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SCIENCE

The Culture of Living Change

Ismail Serageldin

Second Edition

Alexandria, EGYPT
2007

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Bibliotheca Alexandrina Cataloging-in-Publication Data
Serageldin, Ismail, 1944-
Science : the culture of living change / \c Ismail Serageldin. – Alexandria : Bibliotheca Alexandrina, 2007. – 2nd ed.
p. cm.
Includes bibliographical references.
ISBN 978–977–6163–58–4

1. Science and civilization. 2. Islam and science. 3. Women in science. I. Title.

303.483--dc21 2007324273

ISBN 978–977–6163–58–4
Dar El Kuttub Depository No. 3997/2007

Cover Design and Layout by Cherine Samir Bayoumi
Printed in Egypt
2000 copies

CONTENTS

INTRODUCTION TO THE SERIES

The idea of publishing this series started a few years ago. It was in response to the pressing demands of many to have written copies of speeches that I have had the honor to deliver on various occasions, or to seek reprints of chapters that I had devoted to particular topics in publication that may not be available to that particular audience.

The speeches covered many topics, and therefore I felt it appropriate to group them by topic. Each of these little books deserved its own introduction, explaining the circumstances of the speeches and articles provided there and why they were grouped in this particular fashion, to bring a semblance of coherence to words, which at their inception, were not intended to be read as a single continuous text. I believe that they are readable both individually and as a collection with little difficulty.

However, as we progressed in the publication of these books, another issue came to the fore. Some of the essays or speeches fit naturally in more than one grouping. Addressing "Women in Science" could, and should, be part of a collection on Science, as well as a collection on gender issues. I therefore decided to include it in both, on the assumption that readers of one may not be readers of the other. In some cases, and "Women in Science" is such a case, this was complementary to the production of a stand-alone monograph, due to the demand for this particular piece.

All these essays, speeches, chapters, or monographs are available electronically, online on my personal website (www.serageldin.com) as well as the website of the Bibliotheca Alexandrina (www.bibalex.org). Many, however, prefer the convenience of the printed form of the book. I believe it is a wonderful companion, which will continue to co-exist harmoniously with its electronic counterpart for a long time into the future.

Ismail Serageldin
Librarian of Alexandria
Director of the Bibliotheca Alexandrina

January 2007
Alexandria, EGYPT

INTRODUCTION TO THE SECOND EDITION

I am delighted that this little book on “Science: The Culture of Living Change” has now gone into a second edition. In this edition, I have added a special lecture that I had given on “Women in Science” on the occasion of the inauguration of the Academy of Sciences for the Developing Countries (TWAS), in November 2005 and which had subsequently been published as a stand-alone publication. The rest of the essays and lectures remain fundamentally the same. I hope that they will communicate my enthusiasm for scientific discovery and my commitment to the scientific method, which I believe are part of the “Values of Science” that we should pass on to the next generation. Truth, honor, rationality, openness to the contrarian view, engagement with the other, evidentiary arbitration of disputes, a coupled with a certain constructive subversiveness are all values that not only make science possible, they also make for a better society, a more open and tolerant society, a more peaceful society.

Ismail Serageldin

SCIENCE AT THE DAWN OF THE 21st CENTURY[1]

We are living in the age of science. There are more scientists alive and practicing today than in all the previous periods of history combined. Science permeates the cultural outlook of our societies and the worldview of more people than ever before. Science has contributed to enormous achievements in human welfare. Thanks to numerous scientific advances, we are now moving to the third global revolution, a new world that has never been more promising, or more perilous.

The first of the great global revolutions was the agrarian revolution that settled people in small communities and launched civilizations. By the banks of the Nile and along other great rivers of the world, our ancestors established the foundations of organized society and fashioned the wise constraints that make people free. They created the wonders of the ancient world. Even today, it is the surpluses produced by farmers that make city life possible.

The second great global revolution, the industrial revolution, was the harbinger of enormous change in production methods, and in the relationship of people to the

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1 This article first appeared in *Science Magazine*, 5 April 2002, vol. 296.

final product on which they labored. The artisan became a worker; processes of production and specialization led to an enormous burst of output, bringing big improvements for much of humanity during the next two centuries.

The Third Global Revolution

Our world is undergoing a third transformation, one so profound that its contours can only be dimly perceived, its driving forces barely understood, and its momentous consequences hardly imagined. Indeed, it provokes fear as much as it seduces the imagination.

Driven by ever more powerful computers and ever-faster communications, the digital language of bits and bytes allows us to merge the realms of words, music, image, and data as never before. It creates new industries; the old disappear. With the click of a mouse and the flight of an electron, billions of dollars move across the globe. The Internet has revolutionized the very meaning of time and space. Currently, there are about 2 billion pages on the Internet, which will increase to 8 billion pages by 2005. Will these be the forces of homogenization or of diversity? Will they be used to crush the weak or to afford them new opportunities?

From informatics to biology, the revolution continues. We have decoded the DNA blueprint of life, are learning to manage the deployment and expression of genes, are mobilizing bacteria to do our work, and are manipulating the very building blocks of life. Our new capacities pose new and profound ethical and safety issues. Unlike the past, the new issues of proprietary science will also complicate our future.

The Paradox of Our Times

Consider the paradox of our times. We live in a world of plenty, of dazzling scientific advances and technological breakthroughs. Yet our times are marred by conflict, violence, economic uncertainty, and tragic poverty. A sense of insecurity pervades even the most affluent societies. Nations are looking inward, and the rich turn their backs on the poor. Even though we may have pushed back the specter of a nuclear holocaust, other challenges that are just as serious and as daunting loom ahead: globalization, environmental pollution, poverty, and hunger.

Much has been done to make the world a better place. The 20^{th} century was one of struggle for emancipation. The colonies were liberated; many women got the franchise; and racial, ethnic, and religious minorities and nonconformists were acknowledged to have political and civil rights arising from their common humanity. There have been many socioeconomic improvements over the last 40 years:

developing countries have doubled school enrollments, halved infant mortality and adult illiteracy, and extended life expectancy at birth by 20 years. Despite these advances, much remains to be done. A global developmental agenda demands our efforts and our solidarity.

Today

- 1.2 billion people live on less than a dollar per day. 1 billion people do not have access to clean water.
- More than 2 billion people have no access to adequate sanitation.
- 1.3 billion people, mostly in cities in the developing world, are breathing air below the standards considered acceptable by the World Health Organization.
- 700 million people, mostly women and children, suffer from indoor air pollution due to biomass-burning stoves, equivalent to smoking three packs of cigarettes per day.
- Hundreds of millions of poor farmers have difficulty maintaining the fertility of soils from which they eke out a meager living.

To this stock of problems, we can now add a slew of new challenges. The human population is increasing by 80 million persons a year, mostly in the poorest countries. Dramatic overconsumption and waste in wealthy nations and population pressure in poor countries are putting enormous pressures on the ecosystems on which we all depend.

The world's marine fisheries are grossly overexploited. Soils are eroding. Water is becoming scarcer. Deforestation is continuing. We must redouble our efforts to address the global challenges of desertification, climate change, and biodiversity. Agriculture must be transformed to promote sustainable food security for the billions of hungry people in the world. The challenges of urban poverty and environmental destruction are unprecedented, and will only increase with the urban populations of developing nations expected to treble over the next two generations. In the 47 "least developed" countries of the world, 10% of the world's population subsists on less than 0.5% of the world's income. Some 40,000 people die from hunger-related causes every day. One-sixth or more of the human family lives a marginalized existence. Therein lies the challenge before us. Will we accept such human degradation as inevitable? Or will we strive to help the less fortunate? Will we regard ourselves as no longer responsible for future generations, or will we try to act as true stewards of Earth? It is not resources that are lacking; it is the will to harness them. Indeed, the world has never been richer, and the future promises even more.

A Growing Gap between Rich and Poor

It is inconceivable that there should be some 800 million persons going hungry in a world that has the resources to provide for that most basic of all human needs. In the 19th century, some people looked at the condition of slavery and said that it was monstrous and unconscionable—that it must be abolished. They were known as the abolitionists. They did not argue from economic self-interest but from moral outrage. Today the condition of hunger in a world of plenty is equally monstrous and unconscionable and must be abolished. We must become the "new abolitionists". We must, with the same zeal and moral outrage, attack the complacency that would turn a blind eye to this silent holocaust, which claims tens of thousands of hunger-related deaths every day.

Addressing the American people, Abraham Lincoln said that a house divided cannot stand; a nation cannot live half slave and half free. Today, I say that a world divided cannot stand; humanity cannot survive partly rich and mostly poor.

Despite our enormous productivity, the undeniable benefits of globalization and trade, and the amazing achievements recorded on the social indicators for most of Earth's people, there has been an alarming rise in inequality both between and within countries.

The top 20% of the world's population consumes about 85% of the world's income, the remaining 80% live on 15%, with the bottom 20% living on 1.3% of the world's income. And these disparities are growing. A generation ago, people in the top 20% were 30 times as rich as those in the bottom 20%. Now, they are more than 70 times as rich, yet will not give 0.3% of their income to the poorer 80% of humanity. The richest three persons on the planet have more wealth than the combined GDP of the 47 poorest countries. The richest 15 persons have more wealth than the combined GDP of all of sub-Saharan Africa with its 550 million people![2]

If indeed we are moving toward a knowledge-based society, then connectivity and the preparation of human capital and its deployment will be the key to enabling poor developing countries to improve their situation.

Yet, here too, the figures are troubling. There is a vast and growing gap in the production and availability of scientists and engineers between the wealthy Northern Hemisphere and the poorer Southern Hemisphere. Whereas the United States and Japan have about 70 researchers and engineers per 10,000 population, and China can claim six, the

[2] This data dates back to the year 2002 when this article was first published.

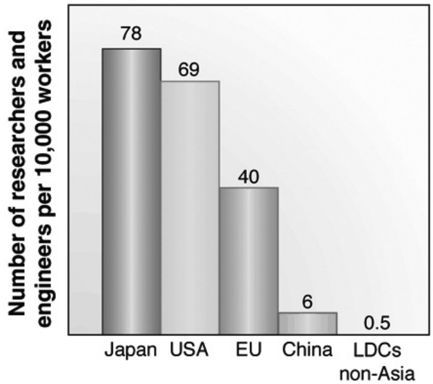

Figure 1. The power of human capital. The United States and Japan have about 70 scientists and engineers per 10,000 population, China can claim six, and the least developed countries (LDCs) of Africa have fewer than one.
Source: *Scientific Partnership for Development*, 1983-1998, European Commission.

poorest developing countries in Africa have fewer than one (Figure 1).

In 2000, telephone lines per thousand persons numbered 567 in high-income countries, and 145 and 37 in middle- and low-income countries, respectively (Figure 2). At the turn of the millennium, personal computers per 10,000 persons stood at 1,800 for the rich, 230 for middle-income countries, and only one for the poor. The rich account for 88% of all Internet connections, yet constitute only 15% of the world's population.

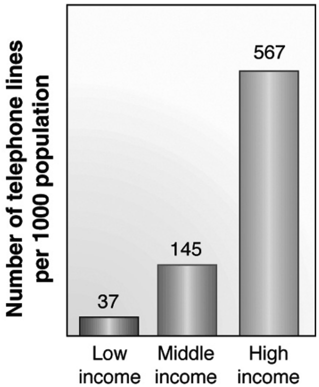

Figure 2. Who is connected? In 2000, there were 567 telephone lines per 1000 persons in high-income countries, 145 per 1000 in middle-income countries, and 37 per 1000 in low-income countries.
Source: World Development Indicators, 2000.

The future does not look any more promising. Tertiary school enrollments in 1980 in the low-, middle-, and high-income countries stood at 4%, 11%, and 34%, respectively (Figure 3). By 1996, these figures stood at 5%, 15%, and 58%, respectively. There are a few exceptions, such as the Republic of Korea and Singapore, which have joined the high-income enrollment statistics (Figure 4). Such quantitative indicators do not take into account the enormous differentials in quality of education, especially at the primary and secondary levels.

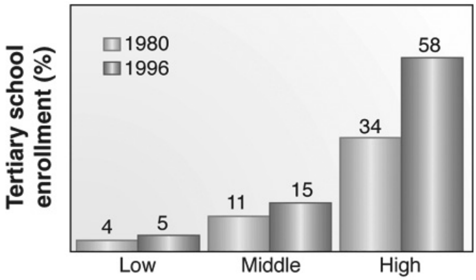

Figure 3. Tertiary school enrollments. In 1980, tertiary school enrollments stood at 4%, 11%, and 34% for low-, middle-, and high-income countries, respectively. In 1996, this had risen to 5%, 15%, and 58%, respectively.
Source: World Development Indicators, 1999.

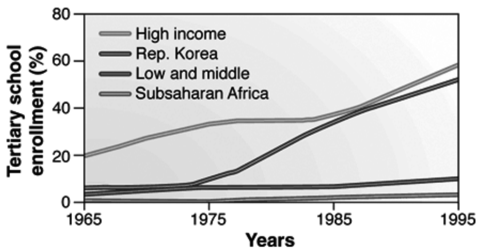

Figure 4. Tertiary school enrollments over time. Whereas tertiary enrollment continues to increase in high-income countries, it has changed little in middle- and low-income nations. The exceptions are the Republic of Korea and Singapore, which show increases in tertiary school enrollments comparable to those in high-income countries.
Source: Task Force, 2000

What Science Can Do

It is against this backdrop that we must address how science can meet head-on the challenge of world poverty and hunger.

On the positive side, science can help to feed the hungry, heal the sick, protect the environment, provide dignity in work, and create space for the joy of self-expression. Yet, on the negative side, lack of opportunity to master science and the new technologies will accentuate the divide between rich and poor. On an average per capita basis, the rich countries have about 40 times the income levels of the poor, but they invest 220 times as much in research.

