potential. That in turn is a necessary antidote to the conditions of our world today. This is not a favor we do to women; it is simply a recognition of their basic human rights, and an affirmation of the values of science and the scientific method.

So let us all commit ourselves to creating a new order of things. But let us not falter, for women's issues are no luxury that we can take or leave. This is not just a matter of equity and fairness, although it is certainly that.. it is also a matter of life and death—

Look at the world around us today. Look at the terrible statistics of maternal mortality and infant mortality. Look at the rampant feminization of poverty and hunger … Look at the world and recognize the facts…

It is strange that facts of rampant discrimination can stare us in the face but not be seen for what they are. Recall my earlier mention of Amartya Sen's stunning essay entitled: "100 million women are missing", which

raised a furor. Just taking the census figures for age-sex-specific mortality rates in the Indian sub-continent, Sen calculated that had the more general global figures prevailed, there would have been 100 million more women in the population. The evidence was there staring us in the face …

Most intriguing was the reaction of many distinguished scientists (men) who started quibbling with the numbers. Redoing the calculations, they would argue that the number is really "only 63 million" or no, "it is really 106 million", or more precisely 93 million … whatever it was, it was and is a very large number. It bespeaks of systematic discrimination against the girl child and calls for urgent action to redress these conditions …

So let us take action. Let us resolve to strengthen the factors of success, those factors that can help determined and deserving women overcome the obstacles. And as we work on the problems of today, let us study and learn from the past. Indeed, just rectifying past injustices in the historical record, is not only fair, it is an important part of empowering the future generations of women. Even when such "revisionist history" proves traumatic to a few, it can be empowering and inspiring to many.

Redressing the wrongs of the past, through historical scholarship, creates strength for the present and the future. Gerda Lerner[35] in 1982 addressing the Organization of American Historians as their new president said:

> *"If the bringing of women—half the human race—into the center of historical inquiry poses a formidable challenge to historical scholarship, it also offers sustaining energy and a source of strength."*

From the past to the present and the future is a straight trajectory that must be bent to our dreams of better tomorrows.

Working for better tomorrows

So, learning from the past, how can we improve conditions for women in science?

We need to provide a working environment that responds to women's needs, enhance support, provide mentoring and ensure encouragement in order that the talented women scientists of tomorrow can truly blossom to full potential.

Today, we are sustained more by networks than by individuals. So let us establish these networks, let us strengthen those that exist. Let us reach out to the women who are not yet reached by such supportive and nurturing networks.

Be inspired by the example of Lydia Makhubu, founder of the Third World Organization of Women Scientists. Try to build links to TWOWS as you establish and expand your own new networks.

Let such networks involve both men and women. For working together men and women can do much to change society. We need to breathe with both lungs, and walk with two legs. The battle for women in science is a battle for the whole of society, for all humankind.

We must not only mobilize women, we must also educate men. We must hold up mirrors that show them society as it really is, and open windows through which they can see the world as it can be. We cannot focus on building and empowering the women of tomorrow without worrying about re-educating the men of yesterday.

The obstacles are large, but they are not insurmountable. The journey is long, but women have already come a long way, and men are increasingly recognizing their responsibilities to help remove the many obstacles that still prevent women scientists from rising to their full potential and to give society the full measure of their talent.

ENDNOTES

[1]**Marie Sklodowska Curie** (1867–1934), physicist and radiochemist; *a two-time Nobel laureate: 1903 Nobel Prize in Physics, and 1911 Nobel Prize in Chemistry*. She was a Polish–French chemist, and pioneer in the early field of radiology. She also became the first woman appointed to teach at the Sorbonne. She was born in Warsaw, and spent her early years there, but in 1891 at age 24, moved to France to study science in Paris. She obtained all her degrees and conducted her scientific career there, and became a naturalized French citizen. She founded the Curie Institutes in Paris and in Warsaw.

