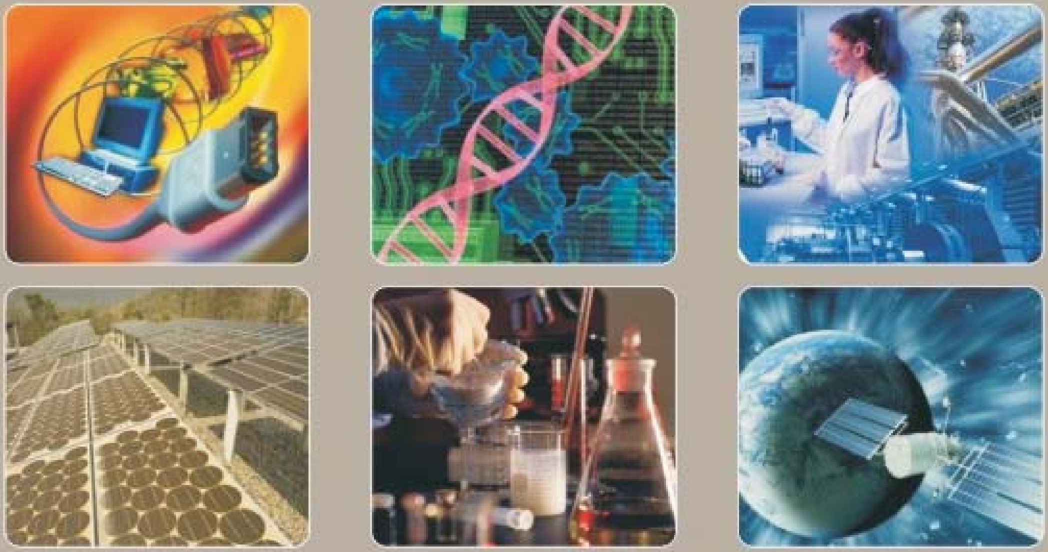
BASIC *OR* APPLIED RESEARCH

Dilemma of Developing Countries

Editors
Dr. Hameed A. Khan
Prof. Dr. M.M. Qurashi
Mr. Irfan Hayee



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BASIC OR APPLIED RESEARCH

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Commission on Science and Technology for
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Commission on Science and Technology for Sustainable Development in the South

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TABLE OF CONTENTS

FOREWORD **i**

PREFACE **iii**

SECTION A: INTERRELATION BETWEEN BASIC AND APPLIED RESEARCH

1. **Can Applied Research Survive without Basic Research?** **1**
— Riazuddin
Introduction, 1; Possible Categorization of Research: *Basic or Applied Research; Mission-Oriented Research, Academic Research, 3;* Why Basic Research is Necessary?: *Education and Training, Cultural, Social, Economic, Entrepreneurship,* 6; Unity of Science, 8; Conclusions, 9.

2. **Creation & Utilization of Knowledge: Relative Importance and Inherent Limitations of Developing Countries** **11**
— Hameed A. Khan, Irfan Hayee and Sadia N. Swati
Introduction, 11; What is Knowledge?: *Limitations of Scientific Knowledge*, 11; Importance of Knowledge as an Economic Good, 15; Science as a Form of Knowledge, 15; Role and Importance of S&T in Human Development, 16; Scientific Research & its Significance: *Basic Research, Applied Research, Mission-Oriented Research, Problem-Oriented Research, Industrial Research*, 17; Importance of Research-Based Knowledge, 24; Basic & Applied Research in Developing Countries: Role of Government, Academia, and Industry: *Basic Research as the Primary Focus, Funding and Support for Research, Establishment of University-Industry Collaboration, Bridging the Gap between Developed and Developing Countries*, 28; Role of 'Centers of Excellence' in Establishing Regional Cooperation in Scientific Research, 34; Some Proposals for

Sustainable Development of Third-World, 35; Summary and Conclusions: *Some of the Key Recommendations for Promotion of Science and Technology*, 36.

3. **Fundamental Research: The Engine of Innovation - Example of Particle Physics** **41**
— Jean-Pierre Revol

4. **R&D in Developing Countries: Case for Applied Research** **53**
— Ishtiaq A. Qazi and Shaukat Farooq
Applied Research: A Case Study from U.S.A., 53; Some Examples from Developing Countries, 57; Summary and Conclusions, 61.

