DEVELOPMENT OF SCIENCE AND ITS IMPACT ON SOCIETY

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“Human civilization did not begin when man learned to make and use tools. It began when he started to decorate them. Essence of culture is always in those things which, from purely utilitarian point of view are useless – be it a fine piece of fine art, a fine piece of literature, a building of great architectural beauty, or a beautiful edifice of a scientific theory incorporating the symmetries of the laws of nature.”

These are not my words. These are not the exact words of Henrick Casimir, as I am quoting from memory.

Who was Casimir? You may not have heard his name. Casimir was a distinguished Dutch Theoretical Physicist who was head of R and D division of Dutch multinational Philips electric company for several years.

Philips is a well known name in Pakistan, even in villages – where people buy Philips electric bulb and electric tube-lights.

One would not expect a layman to know any name besides an electric company which has supplied him the end products in the form of appliances which he can use in variety of ways provided he can afford them. Technology hardly effects the lives of those who are below a certain economic threshold.

Science not only provides a base for modern technology but it is also a part of human culture. How we define culture? One may say; Anything which enriches human civilization, because of its intrinsic value falls in the domain of culture. Philosophy, art, literature and music, mathematics and basic sciences are part of our cultural heritage. They generate social capital. Social capital

creates an environment for an enlightened, tolerant society which value human life and rule of law. It keeps darkness in human soul in a dormant state. There is another aspect of culture which is concerned with cultural traits of a society and its social evolution. Science has made tremendous contributions in the social evolution of mankind. Oscar Wilde once said, a cynic knows the price of everything and the value of nothing. A bigot is a chronic cynic.

In a bigoted society, culture has no value and least appreciated.

Technology is very old; the pyramids in Egypt are an example of ancient technology. Modern science is relatively new; its roots date back to 17^{th} Century.

Galileo has a very special place in development of physics. He is regarded as father of modern science. He challenged the authority of Aristotle; and discovered law of falling bodies

(Terrestrial Gravity). He challenged the authority of Church and came decisively in favor of heliocentric (Copernican) system. This brought him in trouble with the Church which regarded the earth as the centre of the Universe (Ptolemic scheme).

Galileo became victim of biogatory in Italy.

Berchet wrote a play about Galileo. I now quote one scene from this play to illustrate three aspects of science and how they are appreciated

Occasion: *Invention of telescope by Galileo*

Curator: (in his best chamber–of– commerce manner)

Gentlemen: Our Republic is to be congratulated not only because this new acquisition will be one more feather in the cap of Veniation culture (Polite applause) not only because our own Mr. Galilei has generously handed this fresh product of his teeming brain entirely over to you to manufacture as many of these salable articles as you please – (considerable applause) – but,

Gentleman of the senate, has it occurred to you that – with the help of this remarkable new instrument – the battle fleet of the enemy will be visible to us as full two hours before we are visible to him? (tremendous applause)

Three aspects of science: value, price and security are appreciated in reverse order. In this respect we are not behind, but a step ahead.

I now discuss evolution of Physics and its impact on society.

Greeks made remarkable contributions to human civilization. They invented, philosophy, mathematics and science: They introduced Deductive method. From axioms which they regarded as a priori, they deduced results in a self consistent manner. Euclidean geometry is one example of mathematics, which they invented. For them, pure thought was much superior than work with hands.

Between ancient and modern European civilization, the dark ages intervened. Muslims and Byzantines preserved the apparatus of civilization. From the 12th century to 17th century, Ibn Sina was used as a guide to medicine. Ibn Rushd was more important to Christian than in Muslim philosophy.

From arithmetics (numbers) which originated in India, a transition to algebra was made in Muslim era (Khawarizmi, Al Baruni and Omar Khyam). All these men were dead end for Muslim civilization but for Christian civilization, they were beginning. In the West, the access to Greek knowledge came through Muslims. Although Muslims were better experimentalists than Greeks, they did not go beyond observations.

In general, they did not deduce scientific principles from observations. At the most they deduced empirical laws from them. They were more interested in practical applications rather than building a scientific edifice. To build a scientific edifice, it is essential to go beyond existing thought. The ruling class was not prepared to tolerate any thought which would have initiated departure from the orthodoxy prevalent at that time.

European also passed through a similar period, but they came out of it by evolving into liberal democracies.

Bertrand Russell has called the 17th century the century of science.

Not only in this century the foundation of mechanics and astronomy were laid (Copernicus, Galileo, Kepler & Newton) but some of the tools necessary for making the scientific observations were invented: Compound microscope (1590), Telescope (1608), Air pump, improved clocks, thermometer and barometer.

Remarkable progress was made in mathematics: Napier logarithm (1614), Differential and integral calculus (Newton and Leibniz), coordinate Geometry (Descartes). These discoveries in mathematics laid the foundation of higher mathematics in later years. It is remarkable that these discoveries were made by persons who were men of faith:

they never believed that their discoveries were in conflict with their religious beliefs.

Nevertheless their discoveries implicitly implied that science and religion should not be mingled with each other. Their discoveries laid the foundation of a new concept that: natural phenomena can be understood by observation and rational thinking without invoking the divine will. Magic and superstition became things of the past.