To these troubling trends we must add the special challenge of dealing with the emergence of private sector-driven science, which increasingly poses the problem of how to protect intellectual property rights without impeding free access to research tools and the equitable sharing of benefits with the poor who cannot afford to pay. The power of patents and intellectual property regimes to mobilize private sector funding in research is clear. In 1999, one corporation, IBM, had more patents (2,756) than 134 countries combined (2,643). In the new biological sciences this is even truer. Patents are taken out not just on finished products, but also on processes and intermediate inputs. Even though there is a research exemption, it does not hold for products of research that have wide applicability and could be marketed. This issue will lead us to a world of scientific apartheid unless it is addressed in an imaginative way that does not stifle innovation or prevent the flow of private capital into research.

However, it is much more than a matter of money. Never before has the need for the scientific enterprise in developing countries or its potential for success been greater. Yet, as that enterprise reveals the marvels of genes and the secrets of atoms, many in the developing world are looking with suspicion on the new, and are trying to erect barriers to limit where minds may range.

The Values of Science

There is a central core of universal values that any truly modern society must possess, and that science promotes. These are rationality, creativity, the search for truth, adherence to codes of behavior, and a certain constructive subversiveness.

The physicist, biologist, and writer Jacob Bronowski[3] defined science as "the organization of our knowledge in

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[3] J. Bronowski, *Science and Human Values* (Harper and Row, New York, 1956).

such a way that it commands more of the hidden potential in nature". Science goes far beyond the utilitarian application of knowledge and impacts an entire world outlook, from cosmology to what makes us human. Values are not rules. They are, in Bronowski's words, "those deeper illuminations in whose light justice and injustice, good and evil, means and ends are seen in fearful sharpness of outline".

Science values originality as a mark of great achievement. However, originality is a corollary of independence, of dissent against the received wisdom. Independence, originality, and therefore dissent are the hallmarks of the progress of contemporary civilization. It is well established that effective pursuit of science requires the protection of independence. Without independence of inquiry, there can be no true scientific research. The safeguards that independence requires are obvious: free inquiry, free thought, free speech, tolerance, and the willingness to arbitrate disputes on the basis of evidence. These are societal values worth defending, not just to promote the pursuit of science, but to yield a more tolerant society that adapts to change and embraces the new.

Can such ideas resonate in a society wracked by poverty and hunger, riven by civil strife and worried about fiscal crisis? I can already hear the nay-sayers, and their emphasis on pragmatism, realism, and the urgent. But they are wrong. Science does have the capacity to capture the imagination and to move the emotions. We must see science as an integral part of our culture, which informs our worldview and affects our behavior. Even more, science is itself a culture of global dimensions, or at least a cultural current that affects strongly the society where it flourishes. It brings imagination and vision to bear on concrete problems and theoretical speculation. The poet William Blake said, "What is now proved was once only imagin'd". Imagination and vision are at the very heart of the scientific enterprise.

Setting the Agenda

For science to realize its full promise and become the primary force for change in the world, it requires that scientists work to:

- engage scientific research in the pressing issues of our time;
- abolish hunger and reduce poverty;
- promote a scientific outlook and the values of science;
- build real partnerships with the scientists in the South.

It is inconceivable that of the 1,233 drugs that have been approved in the last decade, only 11 were for treating tropical diseases, and of these, half were intended for livestock, not humans. It is inconceivable that many of the persistent issues of child nutrition that could be tackled by changing the nutritional content of crops are receiving so little attention. We need more examples like Quality Protein Maize (QPM) and vitamin-A rice (Golden Rice).

We need to engage in real collaboration between centers in the North and South, and to engage scientists in the South in common research endeavors. Only by joint efforts will the values of science be strengthened and the scientific outlook promoted in societies where strong currents of obscurantism and xenophobia vie with rationality and tolerance for the hearts and minds of people. These efforts also need to involve the public, for only by such involvement do institutions flourish. Robert Putnam's pioneering work in Italy in the 1990s showed how institutional performance dramatically improves with greater civic involvement and support.[4] Such joint efforts require addressing the many issues that govern the practice of science in developing countries, from policy to institutions to human resources to finance. In order to promote true partnerships between the North and South, we will have to think beyond occasional intergovernmental

[4] R.D. Putnam, *Making Democracy Work: Civic Traditions in Modern Italy* (Princeton University Press, Princeton, NJ, 1993).

protocols. We need to bring together the public and private sectors, government and civil society, national and international community groups and foundations, all forged into true and caring coalitions.

Implementing this agenda will mean:

- not just new science and technology, but also relevant science and technology;
- not just communications, but also content;
- not just technology transfer, but also real collaborations that promote the values of science and the scientific outlook.

This last point emphasizes process as much as outcome, for the process itself promotes fundamental ethical values that are at the heart of what good science is all about. In the words of Bronowski, "Those who think that science is ethically neutral confuse the findings of science, which are, with the activity of science which is not".

The Way Forward

Clearly it is essential to fully integrate the international scientific community, without which there can be no effective practice of science. Scientists' voices must be heard loudly and clearly in the national discourse of their own societies.

This absence not only severs science from its salutary effect on the modernization of societies, but also undermines the public support necessary for its pursuit.

To the members of the scientific community in the industrialized world I say: You cannot let the talents of 80% of humanity flourish only if they leave their native lands or remove themselves from their societies. You must extend additional efforts to reach them and assist in the strengthening of the scientific enterprise in the South.

To the members of the scientific community in the developing world I say: We are at a crossroads. Either we are going to reassert the importance of science and the scientific outlook, or we are going to witness our societies increasingly marginalized in the world of the information age.

The scientific communities of the developing world either will become more and more detached from their own societies, or will reassert the links of the scientific outlook and its values in the mainstream of the modernization efforts of their changing societies. They must by their engagement help to create the "space of freedom" that is necessary for civilized constructive social discourse, and essential for the practice of science. This commitment is the only way to create centers of excellence in the developing world and to ensure that the benefits of progress accrue to all the poor and the marginalized. It is these "values of science" that can unleash the full measure of their talent and their genius. All of that, however, requires liberating the mind from the tyranny of intolerance, bigotry, and fear, and opening the doors to free inquiry, tolerance, and imagination.

With centers of excellence in the developing world, there can be real partnerships between North and South. The promise of science can be fulfilled to make the new century one free of hunger and of absolute poverty, accurately described as a condition beneath any definition of human decency. All of that, however, requires our joint commitment as scientists to work for the benefit of the entire human family, not just the privileged minority who are lucky enough to live in the most advanced industrial societies. These tasks are enormous. But the longest journey starts with a single step. So let us start. If not us, who? If not now, when?

THE VISIONARIES OF ACTION

1. Today

Today, we exist in a world where all lives are increasingly affected by science. Globalization and the relentless movement towards the knowledge-based societies of tomorrow brings the promise of longer, healthier more fulfilling lives and the perils of greater inequities. There is a real danger that the benefits of proprietary science would serve to bring more and more to the privileged few rather than serve the needs of the billions of the marginalized poor and their children. That the developing countries will not be able to adjust fast enough to the needs of the competitive global economy of science-based production and knowledge-based income.

Today, a revolution is taking place in the biological sciences. It is fueled by the groundbreaking work in modern molecular genetics, the enormous advances in informatics and computing, and the enormous sums being invested in biotechnology research. The benefits of that revolution must be harnessed for the interests of the poor and the environment.

Today, we are living in a time unmatched for the opportunities that it provides. We can dream of new scientific breakthroughs and new products that can help humanity as never before. New higher yielding plants that are more environment friendly, new remedies for killer diseases, edible vaccines, single cell proteins to feed cattle and clean wastes, hyper-accumulating plants to take toxins out of the soil, expanding forests and habitats where more species thrive, and so much more.

TODAY, we can dream of a future of sustainable development where humans thrive in harmony with each other and with the environment. But there is no guarantee that the products of the new breakthroughs of science will not transgress against nature and deeply held ethical views. Or that they will not exacerbate poverty even as they hold the keys to its reduction.

TODAY is an exhilarating time for the biological sciences; similar to what physics experienced in the glorious 40 years between 1905 and 1945, when all the concepts were changed, from cosmology to quantum physics, from relativity to the structure of the atoms. **TODAY**, we are decoding the very blueprints of life; we are learning to manage the deployment and expression of genes. Like physics in the first half of this century, we are confronted by profound ethical and safety issues, complicated by the new issues of proprietary science.

TODAY, we meet to celebrate the possibilities of harnessing the best of science to serve the needs of the poor…

At the dawn of the new century, we have celebrated our common humanity through myriad declarations and agreements. Yet, if the age of science does not harness knowledge for the benefit of all of humanity, we will have contravened the spirit with which we exalted our search for the mastery of technology. We will have been untrue to the values that many of us hold dear, the values we act on: justice, equality and freedom.

Surely, there is no justice in a world where if one is born into a poor tribe in Sub-Saharan Africa, one can expect to live less than four decades, while those who are born in a rich industrial country are reasonably assured of an expectancy about twice as long. Inequality is on the rise again in many parts of the world, while freedom from hunger, from want, from disease, and from persecution is still elusive for far too many of our global citizenry. Our common humanity demands that we do better. Harnessing science and technology to address the real priority challenges of the world is one way of helping re-dress these many shortcomings.

2. The Values of Science

Science is more than just a profession for scientists and researchers. It involves living by the values of science, and it promotes an entire worldview among its practitioners.

Actually, although science is millennia of years old, the notion of scientist is fairly recent. Indeed it was not until 1840 that the word first appeared in the English language! "We need very much a name" said the brilliant English philosopher–mathematician William Whewell (1794–1866) "to describe a cultivator of science in general. I should incline to call him a Scientist". The forceful link between science and technology, what we have come to call Research and Development (R&D) first appeared in 1923, when the private sector began to enter into a partnership with government and educational institutions in the pursuit of new knowledge and harnessing it to produce new and commercially valuable technologies. Since that time there has been an explosion in the extent of our knowledge and the reach of our applications. Today, almost two-thirds of all research is funded by the private sector and in some advanced industrial countries, even more.

Whether it is done by the private sector or the public sector, in universities or in independent labs, the practice of science is governed by certain values. The values of science are adhered to by its practitioners with a rigor that shames other professions.

Science, arguably the greatest enterprise of humanity, promotes the values of science … Truth, honor, teamwork, constructive subversiveness, engagement with the other, and a method for the arbitration of disputes.

Truth Any scientist who manufactures his data is ostracized forever from the scientific community. Just recently, we have seen the most eminent scientist in South Korea, forced to resign from all his positions for having manufactured his results. It was his colleagues in the scientific community who tore off the mask of achievement and exposed the reality. In science, truth will always come out, and the practicing community of scientists ensures that all its members rigidly adhere to the standards it has set.

Honor to give each his/her due is another tenet for the practice of science. The second most heinous crime in science is plagiarism. A whole array of tools, from footnotes to references, is deployed to ensure that none steals the work of others. Perhaps a most eloquent statement of that is Newton's statement … "if I have seen farther than most, it is because I have stood on the shoulders of giants".

Teamwork has become essential in most fields of science. The image of the lone scientist who challenges the established order with unique and brilliant insights, exemplified by Newton and Einstein, exists only in a few small domains of contemporary science. Increasingly, it is teams of researchers in labs who make the breakthroughs, especially in experimental science. We must teach our young scientists of the future the importance of teamwork, and the essence of that is to ensure that all the members of the team receive the recognition they deserve.

Science advances by overthrowing the existing paradigm, or at least significantly expanding or modifying it. Thus, there is a certain **constructive subversiveness** built into the scientific enterprise, as a new generation of scientists makes its own contribution. And so it must be. Without that, there would be no scientific advancement. But our respect and admiration for Newton, is not diminished by the contributions of Einstein. We can, and do, admire both. This constant renewal and advancement of our scientific understanding is a feature of the scientific enterprise. Its corollary is that scientists must engage with all opinions, coming frequently from very young persons, no matter how strange or weird it appears at first sight, subject only to the arbitration of evidence-based confirmation of the claims.

This final point is essential. For in science, there is a process and a method, based on rationality and empirical evidence that rules. It is the **way to arbitrate disputes**. It is what makes science great. The unknown Einstein's view of the bending of light by celestial objects was accepted when it was empirically verified by the 1919 observations of the positions of stars during a total eclipse of the Sun. Conversely, the claims of cold fusion made by the well-established professors, Pons and Fleischmann, were rejected when the claims could not be replicated in other labs. Thus in science, the ultimate authority is not a person, but a process of reasoning and a method of empirical observation.

These are societal values worth defending, not just for the practice of science, but also because it promotes a tolerant and open society.

On the other hand, the scientific enterprise produces a different kind of understanding of truth than the belief systems of religion. Science, produces an understanding of reality that is partial, probable, awaiting the next interpretation that will take us ever closer to an understanding of our universe and ourselves. It does not claim to be absolute, for all time. Even in mathematics, after the work of Kurt Gödel, it is now accepted that there are indeterminacies in the structure of mathematics that are not likely to be overcome.

So, why has religion so frequently been set up in an antagonistic role vis-à-vis science? We think of the trial of Galileo and the battles over Darwinian evolution. It is largely due to an error in trying to unite two systems or magisteria, where each magisterium has its own authority structure. In reality, as Stephen Jay Gould has ably written Rocks of Ages these are non-overlapping magisterial or NOMA![1]

The reality of human consciousness is that we address some questions in the scientific enterprise, asking questions such as, what is? … But science cannot address the issues of what should be, or what should I do about something or other. That is another magisterium, that of religion and philosophy. These two magisterial are not the only ones. For example, the judgment about beauty in art is neither governed by science nor by moral or religious beliefs. What makes music great or a color composition pleasing is part of another magisterium.

So to those who are concerned by the advance of science and fear its conflict with a system of religious beliefs, we can reassure them. There is no conflict. They operate at different levels.