[2]**Maria Goeppert Mayer** (1906–1972) mathematical physicist; *1963 Nobel Prize in Physics* was born in Silesia. She obtained her education in Goettingen. During 1920s, Goettingen was perhaps the most active place in developing the ideas of modern quantum mechanics and applying them to atoms. She wrote her PhD thesis on the decay of excited states by the simultaneous emission of two quanta. In Goettingen, She met Joe Mayer, a theoretical chemist from the United States on a fellowship and they were married shortly, and moved to the United States. They worked at Johns Hopkins University, and wrote a textbook on Statistical Mechanics, which became widely used. Following World War II, she joined her husband at the University of Chicago, and there she made her famous discoveries on the Nuclear Shell Model. Her contribution to the Nuclear Shell Model can be roughly divided into three parts: (i) Discovery of the Magic Numbers (a configuration of a magic number of neutrons or protons; and are in all kinds of nuclear processes. They are: 2, 8, 20, 28, 50, 82, 126); (ii) Explanation of the Magic Numbers for which she shared the 1963 Nobel Prize with Hans Jensen; and (iii) nuclear pairing.

[3]**Rita Levi–Montalcini** (1909–) neuroembryologist; *1986 Nobel Prize in Physiology or Medicine*; Italian–American neurologist, born in Turin, Italy. A dual citizen of Italy and the United States, Levi-Montalcini did her most important work at Washington University with Stanley Cohen. The pair isolated a nerve-growth factor, the first of many cell-growth factors found in animals. For this discovery Levi–Montalcini and Stanley Cohen were awarded the 1986 Nobel Prize in Physiology or Medicine.

[4]**Rosalyn Sussman Yalow** (1921–) American medical physicist; *1977 co-winner Nobel Prize in Physiology or Medicine for her development of the radioimmunoassay (RIA) technique*. She graduated (1941) from Hunter College, where she developed an interest in physics. Soon after graduation she received an offer for a teaching assistantship in Physics from the University of Illinois. She was the only woman, and the first since 1917, among the department's 400 members. She received her PhD in 1945. Following graduation, she joined the Bronx Veterans Administration Hospital to help set up its radioisotope service. There she collaborated with Solomon Berson to develop RIA, a radioisotope tracing technique that allows the measurement of tiny quantities of various biological substances in the blood. Despite its huge commercial potential, Rosalyn Yalow and Solomon Berson refused to patent the method. In 1976, Rosalyn became the first female recipient of the Albert Lasker Award for Basic Medical Research. The following year she received the Nobel Prize, together with Roger Guillemin and Andrew V. Schally.

[5]**Barbara McClintock** (1902–1992) geneticist; *1983 Nobel Prize in Physiology or Medicine*. She was born in Hartford, CT, and obtained her undergraduate and doctoral degrees at Cornell University's College of Agriculture. She was supported by a fellowship from the National Research Council (1931–1933); 1941 until her death, she worked at the Cold Spring Harbor

Laboratory in New York. In 1944, became the third woman elected to the Academy. In the 1940s and 1950s, McClintock's work on the cytogenetics of maize led her to theorize that genes are transposable, they can move around, on and between chromosomes. She drew this inference by observing changing patterns of coloration in maize kernels over generations of controlled crosses. The idea that genes could move did not seem to fit with what was then known about genes, but improved molecular techniques of the late 1970s and early 1980s allowed other scientists to confirm her discovery, and consequently she was awarded the 1983 Nobel Prize in Physiology or Medicine. She was the first American woman to win an unshared Nobel. Among the many honors awarded, in 1970 the National Medal of Science, the US Government's highest science award.

[6]**Linda B. Buck** (1947–) is an American biologist born in 1947 in Seattle, Washington. *She and Richard Axel shared the 2004 Nobel Prize in Physiology or Medicine* for their work on olfactory receptors, in their landmark paper published in 1991. Buck and Axel cloned olfactory receptors, showing that they belong to the family of G protein-coupled receptors. By analyzing rat DNA, they estimated that there were approximately 1,000 different genes for olfactory receptors in the mammalian genome. This research opened the door to the genetic and molecular analysis of the mechanisms of olfaction. Buck obtained her BSc in Psychology and Microbiology (1975), and her PhD in Immunology (1980). Her primary research interest is on how pheremones and odors are detected in the nose and interpreted in the brain. She is also studying the mechanisms underlying aging and the lifespan of *C. elegans*.