5. **Balancing Basic and Applied Science and Research: A Dilemma for Developing Countries** **65**
— A.H. Zakri and Balakrishna Pisupati
Introduction, 65; Putting Basic Research Against Applied Research, 67; How to Support Scientific and Technological Research?, 67; Where Should the Focus be-Basic or Applied Research ?, 68; Future Scenarios: *Improve Policy-Environment and Support Better S&T Governance, Reinvigorating Research in Public-Sector Institutions, Build National Human-Capacities/Support Human-Resource Development, Reaching the Unreached, Support Innovative Thinking and Action*, 69; Conclusions, 72.

SECTION B: SOCIO-ECONOMIC DIMENSIONS FOR APPLICATION OF RESEARCH

6. **Basic and Applied Research: Role in Economic Prosperity** **73**
— Anwar Nasim and Ikram Abbasi
Introduction, 73; Research in Developing Countries: *Strategy, Implementation*, 74; Basic and Applied Research, 76; Knowledge-Based Economy, 80; Conclusions, 81.

7. **Goal-Oriented Research: A Recipe for Economic Development** **83**
— Kausar A. Malik
Introduction, 83; Development of Biosaline-Agriculture Technology, 84; Development of Abiotic Stress-Tolerant Crops through Genetic Engineering, 87; Development of Cotton-Resistant to Cotton Leaf Curl Virus (CLCuV), 88; Biological Nitrogen-Fixation: Development of a Biofertilizer: *Issues*

Concerning Commercialization, 89; Summary and Conclusions, 92.

8. Putting One's Money Where the Mouth is **101**
— Mustanser Jehangir and Riffat M. Qureshi

Preamble, 101; Basic and Applied Research: *Concept of Basic and Applied Research, Dilemma of Developing Countries viz Science & Technology*, 102; The Strategic Way Forward: *Develop Quest for Knowledge-Economy, Access National Wealth and Investment in Innovation, Access and Develop Knowledge-Database, Focus on Multi-Disciplinary Problem-Oriented Research, Identify Lead Research Institutions, Create Viable Research Groups, Adopt a Fruitful Approach for Transfer of Knowledge for Innovation,* 104; Pakistan's Paradigm in Nuclear Research: *PINSTECH, NIAB, Energy-Sector Applications,* 114; Conclusions and Summary, 125.

9. Linking Industry and Research **129**
— Parvez A. Butt

Introduction, 129; The Banyan Tree, 130; Administrative Factors, 130; Research Gap, 132; Vicious Circle, 132; Linking Industry and Research, 132; Contractual Research, 133; Research by Private-Sector, 133; Research as the Key Factor, 133.

10. Research and Socio-Economic Development: A Comparative Analysis of Pakistan, Malaysia and India **135**
— Tajammul Hussain and Mazhar M. Qurashi

Science-Led Socio-Economic Development, 135; R&D in Pakistan: *Science and Technology Policy, Enterprise, Human-Capacity, Content and Applications, Strategic Integration*, 136; R&D in Malaysia: *Science and Technology Policy, Enterprise, Human-Capacity, Content and Applications, Strategic Integration*, 146; R&D in India: *Science and Technology Policy, Enterprise, Human-Capacity, Content and Applications, Strategic Integration*, 151; Comparative Analysis and Conclusions, 156; Summary, 158.

SECTION C: SOME RELEVANT CONCEPTS OF EDUCATION AND INNOVATION

11. How to Develop Scientists in the Developing World **161**
— R.J. Peterson

Lighting the Fire, 162; The Hard Part, 164; Mentoring, 165; Building a Tradition, 166; Summary, 167.

12. The Mainsprings Driving Research, Discovery and Innovation **169**
— Mazhar M. Qurashi

Introduction, 169; Initial Human Responses: Divergent Thinkers and Convergent Thinkers, 170; Some Typical Modern Examples of Varying Perceptions, 172; The Need for Science, 175; Sustainable Development, 177; Scientific Culture of the Early Muslim World, 178; Some Thoughts on the Mainsprings of Scientific Discovery and Innovation: *The Interaction between Science and Spiritualism*, *Some Typical Predictions and Comments*, *Some Conclusions*, 180; Some Proposals and Recommendations, 184.