3. A Celebration of Science

At the Bibliotheca Alexandrina, we are engaged in a celebration of science and all it stands for. Our meetings and conferences not only inform; they should also inspire. The eminent speakers and the topics they cover should be

[1] Stephen Jay Gould, *Rocks of Ages, Science and Religion in the Fullness of Life*, The Library of Contemporary Thought, The Ballantine Publishing Group, New York, 1999.

an inspiration to the young scientists who participate, and a contribution to the public, not just of new and more accurate information, but also a contribution to the formation their worldview and their cultural outlook…

When we celebrate the centennial year of Einstein's miraculous year of 1905, we meet to pay homage to the young genius who forever changed our perceptions of space and time, of energy and matter. We celebrate the unknown 26-year-old patent office employee, whose insights and imagination made a scientific revolution possible. We celebrate the boldness of the vision and the daring of the conclusions. We admire the elegance and beauty of the equations and the powerful secrets of nature that they allowed us to understand … But we also celebrate the scientific enterprise, which allows the voice of this unknown young man to be heard, to have his revolutionary papers published in the most prestigious journal of physics of the time, and which engages the most established scientists with their youthful colleagues in a search for truth, where different views are arbitrated by evidence. Thus is the realm of science forever renewed by vigorous youths, from Heisenberg to Dirac to Watson and Crick…

The new life sciences are one of the most active areas where science today is pushing the frontier of knowledge and lifting the darkness and illuminating ever vaster domains with an understanding of the most intricate processes of our existence. The extraordinary revolution that is taking us ever closer to the very secrets of life, where the mechanisms of heredity come into play and where we are learning to manipulate the awesome power of organic life. It is a revolution that is leaving no aspect of our lives untouched: our health, our food, our agriculture, our industry and our environment.

With the promises, come the perils: How do we avoid promoting an ever-growing divide between the haves and the have-nots, the know and the know-nots? How do we try to avoid the nefarious applications of our hard-won knowledge?

4. Looking Back and Looking Forward

We have never been very good at looking forward. In 1900, the head of the patent office in the US actually suggested that all possible inventions had already been patented ... Fifty years later, Thomas Watson Sr. of IBM, famously predicted that the global market for computers would never exceed half a dozen or so…

Generally, we can consider that the history of the advancement of science as alternating periods of spurious certainty and anxious uncertainty…

The familiar troubled voice of John Donne (1572–1631) eloquently complained, in 1611, that the new Copernican notions were "creeping into every man's mind" and "may very well be true".

> *And new Philosophy calls all in doubt,*
> *The Element of fire is quite put out;*
> *The Sun is lost, and th'earth, and no man'swit*
> *Can well direct him where to looke for it.*
> *And freely men confesse that 'tis world's spent,*
> *When in the Planets, and the Firmament*
> *They seek so many new; then see that this*
> *Is crumbled out againe to his Atomies.*
> *'tis all in peeces, all coherence gone;*
> *[…]*
> *And in these Constellations then arise*
> *New starres, and old doe vanish from our eyes…*

To these anxieties, Newton would bring the ordered universe. The apparent finality of the Principia was impressive. But it was not to last. Fissures would arise in the elegant structure. For though Lord Kelvin could still remark with a certain smugness that physics seemed to have been fully worked out, except for a two "clouds" that needed to be dissipated, he could not imagine the revolution that was about to be wrought by a young unknown Albert Einstein in the very understanding of space, time, matter and energy!

Einstein for a moment gave a glimpse of hope for a new unified theory. However Heisenberg, Schrödinger and others would cast new doubts. And the twentieth century would be the one marked by the movement from certainty to uncertainty. The time when we would come to accept that the very nature of our scientific understanding of nature is incomplete and likely to remain so. A new kind of understanding started settling in, where the fecundity of the questions is as important as the finality of the answers.

That is the way that science advances: the bold conjecture and the patient and dogged analysis of empirical evidence … and a celebration of the two facets of science that are so essential to the advancement of the scientific enterprise. These are the bold hypothesis or conjecture, and the systematic pursuit of empirical proof.

Some 60 years ago, in 1944, Erwin Schrödinger, a Nobel winning Physicist, crossed over into biology and gave some outstanding lectures entitled "What is Life?"[2] later published under the same title and in which he speculated about life and predicted that the molecule that transmits

[2] Erwin Schrödinger, *What is Life? The Next Fifty Years: Speculations on the Future of Biology,* Cambridge University Press, 1995, p. 41.

the information necessary for the perpetuation of life would have a long structure, and that "aperiodic crystals" would play a key role in the creation of "order from order", the fundamental mechanism for heredity and cell replication. A bold and shrewd conjecture that was to be vindicated by the epoch making discovery of the double helix by Watson and Crick in 1953…

Also in 1944, experiments by Oswald T. Avery with Colin MacLeod and Maclyn McCarty showed that a nucleic acid, deoxyribonucleic acid (DNA), was the chemical basis for specific and apparently heritable transformations in organisms. This contradicted the contemporary wisdom that suggested that genes were proteins (even as they were viewed as discrete units of heredity, which also control metabolic functions). An empirical, experimental scientific achievement of great distinction, that has not been recognized by a Nobel prize to this day.

We salute the spirit of scientists, past and present, who through their dedication and their vision are making possible the dawn of the new biology and the new scientific age of the 21st century.

5. Some Reflections on Science

Today, to use the words of Daniel Boorstin, the eminent Former Librarian of Congress, data is running ahead of meaning for most of us in the world…[3]

Data, when ordered becomes **information**, which when interpreted becomes **knowledge**, which when combined with reflection and experience hopefully yields **wisdom**…

Wisdom will help us deal with the kinds of dilemmas highlighted in our three days of discussions … to select the wisest course of action … to bring the greatest good for the greatest number without, reducing the benefits of any…

For many, we are overwhelmed by a veritable tidal wave of data and information…with precious little knowledge and hardly any wisdom … We are indeed entitled to echo T.S. Eliot's famous questions: How much knowledge have we lost in information? How much wisdom have we lost in knowledge?

We live in a politicized climate, dangerous times, when—according to Walcott: "any group can scream injury and litigate against the dead, sue History, and demand compensation..."[4].

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3 *Cleopatra's Nose: Essays on the Unexpected,* (Vintage) 1995, p. 8.

4 Derek Walcott, *Homage to Robert Frost, The Road Taken*, Farrar Straus Giroux, New York, 1996, pp. 112–113.

People struggle, and scream … but it is not he who screams the loudest who is necessarily right … the great menace to progress is not ignorance but the illusion of knowledge.

Early in the last century Edna St. Vincent Millay said:

> *Upon this gifted age, in its dark hour,*
> *Falls from the sky a meteoric shower*
> *Of facts … they lie unquestioned, uncombined.*
> *Wisdom enough to leech us of our ill*
> *Is daily spun; but there exists no loom*
> *To weave it into fabric…*
>
> —Edna St. Vincent Millay,
> *Huntsman, What Quarry*

It is science, and only science, that can build that loom that she so fervently wanted. Sometimes it seems that the more we learn, the less we understand. Nature urns out to be much more complex than our models of yesteryear had led us to believe! But if the modern quest for discovery and understanding yields ever more questions as we provide one answer after another, it becomes clear that the quest for a final answer to everything may be beyond our reach, but the quest for that deeper understanding, that more profound insight, is the essence of the human condition. It is the noblest of our endeavors, for it transcends the search for utilitarian applications of that knowledge and finds in that knowledge its own finality. It is that quest for knowledge that makes us human. So let us enjoy the quest together.

6. A Tradition of Scientific Excellence

Scientific discoveries are cascading at an unprecedented rate. They are shared much more widely and immediately than anyone could have dreamt a few years ago. It is particularly appropriate that contemporary Arabs and Muslims should feel enthralled by the ongoing quest for meaning and understanding that the modern scientific enterprise is pursuing at a dizzying pace. For even if it is not sufficiently recognized internationally, the foundations of the scientific revolution that followed the renaissance in Europe owes much to the great tradition of Muslim and Arab science, that did so much for humanity for a thousand years. For in those years that are commonly referred to as the dark ages in Europe, our forefathers were those who defended rationality and held up the torch of science in the face of superstition and bigotry. Al-Khawarezmi, El-Razi, ibn El-Nafis, ibn Al-Haytham, ibn Sina, ibn Rushd, Gaber ibn Hayyan, must appear in any list of humanity's benefactors through their efforts at advancing knowledge.

Centuries before the emergence of the modern scientific movement in the west, our forefathers were calling for the experimental method, relying on empirical evidence, and rejecting the authority of the ancients (mostly Aristotle). They were open to new ideas, but kept a healthy skepticism, demanding that assertions be buttressed by experimental verification.

These towering figures in the history of science, who did so much for humanity and for the advance of knowledge … They are our forefathers and we should be their proud successors. We need to recapture that great tradition. It is our tradition, our history, our legacy.

This, to me, is the tradition that Muslims and Arabs should be proud of. The tradition of openness and inquiry, of the bold conjecture and the patient accumulation of evidence that resulted in Arabic becoming the language of science for several centuries, and for the greatest corpus of achievement that made a major contribution to the stellar advances of western science a few centuries later … A contribution whose full contours are only now beginning to come to light with new publications in the history of science. Today, the torch has passed to the west, but we should be proud that we have carried the torch of science for centuries in earlier times, and should strive to take our place, by dint of hard work and innovation, alongside our western colleagues at the forefront of the global scientific enterprise. We should draw inspiration to "close the gap" from our brothers and sisters in eastern Asia, who are demonstrating every day that the chasm is bridgeable.

To achieve this, we must revive the proud traditions of our past centuries, and reinforce the values of science throughout our societies. We must strengthen science and mathematics education throughout the Arab and Muslim world, and create research institutions that will allow the Arabs and Muslims of today to contribute to the global scientific enterprise. These institutions must be active catalysts of change, promoting and defending the values of science. It is thus that we will help build a new Arab and Muslim world in the 21st century that embraces science and rationality and integrates the values of science in the very fabric of society.

7. The Visionaries of Action

Science is a culture of global dimensions, or at least a cultural current that affects strongly the society where it flourishes. It brings imagination and vision to bear on concrete problems and theoretical speculation. After all, in Blake's immortal phrase: "What is now proved was once only imagin'd". Imagination and vision are at the very heart of the scientific enterprise. Again, Bronowski put it beautifully when he said

"…we are the visionaries of action; we are inspired with change ... We are the culture of living change."

Change is built into the scientific enterprise. It is driven by the struggle of ideas, espoused by passionate men and women who believe in the values of science. Seen thus, science is much more than a compendium of information. It is that passion that we find in the true practitioners of science. It is that passion that we must strive to inflame in the practitioners of science throughout our countries today, to get them engaged and excited by the struggle of ideas that is so central to the scientific enterprise. Scientific ideas cannot be allowed to be cast as simple, dichotomous choices. Such "dichotomies must interpenetrate, and not struggle to the death of one side, because each of their opposite poles captures an essential property of any intelligible world".[5] In that context, Goethe said: "the more vitally these two functions of the mind are related, like inhaling and exhaling, the better will be the outlook for the sciences and their friends".

As Stephen Jay Gould observed: "It is important that we, as working scientists, combat these myths of our profession as something superior and apart ... Science can only be

[5] S.J. Gould, Time's Arrow, *Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*, Harvard University Press, Cambridge, Massachusetts, 1987, p. 19.

harmed in the long run by its self proclaimed separation as a priesthood guarding the sacred rite called the scientific method (emphasis in original). Science is accessible to all thinking people because it applies universal tools of intellect to its distinctive material".[6]

I submit that the quest embodied by science, that culture of living change, with its questioning and its wonder, its vigor and its exploration, is the way to a better future. So together … let us join in this endless quest to know our universe and to know ourselves…

> *"We shall not cease from exploring*
> *And at the end of all our exploring*
> *Will be to arrive where we started*
> *And know the place for the first time."*
>
> —T.S. Eliot

8. From Science to Technology

Exploration is fine, but what of the application of that knowledge that our explorations will produce?

Technology is the application of scientific knowledge for utilitarian purposes. And while the applications of science

[6] S.J. Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*, Harvard University Press, Cambridge, Massachusetts, 1987, p. 7.

have brought humanity innumerable blessings over the centuries, they have also been responsible for some of the most lethal weapons ever imagined. To what extent are scientists responsible for the applications that the knowledge they produce is put to? The problems of ethics loom large in this area.

We, in the Bibliotheca Alexandrina, have been very engaged with these issues from the first day of our existence. Our first conference, 48 hours after the official inauguration on 16 October 2002, was devoted to the ethics of science and technology, and it adopted the Alexandria Call jointly signed by Jean Dausset and myself,[7] which essentially calls for a compact between scientists and society, whereby there should be no limits imposed on the pursuit of knowledge, except the ethical standards of scientific research, but conversely, scientists must think carefully about the ethical aspects of the deployment of technologies based on their scientific work. Scientists, after all, are both citizens as well as scientists.

Here we enter the domain of the ethics of science and technology. But conscious of the distinction between the non-overlapping magisteria we discussed, I find the simplest

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[7] See Appendix to this document.

way of presenting our view of the role of science and its links to society is to ask for: **knowledge based on science and application guided by conscience**.

Conscience! By adding “con” to “science” we introduce an enormous new realm of meanings and ideas. Conscience, to be conscious of … to have a conscience…

The English “conscience” is derived from the Latin conscientia, which means “joint knowledge”. The Greek synonym syneidesis (also “joint knowledge”) was defined to mean a sense of “oughtness” (Boorstin Cleo, p. 41). It is that separate part within ourselves that checks our impulses, and gives us pause from rushing headlong into error.