[7]**Diane Fossey** with an early and avid interest in animals, entered college as a pre-veterinary major, but switched majors to occupational therapy. Following her graduation from San Jose State College (1954), she served as Director of the Occupational

Therapy Department at the Kosair Crippled Children's Hospital, Louisville, Kentucky. In 1963, she fulfilled a lifelong dream to travel to Africa, where she met renowned paleontologists Mary and Louis Leakey, who inspired her to study mountain gorillas. She studied and lived with mountain gorillas in the Republic of Congo. She fled to Rwanda when civil war broke out in Congo (1967), and established the Karisoke Research Foundation. She divided her time between conducting field work in Rwanda and earning a PhD from Cambridge University (1976). Her best-selling memoir, *Gorillas in the Mist*, which chronicles her time spent living with the gorillas and battling poachers, was published in 1983, and made into a film starring Sigourney Weaver. Fossey was murdered in a Rwandan camp in 1985.

[8]**Jane Goodall** (1934–), PhD, is an English primatologist, ethologist and anthropologist, probably best-known for conducting a 34-year study of chimpanzee social and family life, as director of the Jane Goodall Institute in Gombe Stream National Park, Tanzania. In 1977, Goodall established the Jane Goodall Institute, which supports the Gombe research and is a global leader in the effort to protect chimpanzees and their habitats. Goodall was instrumental in the recognition of social learning, thinking, acting, and culture in wild chimpanzees, their differentiation from the bonobo, and the inclusion of both species along with the gorilla as Hominids. One of her major contributions to the field of primatology was the discovery of tool use in chimpanzees. Some chimpanzees poke twigs into termite mounds; the termites grab onto the stick with their mandibles and the chimpanzees then just pull the stick out and eat the termites.

[9]**Francine (Penny) Patterson** (1947–), USA, is a researcher who taught a modified form of American Sign Language to a gorilla "Koko". She earned her BA in Psychology (1970), University of Illinois, Urbana–Champaign, and her PhD (1979)

from Stanford University, with her dissertation Linguistic *Capabilities of a Lowland Gorilla* on teaching sign language to Koko and another gorilla "Michael". Currently, she serves as the President and Research Director of The Gorilla Foundation. She is an Adjunct Professor of Psychology at Santa Clara University; is a member of the Board of Consultants at the Center for Cross Cultural Communication in Washington, DC, and is the Editor-in-Chief of the *Gorilla* journal. She is the author of The *Education of Koko*, and has collaborated on the children's books *Koko's Kitten, Koko–Love!: Conversations With a Signing Gorilla*, and *Koko's Story*.

[10]**Merit Ptah** (c. 2700 BCE), was probably the first physician in the world and the first woman in science known by name. Her picture can be seen on a tomb in Egypt's Valley of the Kings. Her son, who was a High Priest, described her as "the Chief Physician". The IAU named the impact crater *Merit Ptah* on Venus after her.

[11]**En Hedu' Anna**, Priestess of the Moon Goddess (c. 2354 BCE). She is the first female recorded in technical history. Her name means "ornament of heaven". We do have translations of 42 of her poems, the most famous *Exultation of Inanna*. To put her into perspective, modern astronomy and mathematics began there, with the priests and priestesses in Sumeria and Babylon. They established a network of observatories to monitor the movements of the stars. The calendar they created is still used to date for certain religious events like Easter and Passover.

[12]**Agnodice** in Greek legend was a virgin of Athens who disguised herself as a man in order to learn medicine from Herophilos. She learned to be a midwife and began to practice as such. She always revealed her femininity to her patients, and as a consequence she became immensely popular. She was so popular that male physicians who were put out of work by her

practice, accused her of corruption to the Areopagus. In court, she revealed her sex, and a law was made to allow all free-born women to learn midwifery.

[13]**Hypatia of Alexandria** (370–415), was the first notable woman in mathematics. The daughter of Theon, Hypatia became the recognized head of the Neoplatonist School of Philosophy in Alexandria, Egypt. Most historians recognize Hypatia as a mathematician, scientist and philosopher. After the accession of Cyril to the patriarchate of Alexandria in 412, Hypatia was barbarously murdered by the Nitrian monks and a fanatical mob of Cyril's Christian followers, supposedly because of her intimacy with Orestes, the city's pagan prefect. Following her death, many scholars departed marking the beginning of the decline of Alexandria as a major center of ancient learning. According to the *Suda Lexicon*, Hypatia wrote commentaries on the *Arithmetica* of Diophantus of Alexandria, on the *Conics* of Apollonius of Perga, and on the astronomical canon of Ptolemy; and Synesius of Cyrene consulted her about the construction of an astrolabe and a hydroscope.