13. Search for a New Kind of Nuclear Energy: Suggestion for a Broad International Collaboration in Basic and Applied Research **187**
— Reinhard Brandt

Introduction, 187; Possible First Indications for New Nuclear Energies at Total Energies $E_T<100$ GeV, 188; Possible, However Feeble, Experimental Evidences for New Nuclear Energies at $E_T>100$ GeV, 191; Suggestion for International Experiments to Search for New Nuclear Energies at $E_T>100$ GeV, 193; Concluding Remarks, 196; Summary, 196.

14. Role of Science and Education in National Development: Basic or Applied Research - Dilemma of Developing Countries **205**
— Abdullah Sadiq

Introduction, 205; Defining Basic and Applied Research, 206; Basic or Applied Research? 207; Science and Developing Countries, 208; Quality and Relevant Education, 209; Some Challenges Faced by Education, 213; Research in the Service of Public Objectives, 213.

SECTION D: CAPACITY-BUILDING AND OTHER FACTORS INFLUENCING RESEARCH AND DEVELOPMENT

15. Capacity-Building and Networking for Basic and Applied Research: Importance of International Collaboration **221**
— Hasibullah

Introduction, 221; Avenues of Hope, 222; Basic and Applied Research, 223; Capacity-Building in Basic and Applied Research, 224; North-South Collaboration, 232; Networking and Capacity-Building, 235; Conditionalities for Success, 239.

16. Development of Institutions: A Key to S&T Capacity-Building in South **241**
— M. Iqbal Choudhary

Introduction, 241; Type of Scientific and Technological Institutions: *Ministries and Central Organizations for S&T, Quality Education-System, Centres of Excellence, Public Funding Institutions, Libraries, Museums and Science-Parks, Industrial Park and Technology-Incubators, Independent National Science-Academies and Professional Societies,* 241; Attributes of Centres of Excellence, 244; Creating Science and Technology Institutions, 245; Problems of S&T Establishments in Developing World and Possible Solutions: *Lack of Political Will, Lack of Qualified Manpower, Sustained Financial Support, Balance between Basic and Applied Research*, 245; Establishment of H.E.J. Research Institute of Chemistry - A Case Study, 247; Conclusion, 249.

17. Climatic Change and Sustainable Development **251**
— Qamar-uz-Zaman Chaudhry

Introduction, 251; Background: *Kyoto Protocol, IPCC's WG-I, Fourth Assessment Report (2007), Accessible Scientific Knowledge*, 251; The Challenge of Climate-Change, 252; Adaptation to Climate-Change, 252; Importance of Adaptation, 254; UNSC Debate on Climate-Change, 254; Impact on Pakistan, 255;Conclusions, 256.

18. Developing Countries and Scientific Research **259**
— N.M. Butt, Malik Irfanullah Khan and Aijaz Karim

Introduction, 259; Applied and Basic Research, 259; Excellence in Science, 260; Development of Scientific Activities: *Categorization on the Basis of Scientific Capacity,* 260; International Interaction and Linkages, 264; R&D in Developing Countries, 264; Collaboration between Advanced and Developing Countries, 266; International Efforts, 266; Suggestions and Conclusions, 267; Summary, 269.

EPILOGUE **271**

AUTHOR INDEX **275**

FOREWORD

It is obvious that no nation in today's competitive world can progress without effectively conducting and utilizing scientific research, which is ultimately the basis of a nation's development in the form of knowledge-capital, human resource, economic growth, improved standard of living and environmental sustainability. The importance of research may vary according to kind, especially in the case of basic and applied, but both are the sources of knowledge-generation. Basic research, applied research and development are closely interlinked in the form of an R&D cycle, which following a series of steps becomes the source of new knowledge and understanding, as well as products and processes. Basic research gives way to applied research that accelerates the development-process, which in turn often stimulates new avenues for basic research to generate deeper fundamental understanding. Moreover, advances in basic research come often, but not always, as the result of advances in applied research and development. The R&D cycle, thus, works to constantly expand the frontiers of knowledge, as well as, to enhance the pace of development.