> *Thus conscience doth make cowards of us all…*
>
> —William Shakespeare, Hamlet

> *Of conscience, into what abyss of fears*
> *And horrors hast thou driven me; out of which*
> *I find no way, from deep to deeper plung’d!*
>
> — John Milton, Paradise Lost

Despite all this poetic moaning, we are all aware that our conscience dictates what is acceptable behavior and what is not. It is therefore to that conscience that we must appeal. For our actions must be guided by ethical concerns for the rights of others, and for our responsibilities to the weak and the marginalized and to the generations yet unborn. The Alexandria Call that our conference adopted on 19 October 2002, strikes a balance between the unfettered pursuit of knowledge and the social responsibility for the deployment of new technologies. It is a clarion call to action. A call that requires the liberation of the Arab and Muslim minds from the shackles of perceived fears and the tradition of acquiescing in the inherited viewpoint … A call to unleash the talents and abilities of great people. It is a call to rekindle the spirit of unlimited inquiry and unbounded imagination that characterized the work of our forefathers in the glorious centuries when science was predominantly being advanced by Muslims, and Arabic was the universal language of learning. It is a call to action now.

9. Conclusions

We have to act. Time is of the essence. If the new realities have one thing in common, it is the increasing speed of change. Perhaps we, Arab and Muslim societies, should take to heart the story of the teacher in Africa, who—in response to those who made fun of the fact that he was always in a hurry—said:

> *"Yes! The clocks are ticking, my friends. History has a terrible timetable. If we are not careful, we might be remembered as the country (generation) where everybody arrived too late."*

However, we are not too late … we are here. And we must act. We must act, if Arab societies are to become truly learning societies, offering our youth the opportunities of fulfillment in the knowledge-based societies and technology-driven economies of the 21st century.

Let us be inspired by the immortal words:

> *There are those who see the world as it is and ask "Why?" We look at the world as it could be and ask "Why not?"*

Within this group, this emergent coalition, this nascent network, and the networks that each of us have, we should be able to promote many knowledge-based development initiatives. We should meet again periodically, to measure our achievements, assess our shortcomings and draw strength from our shared values to re-double our efforts…

Let this be the birth of a coalition of the caring

Let this become an active network of the committed...

Let us invent the future in the crucible of our minds, right here, right now.

For if not us, who? If not now, when?

APPENDIX

A CALL TO SCIENTISTS

Scientists can be proud that through the knowledge they have generated, they have contributed so much to free humanity from toil and suffering. Now scientists are opening new doors faster than ever before.

Never before has science given humans so much power without giving them the time to adapt to it. This discrepancy has entailed profound social anxieties and real dysfunctions, as well as enormous disparities and even threats to the future of humanity.

Never before have scientists had more responsibilities:

- on the one hand, they must contribute to the ACQUISITION of new knowledge, without any limitation, in all domains, and
- on the other hand, they must bring their expertise to bear for a rational APPLICATION of the technologies

which ensue from the knowledge they have generated and for which they are also morally responsible.

In order to do this, scientists should come out of their ivory towers and engage with society, not only as experts working with the authorities, but also by addressing the general public using all modern means of communication.

Scientists have a particular responsibility for presenting discoveries and especially the practical applications which ensue, or could ensue, from the discoveries. Scientists must bring all their commitment to truth, shedding light on complex subjects with the requisite objectivity. They must reach out to the general public, whether the individuals are scientifically knowledgeable or not. Scientists must avoid sensational claims as well as undue alarmism, so common in the media.

By being informed, and informed at the right time, public opinion will weigh upon and influence political and industrial decision-makers, so that new technologies are not used to excess or deployed in wrong ways. In a democracy, politicians listen to the voters and all around the world manufacturers listen to potential buyers. Voters and consumers are the voice of public opinion. It is this huge force which we ask you to mobilize so that humanity does not have to endure their lot but can take charge of creating a better future for all.

To be effective in such an endeavor, we have created the Universal Movement for Scientific Responsibility/ Mouvement Universel pour la Resposibilite Scientifique (MURS), a global coalition of the caring. This international umbrella organization is a non-profit association, without any political, religious or financial ties. MURS branches exist already in France, Egypt, Mexico and Japan.

We urge you to join this movement and to develop in your respective countries MURS branches setting similar objectives but using appropriate approaches adapted to different cultures.

Never have scientists had duties so evident and so pressing.

Ismail SERAGELDIN	Jean DAUSSET
President	President
MURS — International	MURS — France

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Note: This "Call to Scientists" was adopted by an international gathering of hundreds of scientists meeting in Alexandria, Egypt, on 21 October 2002, celebrating the inauguration of the New Bibliotheca Alexandrina.

ISLAM, SCIENCE AND VALUES

1. The Context of Global Knowledge

Consider the paradoxes of our times. We live in a world of plenty, of dazzling scientific advances and technological breakthroughs. Adventures in cyberspace are at hand. The Cold War is over, and with that we were offered the hope of global stability. Yet, our times are marred by conflict, violence, debilitating economic uncertainties and tragic poverty. Globalization and the assertion of local group specificity seem to be everywhere.[1] Worse, we live in a world where the rising inequities between the rich and the poor are everywhere, nationally and internationally. However, these inequities are probably even more acute in the domain of knowledge, at the time when the world is hurtling towards the information-based society. Let us for a moment look at the global reality in which the Muslim intellectuals function, the reality of an enormous and frightening knowledge gap and the risks inherent in it.

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[1] For a discussion of some of these trends, see Ismail Serageldin, *Nurturing Development: Aid and Cooperation in Today's Changing World*, Washington, DC: World Bank, 1995.

There is a vast and growing gap in the production and availability of scientists and engineers between the North and the South by a factor of ten to twenty times.[2] This is purely on the quantitative side, and does not speak of the quality of the training or the resources at the disposal of the scientists.[3] In addition, scientists in the developing countries suffer from problems of access, visibility and recognition.[4] The Muslim world does not escape this remarkable inequality of numbers and resources, nor is it immune to this inequity in

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2 According to UNESCO statistics, as of 1990, the number of scientists per million population was running from 4,700 in Japan to 3,800 in the USA to 2,300 in Europe, Canada and Australia to 1,000 in the "tigers" of East Asia, to well less than 200 in India, Africa and much of the Far East. See Remi Barre and Pierre Papon, "Global Overview" in UNESCO, *Science Yearbook* 1993, UNESCO, Paris, 1993, p. 140.

3 In the United States alone, there are 200,000 academic researchers funded tothe tune of some US$60 billion annually. (See David L. Goodstein, "After the Big Crunch", in the *Wilson Quarterly*, vol. 19, No. 3, Summer 1995, p. 54).

4 The discrepancy between North and South is further magnified by the many obstacles that impede the science of the South from being adequately recognized in the North. Southern journals, even when they try to adhere to impeccable standards find it very difficult to be listed in the authoritative Science Citation Index (SCI). The SCI is run by the Institute for Scientific Information, a private firm in Philadelphia. The SCI lists about 3,300 journals from about 70,000 worldwide. Inclusion in the SCI and a few other databases is very important to be seen by scientists everywhere. See W. Wayt Gibbs, "Lost Science in the Third World", in *Scientific American*, August 1995, pp. 92–99.

treatment. Furthermore, many of our institutions of science and technology are deprived of equipment and supplies, and voided of their standards of excellence in the service of political expediency and cronyism. We are still struggling with the needs of basic laboratory equipment at a time when the north is mainstreaming computers for the average person to use as simply as telephones.

In addition, an amazing information explosion is taking place, and as we enter into the new century, information will be everywhere around us. Furthermore, with simple and inexpensive tools the most remote locations will not be excluded from tapping into it. We can leapfrog some of the slavish location-specific patterns of development of science and knowledge accumulation that earlier generations had to adhere to PCs and network hookups will be as cheap and available as transistor radios.

Against this background, it becomes clear that never before has the need for the scientific enterprise of the developing countries—our scientific enterprise—been greater, and never before has the potential for its success been as present as it is today.

Yet, as the world explores the marvels of the genes and breaks down the secrets of the atom and reaches to the stars and calculates the age of the oldest rocks … we, in the Muslim world, debate "the hadith of the fly"... we debate whether a woman's nail polish prevents her from having full ablutions, we look with suspicion on the new and try to erect barriers to limit where our minds may range[5]...

2. Islamic Attidutes towards Science

It always amazes me to find this pernicious debate on "Islam and Science" being put forward as if they are contradictory. Sadly, many of those who advance such arguments are supposedly scholars of Islamic thought or Muslim scholars. In both cases, they do not merit the mantle of scholarship. They are either mistaken or intentionally misrepresenting the facts.

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[5] The great reformer, Muhammad Abduh, was committed to this idea that there is no limit to where the mind may roam in the search for understanding the world and the search for truth. See Muhammad 'Imara (ed.), *Al-A'mal Al-Kamila lil Imam Muhammad Abduh* (the complete works of the Imam Muhammad Abduh), (in six volumes), *Al-Mu'assasa Al-Arabiya Lil Dirasat Wal Nashr*, Beirut, 1972, vol. 1: p. 183.

Let us first start with the "Usuli"[6] argument from the sources. This means to rely on primary sources as much as possible, but it differs from the "rejectionist" mode of thinking[7] that so many of the contemporary Muslim "Usuli" writers seem to take.[8] Let us not start by postulating the need to

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6 The reference is to the "Usul" or foundations, or bases. It is also a whole domain of Muslim Jurisprudence, referred to as "Usul Al-Fiqh" or Foundations of Jurisprudence. See, inter alia, Mohammed Abu Zahra, *Usul Al-Fiqh* (the Foundations of Jurisprudence), Dar Al-Fikr Al-Arabi, Cairo, 1958, and Abdel Wahab Khallaf, 'Ilm Usul Al-Fiqh (The Science of Foundations of Jurisprudence), Dar Al-Qalam, Kuwait, (1942, 1947), ninth edition, 1970.

7 An extreme statement of this rejectionist viewpoint is given by Maududi as quoted by Leites: "Thus, no elements of Western culture may be incorporated into a truly Islamic society. Maududi warns that in choosing the path of Islam people will [...] 'have to give up all desire for material gains and sensual pleasures that has been created by the fascinations of the Western civilization; they will have to cleanse their mind of all those concepts and ideas that they have borrowed from Europe; and they will have to cast off all those principles and ideals that they have imbibed from the Western culture and way of life." Justin Leites, "Modernist Jurisprudence as a Vehicle for Gender Role Reform in the Islamic World," *Columbia Human Rights Law Review* 22(2) (Spring 1991): 323, quoting A. Maududi, *Purdah and the Status of Women in Islam* (Lahore: Islamic Publications, 1972) 17.

8 Some members of the Islamic movement are themselves re-visiting some of these aspects of contemporary thinking in the "movement". For an interesting and thoughtful insider's critique, see Abdallah Al-Nafisi, ed., *Al-Haraka Al-Islamiyya: Ru'ya Mustaqbaliya: Awraq fil Naqd Al-Dhati* (The Islamic Movement: A View to the Future: Papers in Self-Criticism) (Kuwait, 1989); and Muhammad 'Imara, *Al-Sahwa Al-Islamiyya wal Tahadi Al-Hadari* (Islamic Revival and the Cultural Challenge) (Beirut: Dar Al-Mustaqbal Al-Arabi, 1985).

underline the "otherness" of the Muslim experience. Rather, let us return to the original sources of Islamic doctrine, the Quran[9] and the Sunna of the Prophet,[10] and relate these to the historical context of past experience and present realities.

The search for Knowledge ('Ilm) and Truth (Haq) are an integral and undeniable part of the Muslim tradition. The pursuit of knowledge is the single most striking feature in a system of great revelation such as Islam. The word 'Ilm (knowledge) and its derivatives occur 880 times in the Quran. However, knowledge is not perceived as neutral. It is the basis for better appreciating truth (Haq), which is revealed and which can be "seen" by the knowledgeable in the world

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9 The *Quran*, which is held by all Muslims to be the word of God, is in Arabic. There are many translations of the meanings of the *Holy Quran*, but for this essay I have used the authoritative translation of Yusuf Ali (The Meaning of) The *Glorious Quran*, Dar al Kitab Al-Arabi/Dar Al-Kitab Al-lubnani, Cairo/Beirut, N.D. This is the work which (in its two-volume edition) is distributed by the Rabitat Al-'Alam al-Islami of Saudi Arabia.

10 The "*Sunna*", meaning "the way" in Arabic, technically refers to the way the Prophet showed all Muslims the practice to live as Muslims. More generally, it refers to the words and deeds of the Prophet, his "tradition." The Sunna is the record and analysis of the words and deeds of Prophet Muhammad. It is distinct from the Quran and is considered by all Muslim scholars as complementary to the Quran and second only to the Quran as source of authority for legal and religious rulings. For a discussion of the subject see Ahmad Umar Hashim, *Al-Sunna Al-Nabawiyya wa 'Ulumiha* (The Prophetic Tradition and Its Sciences), Gharib Library, Cairo, 1989.

around them. Indeed, believers are enjoined to look around and to learn the truth. The Prophet exhorted his followers to seek knowledge as far as China, then considered to be the end of the Earth. Scientists are held in high esteem: the Prophet said that the ink of scientists is equal to the blood of martyrs. The very first word of the Quranic revelation was an order to read[11] and to learn, and to seek knowledge.

The earliest Muslims were not averse to applying the best science and technology that they could find. There is no case of the Prophet refusing to apply the best technology either for war or peace. The early Muslims, when confronting the philosophy of Plato and Aristotle, did not call for banning or burning their books. Indeed, they translated them into Arabic, they wrote excellent studies about them and selected those parts of Greek philosophy that suited their needs and interests and rejected the other parts. Al-Farabi's brilliant contributions to the foundations of Muslim philosophy, never

[11] The verses are rendered by Yusuf Ali as:

> Read! In the name of thy Lord and Cherisher who created-
> Created man, out of A (mere) clot of congealed blood:
> Proclaim! And thy Lord is most Bountiful,–
> He who taught (the use of) the pen,–
> Taught Man that which he knew not. (*Quran*, 96: 1–5)

denied his reading of Plato and Aristotle[12], nor is his personal contribution diminished by that, any more than Einstein's contributions would be diminished because he read and studied Newton and Maxwell.