[14]**Jacoba Felicie** was 13th century CE (France-midwife). Women were not allowed to practice medicine in her time, so she was brought to trial for practicing medicine without a license. The cause of conflict with the master physicians of Paris was not to her methods of healing, but the success of Jacoba's practice. The Masters of medicine did not deny the success of her treatment, but took the view shared by the university trained physicians that medicine was a science that had to be learned from books. Jacoba Felicie was brought to trial in 1322 by the Faculty of Medicine at the University of Paris, on charges of illegal practice. Jacoba was literate and had received some unspecified "special training" in medicine. Her patients had consulted well-known university-trained physicians before turning to her. The primary accusations brought against her were that … she would cure her

patient of internal illness and wounds or of external abscesses. She would visit the sick assiduously and continue to examine the urine in the manner of physicians, feel the pulse, and touch the body and limbs. Six witnesses affirmed that Jacoba had cured them, even after numerous doctors had given up, and one patient declared that she was wiser in the art of surgery and medicine than any master physician or surgeon in Paris. However these testimonials were used against her, for the charge was not that she was incompetent, but that—as a woman—she dared to cure at all.

[15]**Émilie du Châtelet** (1706-1749), was a French mathematician, physicist and author. She translated into French, with her own commentary, Newton's celebrated *Principia Mathematica* and derived from its principles of mechanics the notion of conservation of energy. She researched the science of fire, publishing a paper which foresaw what is today known as infra-red radiation and the nature of light.

[16]**Laura Maria Caterina Bassi** (1711–1778), was the first woman to officially teach at a college in Europe. In 1732, was appointed professor of anatomy at the University of Bologna at the age of 21 and two years later was given the chair of philosophy. In 1738, she married Giuseppe Veratti, a fellow academic and had eight children. She was mainly interested in Newtonian physics and taught courses on the subject for 28 years. She was one of the key figures in introducing Newton's ideas of physics and natural philosophy to Italy. In her lifetime she published 28 papers, the vast majority of these on physics and hydraulics, but she wrote no books. In 1745, Lambertini (now Pope Benedict XIV) established an elite group of 25 scholars, Bassi pressed hard to be appointed to this group and Pope Benedict appointed her to the final position, the only woman in the group. In 1776, at the age of 65, she was appointed to the chair in experimental physics by the Institute of Sciences.

[17]**Irène Joliot–Curie** (1897–1956), radiochemist, *1935 Nobel Prize in Chemistry*, born in Paris, France. She is daughter of first female Nobel Laureate Marie Curie. French scientist, wife of Frédéric Joliot–Curie. She studied at the Faculty of Science, Sorbonne, but her education was interrupted by World War I during which she served as a nurse radiographer. After the War, she earned her doctorate in science; was on the alpha rays of polonium. In 1926, she married Frédéric Joliot and collaborated with him on studying atoms. They shared the 1935 Nobel Prize in Chemistry. In 1938, her research on the action of neutrons on the heavy elements was an important step in the discovery of nuclear fission. She became Professor in the Faculty of Science in Paris (1937), and in 1946 the Director of the Radium Institute. A peace activist, she took a keen interest in women's rights, becoming a member of the *Comité National de l'Union des Femmes Françaises* and of the World Peace Council. She was the Chair of Nuclear Physics at the Sorbonne, and in 1936 the Government of France appointed her Undersecretary of State for Scientific Research and ultimately she was named an Officer of the Legion of Honour. Irene Joliot–Curie passed away in Paris from leukemia contracted in the course of her work.

[18]**Hildegard of Bingen** (1098–1179), was a remarkable woman, a "first" in many fields. At a time when few women wrote, Hildegard, known as "Sybil of the Rhine", produced major works of theology and visionary writings. When few women were accorded respect, she was consulted by and advised bishops, popes, and kings. She used the curative powers of natural objects for healing, and wrote treatises about natural history and medicinal uses of plants, animals, trees and stones. She is the first composer whose biography is known. She founded a vibrant convent, where her musical plays were performed. Although not yet canonized, Hildegard has been beatified, and is frequently referred to as St. Hildegard.

[19]**Trotula** lived during the 11th century in Salerno, Italy. She was a famous obstetrician/gynecologist about which she wrote several books that were still consulted hundreds of years later. She is best known for teaching male doctors about the female body and childbirth. She also wrote books about the complications of childbirth and how to overcome them.