After having realized the importance of research for the development of a knowledge-based economy, the developing countries ought to prioritize their research activities and create a balance between basic and applied research. The dilemma for the developing countries has been the inconsistencies in policies viz limited national budget for scientific research for effectively addressing a country's short-term and long-term concerns. The appropriate use of basic and applied research has brought enormous benefits to the developed countries, while the developing countries still lack a strategic approach in this regard. Developing countries are in dire need to distinguish between meaningful and non-meaningful research. Once this is done, the next important step is to conduct and utilize the research through a thought-out plan, and this is what the present book highlights in general.

I am pleased to note that this book carries nicely blended views and ideas of experts from the fields of both, basic and applied research. A wide range of issues concerning developing countries have been aptly discussed that include: the importance of research for sustainable development in the South, maintaining the right balance between basic and applied research for a developing country, commercialization of research, promotion of R&D culture through education, as well as, significance of international collaboration in basic and applied research. These comprehensive discussions lead to the importance of devising workable ideas in the developing societies regarding scientific research and development, by adopting an optimum mix of basic and applied research after accurately identifying and assessing their needs and priorities.

This book reflects the expertise and experiences of seasoned scientists from Pakistan and abroad. Keeping up with its tradition of bringing out scientific publications, COMSATS has once again come up with a book that brings into focus the dilemma of developing countries in maintaining the correct balance between basic and applied research and presents some useful solutions in this regard. I must appreciate and acknowledge the efforts put in by COMSATS' team in accomplishing this challenging task. I particularly applaud Dr. Hameed A. Khan, for being a true advocate of the advancement of science and technology in the countries of the South, and for bringing out this important publication.

The book is highly recommended to academicians, scientists and professionals in the fields of Science & Technology, especially the government functionaries. It is also meant for a person willing to grasp a thorough understanding of issues related to basic and applied research. I sincerely hope that this book, showing a detailed analysis of the relative importance of both basic and applied research with great precision, and presenting useful suggestions, will enable the developing countries to strategically plan their R&D activities, which in turn will take them forward in their struggle to become part of the developed global community.

(**Dr. Ishfaq Ahmad, N.I., H.I., S.I.**)
Special Advisor to the Prime Minister of Pakistan

PREFACE

There always has been a debate on the relative importance of basic and applied research when it comes to setting priorities and earmarking financial resources by the governments. The phenomenon is true for both developed and developing countries. Now it is widely recognized that 'knowledge', or if we may say 'scientific & technological knowledge', has become the main factor of production that contributes to a nation's wealth. The basis of knowledge-based economy is derived from the same conception. The world is experiencing a period of unprecedented advances in science and a colossal growth in the knowledge-base. Today, more than ever, research in science and it's applications in the form of technology are indispensable for development. Science has contributed immeasurably to the development of modern society. The application of scientific and technological knowledge continues to provide powerful means for solving many of the challenges faced by humanity, such as poverty, hunger, malnourishment, scarce healthcare facilities, lack of access to safe drinking-water, deforestation, global warming and climatic changes.

Scientific research is the principal tool for human beings to explore and make use of nature for improving the quality of life. In this context, the emphasis is mainly on two major forms of scientific research, i.e., basic and applied. Traditionally, basic research, often referred to as fundamental or curiosity-driven research, was considered as an activity that preceded applied research, which in turn fosters development; thereby applied research is for a specified period of time and is interchangeably used for mission or problem-oriented or even industrial research. Nevertheless, another school of thought believes that now the boundaries between basic and applied research are eliminated because of the expedited rate at which basic and applied research is being commercialized and implemented for satisfying the human needs. The debate on the importance of individual or blend of both forms of research-activity fervently continues in the present era, which has been nicely captured in this compilation.

The idea to compile a book on this subject was triggered by a series of debates with representatives from COMSATS' member countries, who every now and then spoke and indicated the issues on various fora and platforms of COMSATS. It was with this background that COMSATS, which representing the developing countries, planned to bring out a monograph while taking stock of the issues from its member countries, in particular, and developing countries, in general. COMSATS reveres the support and genius of Dr. Ishfaq Ahmad who has been part and parcel of COMSATS since long and guided us through, in realizing this idea.