Furthermore, evidence from recent scholarship[13] shows that even in the so-called periods of decline, the great scientific disciplines of the astronomers in Damascus and the Maragha School[14] continued to be at the cutting edge of world science well into the 16th century. They preceded Copernicus in their critique of the Ptolemaic system, and in fact, their

[12] Al-Farabi (870–950), is widely considered to be the founder of Islamic philosophy, and his work on Greek philosophy is of particular relevance to this discussion. See *Al-Farabi's Philosophy of Plato and Aristotle*, translated with an introduction by Muhsin Mahdi, Agora Editions, The Free Press of Glencoe, New York, 1962.

[13] See George Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam*, NYU Press, New York, 1994.

[14] The reference is to the activites of scientists at the Maragha Observatory in North-West Iran and others who undertook similar or related work. It is an unfortunate choice because it has been employed by scholars to refer to works preceding the Maragha Observatory and to works done elsewhere. Nevertheless, it has acquired currency in circles dealing with the history of science and Islamic science. See note 11 in Saliba, *Op.cit.*, p. 41.

critique was more profound.[15] The later Muslim scientists also remained open to the study of the Copernican theories at a time when the Church in the West was condemning them as heretical, not surprising considering how much of Copernicus' work had already been developed by the Muslim astronomers one or two centuries before.[16]

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[15] The critique linked observation, philosophy and geometry in model-building. It was a profoundly sophisticated critique that advanced the status of astronomy and the available data sets of observations. The importance of Saliba's contributions in establishing this new view should not be under-estimated. Basing himself on the original manuscripts, he has convincingly refuted the conventional view that these scientific activities were not related to observation, and that the critiques of the Ptolemaic system were of a philosophical nature. Saliba's work has thus superseded such works as Owen Gingerich's "Islamic Astronomy" (*in Scientific American*, 254, 1986, pp.74–83) or A.I. Sabra's "The Scientific Enterprise" (in Bernard Lewis (ed.) *Islam and the Arab World*, Thames and Hudson, London, 1976, pp. 181–200). Regretfully, these older works still have much currency in the West today.

[16] A number of recent scholars have underlined this fact, and the weight of evidence has been accumulating in the last 20 years or so. See, *inter alia*, E.S. Kennedy, et al., *Studies in the Islamic Exact Sciences*, ed. by D. King and M.H. Kennedy, Beirut, 1983, pp. 50–107, and N.M. Swerdlow, "The Derivation of the First Draft of Copernicus's Planetary Theory: A Translation of the commentarial with Commentary" in *Proceedings of the American Philosophical Society*, 117: 1973, pp. 423–512. Indeed, Swerdlow and Neugebauer go as far as to state: "The question therefore, is not whether, but when where and in what form he (i.e. Copernicus) learned of Maragha theory." And further "In a very real sense, Copernicus can be looked upon as, if not the last, surely the most noted follower of the 'Maragha School'", N.M. Swerdlow and O. Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus*, Springer, New York, 1984; (also cited in Saliba, *Op.cit.*, pp. 254–255).

So, let us not waste time on artificial and misleading dichotomies, that are neither supported by the primary sources nor by the historical records of the Muslim societies.

Before proceeding further, however, it is necessary to settle one more false dichotomy which is being put forward by many today, namely that the nature of knowledge and truth is such that it precludes a true Muslim from being a practicing scientist, or accepting scientific evidence. This line of argument was well dissected by Akbar S. Ahmed among others.[17] Indeed, Ahmed points out that Umberto Ecoalong with many influential thinkers, believes that there is an irreconcilable difference between the study of philosophy and being a believer.[18] That view is pernicious, since the

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[17] Akbar S. Ahmed, *Postmodernism and Islam: Predicament and Promise*, Routledge, London, UK, 1992.

[18] Eco has stated "If the *Quran* says something different, the philosopher must philosophically believe what his science shows him and then, without creating too many problems for himself, believe the opposite, which is the command of faith. There are two truths and one must not disturb the other." (See Umberto Eco, "Function and Sign: An introduction to Urban Semiotics", in M. Gottdiener and A. Lagopoulos, (eds.) *The City and the Sign: An Introduction to Urban Semiotics*, New York, 1986, p. 264. cited in Akbar S. Ahmed, *Postmodernism and Islam: Predicament and Promise*, Routledge, London, UK, 1992, pp. 84–85.

religious dimension of the truth being asked of the believer in the Quran is of a different kind than that of the search for knowledge and truth being pursued by science.

Fazlur Rahman, the great Muslim thinker, challenges Eco's assumptions that there are "two truths", one from the Quran and one from philosophy, and that they are to be left undisturbed. Rahman considers that knowledge (ilm), the creation of ideas is "an activity of the highest order". Rahman then challenges not just Eco and other westerners, but also the so-called Muslim scholars who would pursue such a dichotomy: "Otherwise why did it [The Quran] ask the Prophet to continue to pray for 'increase in knowledge'? Why did it untiringly emphasize delving into the universe, into history, and into man's own inner life? Is the banning or discouragement of pure thought compatible with this kind of demand? What does Islam have to fear from human thought and why?

These are questions that must be answered by those 'friends of religion' who want to keep their religion in a hot-house, secluded from the open air".[19]

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[19] Fazlur Rahman, *Islam and Modernity: Transformation of an intellectual tradition*, University of Chicago Press, Chicago, Ill., 1984, pp. 158–59; also cited in Akbar S. Ahmed, *Postmodernism and Islam: Predicament and Promise*, Routledge, London, UK, 1992, pp. 84–85.

Having thus disposed of these false dichotomies, we can proceed to ask a few questions about the current state of the universities in the Muslim world, for it is in the universities that one would expect the practice of science in the Muslim world to take place, and more importantly, it is in the universities that the intergenerational transfer of knowledge and attitudes takes place.

3. The Challenge to the Universities

It is clear that the arenas where ideas are developed and communicated to the next generation are the universities, even if the mass media play a formidable role in mobilizing society as a whole. Yet, it is equally clear that universities in the Muslim world are facing far more than a financial challenge, although many are indeed pitifully short of funds. Indeed, the biggest challenges facing our universities today are the absence of freedom of inquiry, the virtual disappearance of quality standards, a loss of public prestige due to political interference, and a more general and profound questioning of the traditional functions of institutions of higher learning in most societies.

This is not to say that western universities are problem-free. Indeed, many parts of the Western academic establishments have now acquired a bureaucratic and ideological dimension that make the practice of science difficult. It is all the more so in the areas of the social sciences, where it is easier to attack the motivations of the authors than to address the substance of their arguments. The difficulties of addressing a dominant paradigm is also tainted by the politics that pervade the various academic departments and associations.[20] However, this is still a matter of degree, and no objective author would deny that the state of the universities in the Muslim world today leaves much to be desired, and that is the topic of this essay, not the critique of the universities of the West, about which a wholly different critique can be made.[21]

Let us now turn to the more general critique based on the traditional functions of institutions of higher learning. There were three traditional functions that universities were expected to perform:[22]

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[20] See, for example, the difficulties of the socio-biologists to engage in a formal intellectual debate in the anthropological and sociological schools, described at some length by Lionel Tiger, in "My life in the Human nature Wars", in The Wilson Quarterly, vol. xx, No. 1, Winter 1996, pp. 14–25.

[21] See for example, the excellent "What's wrong with the American University?" A special section in *The Wilson Quarterly*, vol. xx, No. 1, Winter 1996, pp. 43–66, which includes a discussion of the economics of higher education in the US: Chester E. Finn and Bruno V. Anno, "Behind the curtain" (pp. 44–53) and the conditions of the faculty: Alan Wolfe, "The Feudal Culture of the Postmodern University" (pp. 54–66).

[22] See *inter alia* Robert Paul Wolff, *The Ideal of the University*, Beacon Press, Boston, 1970.

(a) A certification function

After a certain amount of skill-imparting instruction, a test was conducted and the student was certified as competent in the subject matter. A degree was granted. Increasingly, however, this was supplanted with continuing education and re-certification and other forms of professional peer-reviewed certification and professional licensing arrangements. This was only partly due to the parochialism of the professional societies. It has a lot more to do with the recognition of the speed at which knowledge, especially in scientific and technical fields, is exploding, making obsolescence of technical knowledge one of the great problems of our time.

Furthermore, the structural unemployment that dogs today's societies, even industrial societies, makes the implicit promise of a job at the end of the university degree increasingly uncertain. The doubt about the relevance and the rigor of the training is therefore exacerbated.

(b) The advancement of knowledge and the search for truth[23]

This, too, is being eroded, as the validity of "truth" is increasingly called into question by a rising tide of relativism

[23] In 1969, when Harvard University, along with most of the Universities of the world, was forced to confront its fundamental values in the wake of widespread

and the conflicting claims of competing dogmas.[24] The university is, as it has frequently been, the battleground for the ideological culture wars around the world. The faculty and students are the key and most consistent agents of change in any society. Yet, the ideological dogmas cannot be allowed to define what is true, much less to define what may actually be researched.[25] Therein lies the traps that we face today, from the attacks of dogmatists to the efforts of deconstructivists to relativize everything and thereby void it

student unrest, the University Committee stated: "…the pursuit of truth and learning is the central value of the university." See the "University on Governance" series of monographs, especially: Harvard University, *The Nature and purposes of the University: A Discussion Memorandum* (Interim Report), Harvard University, Cambridge Mass., January 1971, p. 3.

[24] Distinguished philosophers such as Mortimer Adler, consider the idea of "Truth" as one of the three key ideas we judge by. See Mortimer Adler, *Six Great Ideas*, MacMillan, New York, 1981, pp. 56–63.

[25] The clerical attacks on free inquiry come in many different garbs. We tend to think of the battles between the Christian church and the key figures of western science from Galileo to Darwin, but we must also include the clerics of secular ideology as well: Lysenko in Soviet biology, and a wide array of "political correctness" from the right (e.g. McCarthyism in the 1950s) and the left, dominant in France for a long time and on the ascendant on many western campuses today, especially in the United States.

of meaning.[26] Returning to the search for truth as a major commitment of intellectuals is a way to build the common ground between religious and secular thought.[27]

(c) A socializing function

All youths get to learn a set of behavioral and social skills that their society values, and puts store on. In addition, the grounding of the national cultural identity through an emphasis on teaching courses about the peoples culture, history and current societal institutions was a key part of educating the future generation. University education was the place to explore the boundaries of pluralism without

[26] See *inter alia*, the works of Michel Foucault such as, *L'archeologie du savoir,* Editions Gallimard, Paris, 1969 and *L'art du discours*, Editions Gallimard, Paris, 1971. Both of these works have also appeared in English: Michel Foucault, *The Archeology of Knowledge and the Discourse on Language*, translated from French by A.M. Sheridan Smith, Pantheon Books, New York, 1972. Among the French intellectuals, contrast Foucault's work with the more thoughtful work of Edgar Morin, especially the third volume of his trilogy on "La Methode", entitled *La connaissance de la connaisance*, Seuil, Paris, 1986. For a general critique of the deconstructionists, see inter alia, John M. Ellis, (ed.) *Against Deconstruction*, Princeton University Press, Princeton, NJ, 1989.

[27] Thomas Merton, the distinguished Catholic philosopher wrote: "At root one searches for God by only one way, i.e. in following the truth with all the sincerity of one's conscience." From a letter by Thomas Merton to Feminist Argentinean Literary figure Victoria Ocampo dated 13 January 1963; see: Thomas Merton, *The Courage for Truth: Letters to Writers*, selected and edited by Christine M. Bochen, Farrar-Strauss-Giroux, New York, 1993, p. 209.

jeopardizing the cohesiveness of the national identity. It was the possibility of learning the value of rejoicing in the richness of diversity, while learning to appreciate the common threads between different parts of this enriching diversity.

Yet today, at the wake of the global multi-cultural pluri-ethnic environment, all societies are confronted with a lot more questioning of the prevalent social values, and profound doubt about the validity of any single unifying cultural construct. In the United States, as well as in many parts of the western world, there is a rising babble of pseudo-science and astrology that muddy the waters of rational discourse. These are times when the reassertion of the commitment to serious science is needed to reinforce the societal values that undergird the scientific enterprise. The fight against quackery is a never-ending one, and many of the scientists who considered it beneath them to engage in de-bunking these currents of superstition and obscurantism are now getting engaged because they see the corrosive damage these inflict on society.[28] The Muslim societies of today are the crucible of many of these same currents, and they are experiencing many of the same problems.

[28] See Carl Sagan, *The Demon-Haunted World: Science as a Candle in the Dark*, Random House, NY, 1996.

These problems, however, have exploded with particular vehemence in the wake of the intolerant fanaticism of Muslim so-called fundamentalists[29] and the ideological politicized positions of many others, including radical leftists, on the campuses. It is the duty of intellectuals to oppose and question dogma, not to create or perpetuate it.[30] However today, fear of the hegemonic West looms ever larger for an insecure faculty, ill-equipped to handle the challenges of the day, and the domain of inquiry is ever more circumscribed by the bigotry and intolerance that pervade our societies.

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[29] The phenomenon of militant Islamic fundamentalism is well analysed in Daryush Shayegan, *Qu'est-ce qu'une revolution religieuse?* Albin Michel, Paris, second edition, 1991. Shayegan has clearly woven together the philosophical, sociological and religious strands of thought to analyze the double failure of modernity and tradition to meet the needs of an anxious population. This, he argued, gave rise to the new obscurantism, which he prefers to refer to as "the ideologization of tradition".

[30] Edward Said, defined the intellectual as an "individual endowed with a faculty for representing, embodying, articulating a message, a view, an attitude, philosophy or opinion to, as well as for, a public. ... someone whose place it is publicly to raise embarrassing questions, to confront orthodoxy and dogma (rather than to produce them), to be someone who cannot easily be co-opted by governments or corporations, and whose raison d'être is to represent all those people and issues that are routinely forgotten or swept under the rug." See Edward Said, *Representations of the intellectual*, Pantheon Books, New York, 1994, p. 11.