[20]**Maria Gaetana Agnesi** (1718–1799), was an Italian linguist, mathematician, and philosopher. Agnesi is credited with writing the first book discussing both differential and integral calculus. Maria could speak both French and Italian at the age of 5. By age 13, she had acquired Greek, Hebrew, Spanish, German, Latin, and was referred to as the "Walking Polyglot". At age 9, she composed and delivered in Latin women's right to be educated, an hour-long speech to an academic gathering. At age 15, her father Pietro, a mathematics professor, regularly gathered a circle of the most learned men in Bologna, before whom she read and maintained a series of theses on the most abstruse philosophical questions. Records of these meetings are in de Brosses' *Lettres sur l'Italie* and in the *Propositiones Philosophicae*, which her father had published in 1738. By age 20, it is said she had a strong desire to enter a convent. Her wish was not granted and she lived from that time on in an almost conventual semi-retirement, avoiding all interactions with society and devoting herself entirely to the study of mathematics.

[21]**Elizabeth Blackwell** (1821–1910), is well known worldwide as the first woman to receive her degree as a Doctor of Medicine. She represents a historic moment in modern medicine and women's liberation. Several years after her family immigrated to the United States, she studied privately with independent physicians, an education which culminated at Geneva Medical College in Upstate New York. Upon graduation, she founded the New York Infirmary for Women and Children. Later, she helped found the National Health Society, was the first woman to be

placed on the British Medical Register, and taught at England's first college of medicine for women. She pioneered in preventive medicine and in the promotion of antisepsis and hygiene.

[22]**Ada Byron**, Lady Lovelace (1815–1852), was one of the most picturesque characters in computer history. Augusta Ada Byron was born in 1815, and five weeks following her birth Lady Byron asked for a separation from Lord Byron, and was awarded sole custody of Ada whom she brought up to be a mathematician and scientist. Lady Byron was terrified that Ada might end up being a poet like her father. Despite Lady Byron's programming Ada did not sublimate her poetical inclinations. She hoped to be "an analyst and a metaphysician" "Poetical science?" Her understanding of mathematics was laced with imagination, and described in metaphors.

[23]**Cecilia Payne-Gaposchkin** (1900–1979), was a British–American astronomer. She was born Cecilia Payne in England and studied botany, physics and chemistry at Cambridge University. She left England for the United States in 1922. In 1925, she was the first person to earn a PhD in astronomy from Harvard for her dissertation "*Stellar Atmospheres, A Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars*". Her thesis established that hydrogen was the overwhelming constituent of the stars. She spent her entire academic career at Harvard. For decades she held no official position there. In 1938, was she given the title "astronomer", and in 1956, she became the first female tenured professor at Harvard, and later its first female department chair. The trail she blazed into the largely male-dominated scientific community was an inspiration to many. She married Russian-born Sergei I. Gaposchkin, and had three children.

[24]**Lise Meitner** (1878–1968), Austrian–Swedish physicist and mathematician. She was professor at the University of Berlin

(1926–33). A refugee from Germany after 1938, she became associated with the University of Stockholm and with the Nobel Institute at Stockholm. In 1917, working with Otto Hahn, she isolated the most stable isotope of the element protactinium; she also investigated the disintegration products of radium, thorium, and actinium and the behavior of beta rays. In 1938, she participated in experimental research in bombarding the uranium nucleus with slow-speed neutrons. Meitner interpreted the results as a fission of the nucleus and calculated that vast amounts of energy were liberated. Her conclusion contributed to the development of the atomic bomb. In 1949, she became a Swedish citizen. The element with the atomic number 109 is named meitnerium in her honor.

[25]**Rosalind Franklin** (1920–1958), attended St. Paul's Girls' School. Rosalind studied chemistry and physics at Newnham College, Cambridge, and in 1942 began carrying out research at the British Coal Utilization Research Association. In 1947, she went to the Central Government Laboratory for Chemistry in Paris where she worked on X-ray diffraction until 1951 when she moved to King's College, London. The evidence she revealed about viruses helped lay the foundation for structural biology. In the early 1950s, she almost discovered, by herself, enough information about the structure of DNA to explain the molecular basis of heredity. The facts she did uncover about the molecule helped James Watson and Francis Crick beat her to the Nobel Prize, data they used without her knowledge and without fully crediting her. Rosalind produced X-ray diffraction pictures of DNA which were published in Nature in April 1953. She decided to join John Bernal at Birkbeck College to carry out research into the tobacco mosaic virus. In 1957, Rosalind began to work on the polo virus.