There is no space for an authority in science; all laws deduced from observations are tentative subject to modification or change with new data. Theories are accepted by consensus. This is what Neils Bohr called a republic of science. It gave a new concept of man's place in the universe. It was realized that inequalities between human beings (excluding the congenital differences) are product of circumstances.

Circumstances can be changed through education, it opens up new ways to utilize innate potentiality.

To build a scientific edifice both concepts and tools are needed. From the regularities and pattern deduced from observations, concepts are formed which are then expressed as physical laws in a mathematical idiom. Precise measurement requires constant improvement in scientific tools. The interplay of intellect and craftsmanship is hallmark of scientific progress.

The industrial revolution began at the end of eighteenth century with the invention of steam engine. The industrial revolution preceded science of thermodynamics which was developed in the nineteenth century. Most of the concepts beyond mechanics were developed in 19th Century.

Thermodynamics is governed by two laws, called the first law and the second law.

"The energy of the world is constant and its entropy strives towards a maximum." Statistical interpretation of the second law was one of the great advances of the 19th century (Boltzman).

Increase of entropy is linked to increase of disorder which is irreversible.

The irreversibility of evolution in biosphere is an expression of second law. A simple mutation such as substitution of one letter in DNA code for another is reversible. However for an appreciable evolution great many mutations successively accumulated at random;

because of independent events that produce them, is irreversible.

Also in 19th century two great conceptual revolutions associated with Darwin (theory of evolution) and Maxwell (unification of electricity and magnetism) took place. Electric environment is man made. In nature, electricity is seen in lightening. Certain stones called magnetite exhibit magnetic properties.

Nothing seems to be common between them. Basic laws governing electromagnetic phenomena were formulated (Coulomb, Ampere, Faraday) in 19th century. Faraday's law of electromagnetic induction is a discovery of great importance as it made possible to generate electricity directly from mechanical energy. Electric energy has a great advantage that it can be transported to homes and is used in numerous ways. We live in an environment created by electricity.

Maxwell expressed the basic laws of electromagnetism in terms of four differential equations. These equations encompass the whole of electromagnetic phenomena.

A consequence of Maxwell's equations is that electric and magnetic fields propagate through space as waves with speed of light. Hertz experimentally demonstrated the existence of electromagnetic waves.

His work gave stimulus for practical applications of Maxwell's equations. This is how electronic communication was born. One of the far reaching impact of Maxwell's equations is to give birth to a powerful tool in the form of electronic media for entertainment, to shape opinion of people for political aims or ideological indoctrination or for marketing of products especially by multinationals.

Never in the history of physics, such an abrupt and unanticipated transition took place as during the decade 1895 - 1905. Roentgens discovered X-rays in 1895.Radioactivity was discovered by Becquerel in 1896. In 1897, J.J. Thomson discovered electron - the first elementary particle. On December 14, 1900, Max Planck put forward the idea of quantum:

The emission and absorption of radiation from an atom take place in discrete amounts that he latter called quanta. The discovery of atomic nucleus was announced by Rutherford in 1911. Neutron was discovered by Chadwick in 1932. Radioactivity is the only nuclear phenomenon which is found on earth. Nuclear environment exists in star. With the development of nuclear reactors and nuclear weapons an environment is created by human beings, which is natural in stars.

The development of nuclear energy and nuclear weapons of mass destruction have left a strong mark on modern society.

The birth of quantum theory (1900) and relativity theory (1905) marked the beginning of an era in which foundation of physical theory needed revision. Transition from Newtonian mechanics to special theory and general theory of relativity was smooth. Maxwell's equations are consistent with the theory of relativity.

But Newtonian mechanics is not compatible with the special theory of relativity; when it is made compatible with the special theory, one gets Einstein's famous equation $E = mc^2$. Another consequence of special theory was time dilation i.e. moving clocks are slowed down. The general theory of relativity is concerned with gravity. In this theory, Einstein unified gravity with geometry.

But the transition to quantum theory was not smooth. It was like a revolution. As in a revolution, there is a period of turmoil and it takes some time to restore a new order; this was also the case for quantum revolution.

New order was established by Heisenberg with his discovery of Matrix Mechanics in 1925 and by Schrödinger by his wave mechanics a little bit latter. By unifying special theory of relativity with quantum mechanics, Dirac predicted the existence of antimatter.

Determinism of classical mechanics is replaced by uncertainty principle i.e. when events are examined closely, uncertainty prevails; cause and effect become disconnected;

Causal relations hold for probabilities; waves are particles and particles are waves; matter antimatter are created and destroyed (vacuum polarization); chance guides what happens.

The unification of terrestrial and celestial gravity by Newton; the unification of electricity and magnetism by Maxwell; the unification of geometry with gravity of Einstein, the unification of special theory of relativity with quantum mechanics by Dirac were hallmark of physics. In the same context the unification of electromagnetism

with radioactivity was achieved by Glashow, Salam and Weinberg in late 1960's with prediction of a new kind of weak current called the neutral weak current, subsequently discovered experimentally in 1978. This unification also predicted the existence of massive weak vector bosons called $W^{\pm}$, Z^{0} which mediate the weak force (responsible for radioactivity). W and Z bosons are partners of photon (quantum of electromagnetic field which is mass less and mediates the electromagnetic force).