Thus, it is not just a matter of pouring money in the universities of the Muslim world to enable them to be "centers of excellence" in science and technology that is required. Far from it. It is a re-thinking of the University as a vector of social change in our modernizing societies, in the rapidly changing world environment of today, that is called for.

This will require liberating the Muslim mind from fear of the different, the new and the foreign, and the promotion of the respect of diversity in a shared collectivity. These are values inherent in the scientific outlook, that promotes bonds that transcend race and culture to re-shape culture in the broader, more tolerant framework that the true scientific enterprise requires and engenders. These are also profoundly Islamic values.

It is a profound challenge. Paradoxically, this challenge can only be answered by promoting the scientific outlook throughout society. For the scientific outlook helps in the modernization (as distinct from "westernization") of society, and that kind of modernization will strengthen the possibility of universities to play their full role, in arts and philosophy as well as science. As universities play their full societal role, they will further help to promote the scientific outlook.

4. The Scientific Method and the Values of Science

These issues go to the very heart of the meaning of development. The promotion of science per se is an integral part of the modernization process. Without it, the social transformation that is implicit in modernization will not take place.

I hasten to add that modernization here is not synonymous with westernization,[31] although there is a central core of universal values that any truly modern society must possess, and these are very much the values that science promotes: rationality, creativity, the search for truth, adherence to codes of behavior and a certain constructive subversiveness.

4.1 The meaning of science

Let me start by asserting, along with Bronowski, that I define science as "the organization of our knowledge in such a way that it commands more of the hidden potential in nature".[32] In that definition, it is clear that it goes far beyond the utilitarian application of knowledge. It impacts on an entire world outlook from cosmology to being. It is an enterprise that

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[31] This is an issue that touches all developing societies. See among others Alvin Y. So, *Social Change and Development: Modernization, Dependency, and World-System Theories*, Newbury Park, Cal., Sage, 1990.

forces upon its practitioners values and outlooks peculiar to science and that in its essence are the keys to modernization. These approaches to thinking are very different from the cheap embrace of technology as the savior of society and the world, and the disengagement from moral issues that is prevalent among many today.[33]

Values are not rules. They are in Bronowski's beautiful phrase: "... those deeper illuminations in whose light justice and injustice, good and evil, means and ends are seen in fearful sharpness of outline."[34] This is a critical thought, and an important reminder of the core Muslim values of openness, honor and tolerance, in the context of the intolerant debate that permeates so much of the public discourse in the Muslim world today, where a person is judged by the color of their skin or the god they choose to worship or the ethnic group they were born into or their gender.

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[32] J. Bronowski, *Science and Human Values*, (revised edition with a new dialogue, the *Abacus and the Rose*, 1965), Perennial Library edition, Harper and Row, New York, 1972, p. 7.

[33] See *inter alia*, Theodore Roszak, The *Cult of Information: A Neo-Luddite Treatise on High Tech, Artificial Intelligence*, and the *True Art of Thinking*, University of California Press, second edition, 1994; and Neil Postman, Technopoly: The Surrender of Culture to Technology, Knopf, NY, 1992.

[34] J. Bronowski, *Op.cit.*, p. xiii.

This thought—that the openness and rigor of science, and its dedication to the search for truth, can give a context for our judgments—is a powerful reason to re-think the need to promote science as an essential element in the development process. Let me hasten to acknowledge that not all scientists have been pursuing the truth with that same level of commitment to the values of science.[35] Wittingly or unwittingly, we are all partially captives of our milieu, but science certainly does more to help us overcome the limits and prejudices of this milieu than almost any other activity involving knowledge. Interestingly enough, there is a profound critique of the values of science by the more extreme of the artistic and liberated minds for the reductionist, quantifying rigor they associate with science.[36] This is a different critique,

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[35] Scientists, of course also have their prejudices, and frequently politics and ideology intrude into the scientific realm, as was dramatically the case with Lysenko and biology in the Soviet Union. More subtle and pernicious intrusions or researcher prejudices can intrude into the scientific assessments of the researchers, even when they think that they are indeed being as rigorous as they can be. See Stephen Jay Gould, *The Mismeasure of Man*, Norton, New York, 1981, for an impressive expose of this phenomenon.

[36] When Vaclav Havel, playwright and President of the Czech Republic, writes about modern rationalism and modern science: "This era [of science and rationalism] has reached the end of its potential, the point beyond which the abyss begins." (Cited in J. Michael Bishop, "Enemies of Promise" in the *Wilson Quarterly*, vol. 19, No. 3, Summer 1995, p. 62); he is asserting that other realities of the human condition are beyond the scientific method to explore

which really has more to do with appreciating the limits of scientific investigation,[37] not a challenge to the values that undergird the scientific enterprise or to the need to recognize other forms of endeavor beyond the scope of science.

4.2 The humanist perspective

I think that all would agree that the essence of development is a deep humanism. Humanism is itself defined by a set of profound values that, in my mind require the scientific outlook and the values of science. Sadly, there are many

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and decipher. That is, of course the realm of religion, art and philosophy. This existential lament, however, is no justification of obscurantist, authoritarian societies that want to lock up the minds of their citizens. Havel, himself, sprang to political prominence precisely for defending the freedom to think. The critique of the "limits to rationality" type is well represented in the work by John Ralston Saul, *Voltaire's Bastards: the Dictatorship of Reason in the West*, Vintage Books, New York, 1992. Antonio R. Damasio has looked at the question in a different light, linking the neural underpinnings of reason and the emotional aspects of human behavior to gain better insights into the phenomenon of rationality. See: Antonio R. Damasio, Descartes' *Error: Emotion, Reason, and the Human Brain*, Grosset/Putnam, New York, 1994. Such efforts at deepening our understanding are themselves the fruits of the values of science as I have been discussing them, and will enrich our understanding as all good science is intended to do.

[37] This notion of a hierarchy of theories or constructs is ably presented by one of the leading scientists in the world. See Stephen Jay Gould, *An Urchin in the Storm: Essays about Books and Ideas* (New York: W.W. Norton & Co., 1988), 68–69.

who fear this view in the Muslim countries today. The rise of intolerant fundamentalism is a manifestation of this fear.

This fear starts from a view that concepts of value— justice and honor, dignity and tolerance—have an inwardness which is not accessible to experience. Accordingly, "because they believe that there is no rational foundation for values, they fear that an appeal to logic can lead only first to irreverence and then to hedonism."[38]

How mistaken they can be.

Science values originality as a mark of great achievement. However, 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.[39]

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[38] Bronowski, *Science and Human Values*, *Op.cit*., p. 53.

[39] The resistance by the scientific community to changes in the dominant paradigm of a particular branch of science, however, can be severe. It tends to be partly due to vested interest and partly to inertia and partly to cliquishness in scientific circles. These are in addition to the reasonable "burden of proof" on the innovators. The process however is well known and has been brilliantly described by Thomas Kuhn in his *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago, 1962 (Phoenix Books edition, 1970).

Independence, originality, and therefore dissent—these are the hallmarks of the progress of contemporary civilization. ... (For) ... "Dissent is the mark of freedom as originality is the mark of independence of mind."[40]

4.3 The value of modernization and the modernization of values

We all know that effective pursuit of science requires the protection of independence. Without independence of inquiry, there can be no true scientific research. The safeguards which independence requires are obvious: free inquiry, free thought, free speech, tolerance, and the willingness to arbitrate disputes on the basis of evidence. These are societal values worth defending, not just to promote the pursuit of science, but to have a better and more humane society. A society that is capable of adapting to change and embracing the new. A tolerant society.[41]

[40] Bronowski, *Op.cit*., pp. 61–62.

[41] See Barrington Moore, Jr., "Tolerance and the Scientific Outlook" in Robert P. Wolff, B. Moore, Jr. and Herbert Marcuse, *A Critique of Pure Tolerance*, Beacon Paperbacks, Boston, 1969, pp. 53–79. Regretfully, in the concluding paragraph, this excellent essay uses some unfortunate references to Muslims and the Quran, attributing to them the willingness to see … "other books ... may be cast on the flames." This typically ignorant comment is a use of a Western stereotype that is unworthy of the rest of the essay, which deals with science and tolerance and reason in the Western context.

Tolerance based on the adoption of the values of science is different from the tolerance begotten by indifference to the behavior of others, dismissing them without engaging them. Tolerance among scientists "must be based on respect. Respect as a personal value implies, in any society, the public acknowledgments of justice and due honor.... If these values did not exist the society of scientists would have had to invent them to make the practice of science possible. In societies where these values did not exist, science has had to create them."[42]

4.4 Promoting the scientific outlook

So, if we accept that science promotes certain values we hold as essential for the true modernization of a developing society, how does one promote this broad concept of science? How does one involve the leaders and decision-makers in the promotion of scientific outlook? Can such ideas resonate in a society wracked by poverty and hunger, riven by civil strife and worried about fiscal crisis? I can already hear the nay-sayers, and their emphasis on pragmatism, realism, and the urgent; but they are wrong.

[42] Bronowski, *Ibid.*, p. 63.

Science does have the capacity to capture the imagination and to move the emotions. As Steven Weinberg noted: "Today's basic scientific research is part of the culture of our times."[43]

Weinberg is right. We must see science as an integral part of our culture that informs our world view and affects our behavior. It promotes fundamental ethical values. Indeed "Those who think that science is ethically neutral confuse the findings of science, which are, with the activity of science which is not."[44]

Even more, science is itself a culture of global dimensions. To the extent that culture can be defined as comprising, both an activity and a vision, a way of doing things, and a way of thinking and feeling them; then science is a culture, or at least a cultural current that affects strongly the society where it flourishes.

It is a culture of living change, to use the inspired formulation of the late Jacob Bronowski who said "…we are the visionaries of action; we are inspired with change. We think the past preserves itself in the future of itself, the

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[43] Steven Weinberg, "Life in the Universe", *Scientific American*, vol. 271 : No. 4, October 1994, p. 49.

[44] Bronowski, *Ibid.*, pp. 63-64.

way Isaac Newton is changed and still preserved in Albert Einstein. We are the culture of living change."[45]

How different is this vision of continuity with its respect for past achievements re-born in contemporary ones, from that of those militant Muslim fundamentalists who would freeze us forever in their own interpretation of the past.

In fact, the values promoted by that scientific outlook: honesty, honor, truth, and the use of reason, are profoundly Islamic values. These were the values in the period when Islamic science was defined as the contributions that Muslims made to the collective scientific enterprise, rather than an effort to dissociate ourselves from the rigor of scientific debate by claiming a separateness to our scientific enterprise. So let us not allow the essence of these arguments to be sidelined by arguments about Islam and the west.[46] Let us reclaim, as

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[45] Bronowski, *The Abacus and the Rose*, *Op.cit.*, p. 118.

[46] Fundamentalists tend to define themselves as much by "anti-Western" as by "pro-Muslim" views. The adversarial character of this dichotomy leads to the pursuit of "Islamic science" and "Islamic medicine" without regard to the vast areas of inevitable overlap between such constructs and "Western science" and "Western medicine". Such attempts miss the fact that science and culture operate at different levels. Discussion of these types of issues are addressed in many writings, see, for example, Robert Walgate, "Science in Islam and the West: Synthesis by Dialogue," in *The Touch of Midas: Science, Values, and Environment in Islam and the West*, ed. Ziauddin Sardar (Manchester, United Kingdom: Manchester University Press, 1984), 240–53.

intellectuals, our right to reason,[47] let us liberate the Muslim mind.

Let us hold up mirrors for our societies to see themselves, and windows through which they can see the world.[48] Let us accept that the promotion of the scientific outlook is necessary and unavoidable for the pursuit of science, and is in itself a major part of promoting the societal values that are at the core of modernization and development. These are not two separate tasks, promoting two separate endeavors; they are a single, more effective way of doing either or both.

The role of government at the intersection of the university and the practice of science needs to be discussed.

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[47] Muhammad Abduh, the Mufti of Egypt in the late 19th century and one of the towering figures of the Muslim intellectual tradition, always made a compelling case for the place of reason in anything dealing with Islam. He gave a very strong argument against those who would ban pictures or statues because of the Islamic injunction against graven images. He pointed out that the prohibition was related to the fear of idolatry, not the images *per se*, and based his defense of allowing the use of images largely on the benefit that it would have for the teaching of science. See Muhammad 'Imara (ed.), *Al-A'mal Al-Kamila lil Imam Muhammad Abduh* (the complete works of the Imam Muhammad Abduh), in six volumes, *Al-mu'assasa Al-Arabiya Lil Dirasat Wal Nashr*, Beirut, 1972, vol. 2, pp. 204–208, especially p. 206.

[48] See Ismail Serageldin, "Mirrors and Windows: Redefining the Boundaries of the Mind." In *The American Journal of Islamic Social Studies*, vol. II(1) (Spring 1994): 79–107. "Mirrors and Windows" was also published in two parts in *Litterae* (The Review of the European Academy of Sciences and Arts), Part I in 3(2–3) (11 October 1993): 4–15 and Part II in 4(1) (1994): 8–26.

Governments are, without question, the key institutions that help create an overall climate of openness or fear, of tolerance or of prejudice. They can create a nurturing climate, or one in which the persecuted and alienated intellectuals have to struggle. I believe that the attitudes of the leaders to science and its values will doubtless be very significant in the kind of climate they seek to nurture.[49] This does not mean that they themselves have to be scientists or even that they specifically want to have a close relationship between government and science, a position that many scientists would be concerned about in terms of their freedom of inquiry. Indeed, the arguments I have been presenting here are very different from the issues of the relationship between Science and Government. The promotion of a scientific outlook that permeates public discourse is different from the issues related to government and military funding of science in the universities and the implications of that for free inquiry and the purposes of the scientific enterprise.[50]

[49] In fact, the scientific outlook, if not outright scientific achievement was closely allied to the world view of the founders of the American Republic. See, *inter alia*, J. Bernard Cohen, *Science and the Founding Fathers: Science in the Political Thought of Jefferson, Franklin, Adams, and Madison*, Norton, New York, 1995.