[26]**Margaret Burbidge** (1919-), was born in England and educated at the University of London, where she remained until

1951. She worked at Yerkes Observatory and the California Institute of Technology and has been at the University of California, San Diego since 1962. She held many administrative positions, including that of director of the Royal Greenwich Observatory and first director of the Center for Astrophysics and Space Sciences at UCSD. In 1957, she, Geoffrey R. Burbidge, William A. Fowler and Fred Hoyle showed how all the elements except the very lightest are produced by nuclear reactions in stellar interiors. She also studied spectra of galaxies, determining their rotations, masses, and chemical composition, and has achieved particular renown for spectroscopic studies of quasars. She played a major role in developing instrumentation for the Hubble Space Telescope.

[27]**Harriet Wallberg-Henriksson** began her career as a director of gymnastics following her graduation with a degree in Physical Education Teaching from the University College of Physical Education and Sports. She maintains her interest in physiology through her passion for issues related to physical activity and metabolism. Her work besides that of University President involves researching into finding ways to combat diabetes, a chronic disease that is becoming increasingly endemic with the rising tide of obesity, stress and physical activity amongst the public. She has written or co-written some 130 scientific articles in the field of diabetes and clinical physiology, and is Vice-Chairman of the European Association for the Study of Diabetes (EASD). Professor Wallberg–Henriksson was appointed president after over 25 years at Karolinska Institutet, one of Europe's largest medical universities and one of the highest ranking in the world, where she studied at both undergraduate and postgraduate levels, earned a PhD in medicine, became an associate professor and, since 1998, has held a professorship in physiology.

[28]**Susan Hockfield**, MIT's sixteenth president, is "President and Professor of Neuroscience". Scientists working under her direction identified a family of cell surface proteins whose expression is regulated by neuronal activity early in an animal's life. Her early work involved the application of monoclonal antibody technology to questions within neurobiology. A link between her research and human health was made when it was suggested one of these proteins played a role in the progression of brain tumors. Hockfield's work has recently focused on one type of brain tumor "glioma". Before leaving to head MIT, Hockfield served at Yale University as provost, the University's second highest officer. She had previously served at Yale as dean of the Graduate School and as a professor of neurobiology. Hockfield received her undergraduate degree from the University of Rochester and her doctorate from the Georgetown University School of Medicine. Her doctoral dissertation was on the subject of pathways in the nervous system through which pain is perceived and processed.

[29]**Shirley Ann Jackson** received her BSc (1968) in Physics, and PhD (1973) in theoretical elementary particle physics, Massachusetts Institute of Technology. She was a research associate at the Fermi National Accelerator Laboratory; a visiting scientist at the European Center for Nuclear Research, and a theoretical physicist at the former AT&T Bell Laboratories (1976–91). She was a professor of theoretical physics at Rutgers University (1991–95), and Chairman of the US Nuclear Regulatory Commission (1995–99). She was named President of Rensselaer Polytechnic Institute in 1999. She is a director of Federal Express Corporation, International Business Machines Corporation, Medtronic, Inc., and Public Service Enterprise Group Incorporated, and also a director of the New York Stock Exchange. She is a member of the Board of Regents of the Smithsonian Institution, a member of the MIT Corporation, and a Trustee of Georgetown University and The Brookings Institution. She holds 33 honorary degrees and granted numerous awards.

[30]**Rita Colwell** served as the eleventh Director of the National Science Foundation (1998–2004). She is chairman of Canon US Life Sciences. She obtained a bachelor's degree in bacteriology and a master's degree in genetics from Purdue University, followed by a doctorate in oceanography from the University of Washington. Colwell was president of the University of Maryland Biotechnology Institute (1991–1998), and she remains professor of microbiology and biotechnology at the University of Maryland. She was also a member of the National Science Board (1984–1990). Colwell held many advisory positions in the federal government, and has authored or co-authored 16 books and more than 600 scientific publications. She produced the award-winning film Invisible Seas and has served on editorial boards of many scientific journals. The recipient of numerous awards, Colwell has also received 26 honorary degrees from institutions of higher education. A geological site in Antarctica, Colwell Massif, was named after her.