Weak bosons were experimentally discovered in early 1980 at CERN Geneva.

We conclude the evolution of science with following remarks.

- Unlike goal oriented project;
- Basic research is an unending project;
- Going from one generation to another generation;
- It is shared by whole mankind;
- No state has sovereignty over it;
- No sovereignty – no conflict
- Enhances our vision
- Gives both humility and pride

C.P. Snow in his book “Two Cultures” divides the industrial revolution in three phases. The first phase which began with the invention of steam engine at the end of 18th Century was mainly created by handy men as C.P. Snow calls them. In the second phase of industrial revolution: chemistry played a major role. Giant chemical companies were established in Europe and USA.

In the third phase of industrial revolution atomic particles like electrons, neutrons, nuclei and atoms played a crucial role. This revolution is based on physics of 20^{th} Century. The birth of quantum theory in the 20^{th} century had a tremendous impact on future development.

It is hard to imagine that without quantum mechanics, transistors, computer chips and lasers would have been invented.

Physicist Freeman Dyson calls the fourth phase of revolution tool driven revolution. Scientists develop new tools and computer software.

The craftsmanship used in their tools may initiate new technologies. Two examples: X-rays and nuclear magnetic resonance $\Rightarrow$ computed Axial Tomography (CAT), Magnetic Resonance Imaging (MRI).The scanning technology revolutionized diagnostic techniques in medicine. It may also lead to some landmark discoveries in basic sciences. A prime example is the use of X-rays crystallography to study biological molecules.

Such a study lead Crick and Watson to unfold the structure of DNA – the genetic code-perhaps the greatest discovery in biology after Darwin.

The subsequent developments in DNA testing, genetic engineering and bioinformatics had made an enormous impact on human society. Another example is the World Wide Web (www) developed at CERN for basic research, which has revolutionized the information technology.

On the other hand tremendous progress in space technology has been used to put the probe in outer space to study the structure of universe.

We conclude that science has not only made an enormous impact on human intellect but has also drastically changed human living.

Scientific discoveries are beautiful but scientific inventions can be good or bad.

There is no doubt that science and technology have made remarkable contributions to raise the standard of living and to improve the quality of life. But it has also increased the gap between the rich and the poor. While on one hand tremendous progress in the medical science, immunology and drugs had alleviated the human sufferings and has increased the span of life; on the other hand it has increased the destructive power of man in the form of weapons of mass destruction.

British historian Hobsbawn calls the 20th century, the age of extremes. A century of unprecedented progress and unprecedented destruction and killing. It witnessed the best of science in terms of two conceptual revolutions viz special and general theory of relativity and quantum mechanics, the discovery of structure of DNA and tremendous progress in medical science.

In this century we witnessed the culmination of domestication of technology in terms of internet, computer games and mobile phones.

The culmination of three hundred years of science in the forms of weapons of mass destruction was the worst of science. A new nation was born and militarization of space in the last century- a nation that dwell in total silence. Scottish writer Gil Elliot calls it a nation of dead. He estimates its population to be 110 million- a fully cosmopolitan nation (Richard Rhodes: The Making of Atomic Bomb: Epilogue). It was created by man-made weapons.

Excessive use of technology has increased the industrial pollution. This poses a long term threat to natural environment which would effect the quality of life. Science by itself does not guarantee the genuine progress, though it is one of ingredient for the progress. Social capital is needed for synthesis of society: to narrow the gap between the rich and the poor.

It took millions of years for biological evolution through natural selection. Evolution in the biosphere is necessarily irreversible process. Changes in the form of society, in ideas, in tools, new ways to utilize innate potentialities are salient features of social evolution. These changes are steady, appreciable changes occur over a period of time. Time scale for social evolution is much smaller than that for the biological evolution. Is social evolution reversible?

We do not have second law for socio sphere although social structure is also complex. History tells us that any great civilization which has decayed has never come back in its original form. Those who dream to regain lost glory and do not want to go above the past are defying the history.

P. R. Mooney in an article (in the Development Dialogue 1999, published by Dag Hammerskjold Foundation) has expressed the viewpoint that 21st century will be the ETC century. ETC stands for Erosion, Technological Transformation and Corporate Concentration.

Erosion includes not only genetic erosion and erosion of species, soils, and atmosphere– also the erosion of

knowledge and global erosion of equitable relation.

Technology means new technologies such as biotechnology, nanotechnology, informatics and neuroscience.

Concentration describes the re-organization of economic power into the hands of high-tech global oligopolies.

Recent trends indicate that some of his observations may come through.

“ Man, above and beyond his biological aspects, has mind and spirit ------- that he is capable of selective evolution ------ and hat as a knowing creature he can use his tools of experience, mind, and spirit to shape his existence and determine his destiny.”

(Sir Julian Huxley)

Thanks