[50] These issues are coming to the fore in the post-cold war United States, see for example, Daniel J. Vles, "The Crisis of Contemporary Science: The Changed Partnership", in The *Wilson Quarterly*, vol. 19, No. 3, Summer 1995, pp. 40–52.

I submit that the scientific outlook, as I have described it here, will make it possible to empower philosophers, writers, artists and critics to pour forth their myriad contributions that fashion culture, identity and the very fabric of society.[51]

Thus are all intellectuals, not just scientists, the artisans of this new Muslim renaissance. Thus, will they rise up to the tide of challenges that confronts the Muslim world today?

5. Science and the Future of Muslim Societes

The key questions in the preceding discussion are the extent to which the scientific enterprise can indeed be exercised in the Muslim societies of today in the manner that I have described here. In other words, the scientists in the Muslim world can indeed flourish and make their contributions to the world of global knowledge while interacting with their own societies. This was after all the case at the time of the medieval and renaissance eras. A willful commitment by the intellectuals of today should be able to overcome the effects of the historic

[51] Muhammad Abduh, was committed to the idea that the rational mind ('Aql) was the best instrument to deal with problems, and even for the understanding of the Quran. See Muhammad 'Imara (ed.), *Al-A'mal Al-Kamila lil Imam Muhammad Abduh* (the complete works of the Imam Muhammad Abduh), in six volumes, Al-Mu'assasa Al-Arabiya Lil Dirasat Wal Nashr, Beirut, 1972, vol. 1: pp. 182–186.

rupture[52] that the Muslim societies have encountered from the 18th century through the time of colonialism. National independence and post-colonial reassertion of their social identities should have laid the ground for that renewal. But it did not.[53] We, Muslim intellectuals, must overcome these obstacles from the past to pave the way for a better future.

There is a widespread view in many Muslim societies today, being promoted by obscurantist currents that contemporary science is a western import, and that it is alien to the Islamic tradition, or others who speak of "Islamic science" as being derived from verses of the Quran rather than through empirical study.

How mistaken they can be. To me, these people are turning their backs on the great tradition of Muslim and Arab sciences that did so much for humanity for a thousand years, when we were the bearers of the torch of knowledge and rationality. When we advanced knowledge like no other.

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[52] For a discussion of this issue of rupture, see Mohammed Arkoun in the proceedings of *Architectural Education in the Islamic World*, Seminar Ten in the series "Architectural Transformations in the Islamic World", (Seminar series held in Granada, Spain, 21–25 April 1986) (Singapore: Concept Media for the Aga Khan Award for Architecture, 1986), 15–21, and subsequent discussion, 22–25.

[53] See *inter alia* Edward Said, *Culture and Imperialism*, Knopf, New York, 1993.

Names like El-Khawarezmi, El-Razi, ibn Al-Nafis[54], ibn Al-Haytham, ibn Sina, ibn Rushd, are forever engraved in the honor roll of humanity's benefactors through their efforts at advancing knowledge and rejecting superstition. Listen to their powerful, modern voices as it speaks to us through the centuries.

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[54] Ibn Al-Nafis (1213–1288) was born in 607 AH/1213 CE, in Damascus. Ibn Al-Nafis became a renowned expert on Shafi'i School of Jurisprudence as well as a reputed physician. After acquiring his expertise in medicine and jurisprudence, he moved to Cairo where he was appointed as the Principal at the famous Nasri Hospital. Here he imparted training to a large number of medical specialists. He also served at the Mansuriya School at Cairo. When he died in 678 AH/1288 AD, he donated his house, library and clinic to the Mansuriya Hospital.

His major contribution lies in medicine. His approach comprised writing detailed commentaries on early works, critically evaluating them and adding his own original contribution. His major original contribution of great significance was his discovery of the blood's circulatory system, which was re-discovered by modern science after a lapse of three centuries. He was the first to accurately describe the constitution of the lungs and gave a description of the bronchi and the interaction between the human body's vessels for air and blood. Also, he elaborated the function of the coronary arteries as feeding the cardiac muscle.

The most voluminous of his books is *Al-Shamil fi al-Tibb*, designed to be an encyclopedia comprising 300 volumes, but it was not completed due to his death. Ibn Al-Nafis' works integrated the then existing medical knowledge and enriched it, thus exerting great influence on the development of medical science, both in the East and the West. However, only one of his books was translated into Latin at early stages and, therefore, a part of his work remained unknown to Europe for a long time.

Listen to ibn Al-Nafis, on the importance of listening to the contrarian view:

> *"When hearing something unusual, do not preemptively reject it, for that would be folly. Indeed, horrible things may be true, and familiar and praised things may prove to be lies. Truth is truth unto itself, not because [many] people say it is."*
>
> —Ibn Al-Nafis (1213–1288)
> *Sharh' Ma'na Al Qanun*

Listen to ibn Al-Haytham,[55] known in the west as Alhazen, who revolutionized optics and made major contributions in several fields of inquiry. Listen to him speak of and how

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[55] Ibn Al-Haytham (965–*c.*1040) sometimes referred to in the western classical sources as Alhazen; a distinguished Arab mathematician. Ibn Al-Haytham was born in Basra, but made his career in Cairo, where he supported himself copying scientific manuscripts. Among his original works, only those on optics, astronomy, and mathematics survive. His Optics, *which relied on experiment rather than on past authority*, introduced the idea that light rays emanate in straight lines in all directions from every point on a luminous surface. Latin editions of the Optics, available from the 13th century onwards, influenced Kepler and Descartes. As a cosmologist, Ibn Al-Haytham tried to find mechanisms by which the heavenly bodies might be shown to follow the paths determined by Ptolemaic mathematics. In mathematics, Al-Haytham elucidated and extended Euclid's Elements and suggested a proof of the parallel postulate. (from The Columbia Electronic Encyclopedia, 6th ed. Copyright © 2005, Columbia University Press).

he prefers the experimental method to the authority of the ancients, which should always be approached with caution:

> *"He who searches for truth is not he who reviews the works of the ancients … [it is] he who follows argument and evidence, not the statement by an individual, who is inevitably affected by context and imperfection. It is the duty of he who reads science books, if he wants to learn truths, that he should set himself up as an opponent to all he looks at... [accepting only what is supported by evidence and argument]."*
>
> —Ibn Al-Haytham (965–c.1040)
> *Al Shukuk Fi Batlaymous*

Even more impressive, is this description of how the scientific method should operate, through observation, measurement, experiment and conclusion:

> *"We start by observing reality … we try to select solid (unchanging) observations that are not affected by how we perceive (measure) them. We then proceed by increasing our research and measurement, subjecting premises to criticism, and being cautious in drawing conclusions… In all we do, our purpose should be balanced not*

arbitrary, the search for truth, not support of opinions.
Hopefully, by following this method, this road to the truth that we can be confident in, we shall arrive at our objective, where we feel certain that we have, by criticism and caution, removed discord and suspicion.
Yet we are but human, subject to human frailties, against which we must fight with all our human might. God help us in all our endeavors".

—Ibn Al-Haytham (965–*c.*1040)
Kitab Al-Manadhir

Centuries before Bacon and Descartes, before the emergence of modern science in the west, our forefathers were calling for the experimental method, relying on the power of observation and the application of rationality and logic. They promoted openness to the contrarian view, balanced by a healthy skepticism. They advocated prudence in running ahead of the available facts, and finally to beware of our innate prejudices and weaknesses that may bias our work without our noticing it. This is a truly amazing description of the modern scientific method, which was way ahead of its time! The last section is stunning, considering the hubris of Paul Broca and his supposedly accurate work on brain measurements centuries later![56]

These are stellar lights in the history of science and in the advance of knowledge. They are our forbearers and we should be their proud disciples. We need to recapture that great tradition. It is our tradition, our history, our legacy.

This, to me, is the tradition that Muslims and Arabs should be proud of. They took the torch and carried it for centuries, and if today the torch has passed to the west, we should be proud that we have done our share and more in earlier times, and should strive to take our place, by dint of hard work and innovation, alongside our western colleagues at the forefront of global scientific endeavor.

We need to reinforce science and mathematics education throughout the Arab and Muslim world, and create research institutions that will allow the Arabs and Muslims of today to make their contribution to the enormous collective human enterprise that science has become. These institutions must promote and defend the values of science which were crafted by these very names I have been quoting.

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[56] Paul Broca was incredibly accurate in his measurements of human brains, but was driven by an innate racism to bend his work towards "proving scientifically" the superiority of the white race. Excellent discussions of the problems exemplified by Broca, but by no means limited to him or to its time, cf. Stephen Jay Gould, *The Mismeasure of Man*, Norton, New York, 1981 (*Op. cit.*), and also Carl Sagan's Broca's Brain, (c. 1974), Ballantine Books, New York, 1980.

Two obstacles can affect that, beyond the ones I have described above. These include the receptivity of the society at large to the work of the scientists and the attitudes of the scientists themselves.

On the receptivity of society, I believe that there is a widespread hunger in societies everywhere to know more about scientific change even if they cannot fully comprehend the full ramifications of that work. Thus, I believe that I am not being unduly romantic when I talk of the influence of science and scientific ideas on culture and outlook of entire societies. True, there is a special language of science, and the public at large cannot be expected to absorb the intricacies of scientific research. As Steven Weinberg observed: “Whatever the barriers that now exist to communication between scientist and the public, they are not impermeable. Isaac Newton’s Principia could at first be understood only by a handful of Europeans. Then the news that we and our universe are governed by precise, knowable laws did eventually diffuse throughout the civilized world. The theory of evolution was strenuously opposed at first; now creationists are an increasingly isolated minority”.[57] The same can and must be true of any society. The Muslim societies of the past that encouraged science and respected scholarship did not

[57] Steven Weinberg, “Life in the Universe”, *Scientific American*, vol. 271: No. 4, October 1994, p. 49.

fully understand the chemistry or algebra that the scientists were developing, but they were satisfied that these learned men deserved respect and that their studies contributed to a better understanding of the world. Today, with universal education and omnipresent communications, there is no reason that the attitudinal direction that the practice of science can provoke in society will not be very strong indeed. The universities are the key arena where these values of honor, tolerance and the pursuit of truth have to be forged and strengthened by teacher example and student practice.

The other type of obstacle to the application of these ideas may well be the attitudes of the scientists themselves. It is not uncommon to find many scientists, especially in the poorer parts of the world, including the Muslim world, who not only do not see the value and benefit of that symbiotic link between science and society, but would prefer to keep the two worlds apart.[58] Some of them may well become

[58] Muhammad Abduh, in one of his writings in the journal *Al-Waqai' Al-Misriyya*, 28 March 1881, observed that the real poverty of Egypt, that would keep it in backwardness was the disengagement of the elites from the conditions of the country, and the limited number of the learned and the able in the country. In the same journal on 11 May 1881, he wrote about the problems of scientific books and the fight against obscurantism and quackery. See Muhammad 'Imara (ed.), *Al-A'mal Al-Kamila lil Imam Muhammad Abduh* (the complete works of the Imam Muhammad Abduh), in six volumes, Al-Mu'assasa Al-Arabiya Lil Dirasat Wal Nashr, Beirut, 1972, vol. 3: pp. 42–48 and 49–52.

"intellectual migrants" who identify only with their external colleagues with whom they are linked by internet or other forms of communication. It is another form of brain–drain, even if the scientists physically exist in the country, when they totally disengage from the difficult surroundings in which they find themselves.

We must all fully support their full commitment to relations and dialogue with the international scientific community, without which there can be no effective practice of science. However, it would be a great loss if their voices were not to be heard loudly and clearly in the national discourse of their own societies. This not only de-links science from its salutary effect on the modernization of societies, but also undermines the public support necessary for the pursuit of science.

Overcoming these obstacles, as much as the preceding ones that I have described, is an essential task in reforming and reconstructing the educational institutions of the Muslim world to make them more receptive to and supportive of science and technology. Indeed, I am convinced that this is a two-way street. The promotion of the scientific outlook is necessary and unavoidable for the pursuit of science, and is in itself a major part of promoting the societal values—the profoundly Islamic values—that are at the core of modernization and development. These are not two separate tasks, promoting two separate endeavors; they are a single, more effective way of doing either or both.

To the members of the scientific community in the developing world generally, and the Muslim world specifically, I say: we are at a crossroad: either we are going to reassert the importance of science and the scientific outlook, or we are going to witness our societies increasingly marginalized in the world of the information age. The scientific communities of the developing world will either become a mere appendage to the elite of the global (mostly western/northern) scientific establishment and more and more detached from their own societies, or they will reassert the links of the scientific outlook and its values in the mainstream of the modernization efforts and discourse of their changing societies. They must, by their engagement, help create the "space of freedom" necessary for civilized constructive social discourse and essential for the practice of science, even more than the availability of money.[59] This

[59] The research laboratory dealing with animal diseases in the International Livestock Research Institute (ILRI), located in Nairobi, Kenya, and operates under the umbrella of the Consultative Group for International Agricultural Research (CGIAR), is currently not just at the cutting edge of world science in its field, it is undertaking about 20% of the world effort on mapping the bovine genome on an annual budget of around US$7 million. It is not the location nor the budget that is not easily replicable in the developing countries; it is the commitment to the values of science and the dedication to excellence and a space of freedom for the researchers that makes all the difference.

commitment is the only way to create centers of excellence in the Muslim world and to ensure that the benefits of progress accrue to all the poor and the marginalized. It is this re-dedication to the values of science, those intrinsically Muslim values that I have described, that will bring about a renewal of thought for a better future for the Muslim societies.[60] Those same Muslim societies that have so much to offer the world, if only they would unleash the full measure of their talent and their genius. All of that however, requires liberating the Muslim mind from the tyranny of intolerance, bigotry and fear, and opening the doors to free inquiry, tolerance and imagination.