[31]**Jane Lubchenco**, an environmental scientist and marine ecologist who is actively engaged in teaching, research, synthesis and communication of scientific knowledge. She received her PhD and taught at Harvard University. She moved to Oregon State University where she is Valley Professor of Marine Biology and Distinguished Professor of Zoology. Her research interests include biodiversity, climate change, sustainability science and the state of the oceans. She has received numerous awards including a MacArthur Fellowship, a Pew Fellowship, eight honorary degrees (including one from Princeton University), the 2002 Heinz Award in the Environment and the Nierenberg Prize for Science in the Public Interest from the Scripps Institution of Oceanography, 2003.

[32]**Mamphela Ramphele**, a South African national is Co-chair of a new UN Commission on International Migration since June 2004 and a former Managing Director of the World

Bank. Prior to joining the Bank, Mamphela Ramphele was the first black woman as Vice-Chancellor at the University Cape Town and has been honored for her contribution to the struggle against apartheid. She is a qualified medical doctor and holds a PhD in Social Anthropology, a BCom degree in Administration and several diplomas. She is an author of a number of books and articles.

[33]**Mary Fairfax Somerville's** scientific investigations began in summer 1825, when she carried out experiments on magnetism. In 1826, she presented her paper entitled "*The Magnetic Properties of the Violet Rays of the Solar Spectrum*" to the Royal Society. The paper attracted favorable notice and, aside from the astronomical observations of Caroline Herschel, was the first paper by a woman to be read to the Royal Society and published in its Philosophical Transactions (Grinstein and Campbell 213). Although the theory presented in her paper would eventually be refuted by the investigations of others, it distinguished her as a skilled scientific writer respected among her colleagues.

[34]**Julia Robinson** (1919–1985) was an American mathematician. She spent several years at San Diego State College (now San Diego State University), but completed her undergraduate and graduate degrees at the University of California, Berkeley. In 1976, Robinson was elected as the first female member of the mathematical division of the National Academy of Sciences. In addition, she was the first woman president of the American Mathematical Society. She is best known for her work on Diophantine equations and decidability which provided much of the ground work for the negative solution of Hilbert's tenth problem by Yuri Matiyasevich. In fact Robinson only strayed from this topic twice. The first was her thesis on effective solvability and unsolvability of mathematical problems. The second was in game theory where she proved

that fictitious play dynamics converges to mixed strategy Nash equilibrium in two player zero sum games.

[35]**Gerda Lerner** is considered a pioneer in the field of women's history. Indeed she is credited with teaching the first postwar college course in women's history and helping establish several women's history graduate programs. She studies issues of race and class in relationship to gender issues, not making the mistake of generalizing about women's experiences. Her book *Black Women in White America: A Documentary History* was one of the very first historical works to address this group. In her work she had drawn on many sources that were previously unpublished, including letters, diaries, newspaper clips and speeches. Prominent women's historian Elizabeth Fox–Genovese credits Lerner with uncovering the sources necessary for the writing of women's history.

Ismail Serageldin

Director of the Library of Alexandria, also chairs the Boards of Directors for each of the BA's affiliated research institutes and museums and is Distinguished Professor at Wageningen University in the Netherlands. He serves as Chair and Member of a number of advisory committees for academic, research, scientific and international institutions and civil society efforts which includes L'Institut d'Egypte (Egyptian Academy of Science), The Academy of Sciences for the Developing World (TWAS), the Indian National Academy of Agricultural Sciences and the European Academy of Sciences and Arts. He is former Chairman, Consultative Group on International Agricultural Research (CGIAR, 1994-2000), Founder and former Chairman, the Global Water Partnership (GWP, 1996-2000) and the Consultative Group to Assist the Poorest (CGAP), a microfinance program (1995-2000). Serageldin has also served in a number of capacities at the World Bank, including as Vice-President for Environmentally and Socially Sustainable Development (1992-1998), and for Special Programs (1998-2000). He has published over 50 books and monographs and over 200 papers on a variety of topics including biotechnology, rural development,

sustainability, and the value of science to society. He holds a Bachelor of Science degree in Engineering from Cairo University and Masters degree and a PhD from Harvard University and has received 19 honorary doctorates.