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[60] There are a number of efforts at present, although still too few, to call for a progressive reading of Islam, that meets the needs of the believers for faith and respect the domain of the rational, and try to address the problems of today and tomorrow. This balance between the rational and the faith for the more complete human being and the more justly balanced society is well articulated in Ahmad Kamal Aboulmagd, *Hiwar la Muwajaha* (Dialogue, not Confrontation), Kitab Al-Arabi, 15 April 1985, Kuwait, 1985. See also Ismail Serageldin, "The Justly Balanced Society: One Muslim's View." In *Friday Morning Reflections at the World Bank: Essays on Values and Development* by David Beckmann, Ramgopal Agarwala, Sven Burmester and Ismail Serageldin, Washington: Seven Locks Press, 1991, 55–73.

BENDING THE CURVE: CAPACITY-BUILDING IN SCIENCE AND TECHNOLOGY

Introduction

The development of an indigenous capacity in Science and Technology (S&T) is not a luxury, but an absolute necessity if the developing world is to realize its potential in the coming decades. This is also true of the Muslim and Arab worlds, whose populations are mostly poor, and whose national economies are mostly developing or lagging.

To better understand where, when, and how we must act, it is useful to develop scenarios that are functions of certain key elements and that clearly identify the actual "drivers" of change. Such scenario construction does not render exact predictions but rather provides insight into the transformation process. The recommendations that ultimately flow from such insight may then be formulated to "**bend the curve**" of the most likely forecast in the direction of the most desirable forecast. By focusing on the levers for so doing, we may bring realism to bear on our collective goal—building worldwide science and technology capacity—and the selected ways of trying to achieve it.

A major study by the Inter-academy Council linking all the academies of science of the world (undertaken by a Panel that I had the honor to co-chair) has produced a report on the subject, that suggests five clusters of recommendations, dealing with each of these five topics: policy, human resources, institutions, the public/private interface, and financing. I will summarize here some observations drawn from that study. To these, I must add a special mention of the digital libraries of tomorrow, which, I believe, will have a major role to play in helping bring about the desired outcomes.

Policy for Science and Science for Policy

Countries need a coherent national framework for actions that directly affect the promotion of Science and Technology (S&T). Such a national S&T strategy should be developed by the government in consultation with scientific, engineering, and medical academies of the country. The strategy should benefit from the experiences of other countries, and it should spell out the government's commitments to funding, standards of excellence, openness to innovation, dissemination of knowledge, regional consortia and networks, private/public interactions, and entry into partnerships with others—locally, regionally, and globally.

National academies of science, engineering, and medicine can improve the quality of national S&T programs. National academies, as understood here, are member-based autonomous institutions, motivated by their commitment to scientific or engineering excellence, in which peers elect new members, elect their officials, and execute agreed-upon work programs for decision-makers in government. The presence of such institutions is extremely important for upholding the quality of S&T activity in a country, for guiding national policies based on science and technology, and for maintaining dialogue with other countries, often through their counterpart academies. In some countries a National Research Council (sometimes mistakenly called "Academy"), is supposed to set the strategy, but it usually suffers from conflict of interest as its members head the institutions that are the primary recipients of the funding to be provided. Sometimes it will be necessary for the countries to rely on an eminent group of scientists and intellectuals to act as an adhoc committee in the absence of formal academies, and they may even find it beneficial to create such an adhoc committee for the specific task of helping draft a national strategy or to ascertain excellence in certain centers, and frequently it can also draw on international expertise, including some of its own expatriated talents.

International institutions such as TWAS, IAP, and ICSU should help in the formation and strengthening of nascent national and regional institutions. The participation of these international bodies will help new organizations establish the requisite high standards and effective mechanisms of operation. Sometimes casting a fresh eye on problems, can bring added insight missed by the jaded eye of the local practitioners. Sometimes the participation of international experts enables the locals to avoid the social and political pressures that the work of such committees can be subjected to.

In addition, it is essential that the academies actively participate in national and international debates in order to make the voices of science and technology heard on a broad range of issues. Scientists are citizens too!

Human Resources

The Education and Training System (ETS) of a country must address the quality of instruction especially in science and math, from pre-school through graduate studies. The issue is not just coverage of curricula and teacher-training, important as these are, it is much more about being able to communicate to children the enormous adventure of discovery that is the scientific enterprise. It is to teach them to appreciate the elegance and beauty of mathematics; it is to help those who have the interest and aptitude to pursue such a career to discover their latent potential and to realize it. It is to engage them with the quest for knowledge and to impart that most valuable of all skills: learning to learn. That will be the key to life-long learning.

Reforming universities and their governance is a major topic that needs our attention and our support. It is a vital task that cannot be ignored. The university as a locus of modernization and change in any developing society is an enormous power for progress. Thus, its social and political roles are as important as its scientific and technological roles. However, these former should not be allowed to eclipse the latter.

In addition, it is important to address the so-called "brain-drain" issue. The enormous gaps existing between the north and the south as well as the demographic trends that show an aging north unable to provide enough young people for the needs of its growing, technologically-driven economy, all imply that brain-drain will continue. The South should accept that and try to train more young people in the needed disciplines and encourage more of the training burden to be picked up in the advanced research universities of the north, through arrangements like sandwich programs and enhanced fellowships. Special outreach and support programs should be promoted by the S&T community for assuring gender and diversity. The developing countries should try to retain talent in their own institutions, within their own borders, by such measures as providing, on a temporary basis, special working conditions for our best talents (whether formed abroad or at home), including income supplements and adequate research support.

In addition, the government and the national S&T community should build ties with our expatriate scientists, doctors and engineers, especially those who are working in industrialized countries.

Centers of Excellence

Science, medicine and engineering advance largely at "centers of excellence"—physical locations where research and advanced training are carried out, often in collaboration with other centers, institutions, and individuals. Centers of excellence are the key to innovation, and their importance cannot be overestimated. For the S&T capacities of developing countries to grow, therefore, they too should have centers of excellence—whether of local, national, regional, or international status. These centers of excellence do not necessarily have to be created de novo. The bolstering or reform of a country's most promising existing R&D programs can achieve the desired outcome. A key to promoting excellence is merit-based allocation of resources based on rigorous review, both in deciding on new research projects and evaluating current programs. Given the relatively modest scientific capacity of most developing nations, such reviews should ideally include appropriate experts from other nations.

Centers of excellence—whether of local, national, regional, or international status—should be created, or seriously planned for the near future, in practically every developing country in order for its S&T capacity to grow. Such centers can serve as the main nodes for individuals or groups charged with enhancing S&T knowledge of national and even regional importance. The centers should have institutional autonomy, sustainable financial support, knowledgeable and capable leadership, international input, focused research agendas that include interdisciplinary themes, applied research as well as basic research, technology transfer, peer review as a systemic element, merit-based hiring and promotion policies, and mechanisms for nurturing new generations of S&T talent.

Where such institutions already exist, they should be reinforced or, if necessary, reformed. When reform is indicated, changes should be system-wide and carried out in ways that make best use of scarce resources (including the local talent).

New scientific and technological research projects should be decided on the basis of input from expert review, with each project and program evaluated both for technical merit and its potential benefits to society. All existing research programs and centers of excellence can similarly benefit from periodic expert review and evaluation. Techniques for such procedures should include, as appropriate, peer-review teams, relevance-review panels, or benchmarking studies.

Merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the meritreview processes more effective—and not just for particular programs but in general.

Virtual networks of excellence link the scientific talents of entire regions and the globe. An important step toward building centers of excellence will be the creation of Virtual Networks of Excellence (VNEs), extending throughout the developing world, with the primary objective of nurturing scientific and engineering talent in mostly "virtual" science and technology institutes. These entities should be relatively small, efficient, and embrace innovative research groups that may be far apart geographically but closely linked via the Internet and anchored in recognized research centers. The VNEs' institutes will work to blend their activities into coherent programs, yet the individual research groups will work in areas of prime interest to their own countries. Successful examples of VNEs are the Millennium Science Institutes created in several countries by the Millennium Science Initiative with the support of the World Bank. Virtual Networks of Excellence (VNEs)—innovative groups that are located far apart but closely linked via the Internet and anchored in recognized research centers—should be created nationally, regionally, and globally.

Private/Public Interface

In the advanced industrial countries the private sector accounts for well over 50% of the R&D effort, and in the US it covers close to 68% of R&D, but implements about 75%, since some public-funded projects are executed by private contractors. Globally the figure has gone up from about 30% 15 years ago to about 62% today. This enormous expansion has valued marketable outcomes and patenting or other forms of IPR. This raises many questions for developing countries like Egypt, since we have to rely on an overwhelming share of our R&D coming from public funding. Increasingly we will find the administrative and financial burdens of coping with an intrusive patenting system inhibiting for the conduct of research since a large part of intermediate outputs that serve as research inputs are being covered by IPR protection.

No one would argue against the private sector's enormous value to the global research enterprise. Imaginative proposals must be found to create true partnerships that benefit both Egypt and the advanced industrial countries to advance R&D, locally and regionally. This is an enormous area of attention where not just legislation, but the climate within which research is undertaken will have to be revisited.

Financing

While conventional mechanisms for funding R&D will probably continue to play an important role, it is essential to move to more efficient and effective mechanisms to implement the reform agenda. However, the fundamental issue about funding is not the absolute amount of funding that a country provides, although we believe that this is quite important to create a critical mass of R&D work to enhance the S&T base in the country. The essential point is how that funding is allocated. It must be focused on strategically important research priorities determined in the national strategy, and must be allocated in a competitive grant system based on merit. That alone is the single most important condition that will ensure effectiveness of the utilization of what funds are available.

Beyond these basic questions, we can mention some new funding instruments worthy of consideration.

National Sector Funds. Sectoral funding for R&D should be seriously considered by the public, private, and academic sectors of Egypt and the region. Brazil successfully re-directed corporate taxes for the conduct of research in areas of economic interest to the nation. The management of each sectoral fund should be tripartite, with the participation of the academic community, government, and industry. A portion of each fund's resources should be used to support basic science, and another portion should support infrastructural needs. These sectoral funds, which can help implement the national strategic policy goals, require close interaction of the academic community, private sector, and government in creating the funds, setting their priorities, and managing them. Decisions on the selection of strategic sub-sectors, their respective shares of the fund's resources, the blend of basic and applied research, the required overall budget, and sources of support are all jointly made.

Regional S&T networks. Regional networks, through which neighboring nations could together pursue world-class research and training activities on issues of mutual concern, should be created and supported in order to complement sectoral funds. The regional networks could, in turn, be involved in cooperative programs with S&T-advanced countries (US, EU, Japan, others), which should, along with the international-donor and financing community, be willing to fund these networks.

Global funding mechanisms should be strengthened for support of S&T in developing nations. While the possibility exists for such funding through the targeted sectoral funds discussed above, it would require exceptionally committed governments and in some places could be insufficient for generating the needed foreign-currency resources. Therefore, the Study Panel suggests that two global funds—an institutional fund and a program fund—be set up in a consultative fashion. These global funds would not have to be pooled but could remain distinct, though coordinated centrally, and they would allow those donors with particular restrictions to honor them while still participating in the funding.

An Institutional Fund (GIF) should be established that would provide "soft funding" over a period of 5 to 10 years to some 20 centers of excellence of a national or regional character (operating by themselves or in developing-world networks). This funding would not be program-specific; it would be used instead to allow centers to promote the values of science and engineering and to create atmospheres in which the practice of high-quality research can flourish. Specifically, the money would help each center to develop its programs, cultivate its management, and build its long-term funding base. The Egyptian Government and donors would meet in a consultative mode to review proposals resulting from an open call for competitive submissions, and they would select the centers according to clearly established evaluation criteria.

A Program Fund (GPF) should be established as a competitive-grants system—for support of research programs in centers of excellence—in which international referees would review the quality of the projects being proposed. Preference would be given to proposals that involved cooperation with a research institute in an S&T-advanced or proficient nation.

The Digital Libraries of Tomorrow

Digital libraries of S&T can provide knowledge to virtually everyone, everywhere. Scientists and technologists in developing countries, including Egypt, have limited access to recent research findings (mostly in journals), to reference materials (mostly in libraries elsewhere), and to databases (some of which are proprietary); and these problems have been exacerbated in the last decade as information streams turned into torrents. The enormous advances in Information and Communications Technology (ICT) have opened up opportunities for remedying the situation as never before, though these same advances have also raised issues of intellectual property rights. The proper harnessing of digital technologies is essential to S&T capacity-building in Egypt as in other developing countries, which should make major efforts to provide adequate ICT infrastructure and trained technical personnel for the learning and research institutions. The Bibliotheca Alexandrina, the new Library of Alexandria, is making enormous efforts in this direction, but it is clearly a small part of what must become a vast regional and global enterprise.

ENVOI

The future is not pre-ordained. We can create our own futures. We can bend the curve towards that more desirable outcome, where the vista is unconstrained, and where our most creative minds can soar. The future generations of Arabs and Muslims can reclaim their proud heritage and ensure that the values of science are integrated into the fabric of our societies. Only thus, will the promise of science, with its exhilarating journey of discovery of the self and the cosmos, with its quest for understanding the mysteries of nature, be realized. Only thus, will we be able to harness the technology of the new century to ensure better lives for all.

WOMEN IN SCIENCE
Time to Recognize the Obvious

Address delivered at the 16th TWAS Annual Meeting
Alexandria, Egypt, 30 November 2005

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 McLintock[(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.

* Besides Marie Curie, the first person to be awarded two Nobel Prizes (1903, Physics; and 1911, Chemistry); among other Nobel Laureates in the field of science 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.

The systematic discrimination against the girl child was not easy to acknowledge.

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.

Thus, 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. 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. 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, 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. He is also member of Supreme Council for Culture, 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.