This monograph aptly attempts to identify the various myths that have been associated with the phenomena under discussion and tries to explicate the question of "basic or applied research". It aims at bringing visibility to the nature of scientific and technological research, its historical importance and future implications for the developing countries. An effort has been made to present these comparative advantages of both basic and applied research, while identifying the needs for mutual cooperation between developed and developing countries to address issues of key importance. The consequent effects of neglecting this crucial tool, i.e., regional cooperation for development have been touched upon, while taking into account the relatively different characteristics, needs and problems of the developing world.

The book conclusively calls for formulating and adopting a realistic, strategic and multi-channeled approach in conducting research, whereby subsequent national exchequer is consumed. It has also been emphasized that research-policy of a state should be country-specific, need-oriented and sensitive to existing human, financial and intellectual capacity and capital.

I am extremely grateful to all the authors who are leading scientists and engineers from world renowned-international institutions and laboratories. Their invaluable contributions have made this book a worthwhile resource in the domain of scientific and technological research. I must also acknowledge the efforts and dedication of my colleagues, particularly Prof. Dr. M. M. Qurashi and Mr. Irfan Hayee of COMSATS, who made this publication possible.

In the end, I would like to conclude by saying that this book is a humble effort on the part of COMSATS, whereby contributions from a limited number of professionals and experts were sought. However we look forward to and welcome the valuable suggestions and comments from the readers that shall help us bring out even a better publication next time. I hope this book gives you an enlightening experience.

(Dr. Hameed Ahmed Khan, H.I., S.I.)
Executive Director, COMSATS

SECTION A

INTERRELATION BETWEEN BASIC AND APPLIED RESEARCH

CAN APPLIED RESEARCH SURVIVE WITHOUT BASIC RESEARCH?

Riazuddin
National Centre for Physics,
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"The relationship between applied and basic research is that of fish and water. Without water, fish cannot survive. So it is with applied and basic research".

(T.D. Lee)

1. INTRODUCTION

The role of science in development of human society has been crucial. It has not only made an enormous impact on the human intellect, but also changed the living conditions of humanity. It has also given a new conception to man's place in the universe. It is an undeniable reality that scientific and technological development is a prerequisite for socio-economic development, of any society, although it alone does not ensure it. However, it is crucial to make clear that sustainable growth cannot be based on mere transfer of technology. Since scientific inventions keep on changing, the technology these create also change. Unless the underlying scientific knowledge is there, growth cannot be sustained. Abdus Salam stated: "Tomorrow's technology is today's science, so technology transfer, if it is to work in the long term, must be accompanied by science transfer,". Thus a nation must invest for the promotion of basic research to attain real development.

One of the basic instincts of man is the desire to know, to look at the intricacies of nature and try to discover the simple laws that control her process. Ever since his creation, man has done his best to satisfy this instinct. Whenever man discovers something new and solves one riddle, it becomes the starting point for another riddle, making scientific research a living process of investigation, an intellectual adventure and a process of creation. This quest for knowledge has given man the power to drive. Man has increasingly been captivated by the beauty of nature and keeps trying to understand it because 'the end of understanding is enjoyment'. But nature, though simple and perfect, has been very skilful in hiding her secrets under covers of darkness. This romance of nature has given man a purpose, which is to reach the ultimate understanding. It is vague, but it is there. Although nobody knows whether man ever will be able to find the ultimate understanding, but the hope is still there. In fact, this very uncertainty is the source of interest and dynamism in man's quest to discover new boundaries of nature. As a result of this struggle, man has gathered a great treasure of coordinated and organized knowledge about nature. This is called scientific knowledge. Thus our science is a store of knowledge of natural phenomena.

Having defined science as a systematic study of natural phenomena, let us now discuss how this study is done. This study is based on man's power of observation, his ability for generalization, imagination, and ultimately his mind's capacity to evolve concepts, to construct theories to explain the facts he observes, and to predict new things which he then tries to discover. Traditionally this scientific method is based on two steps: theory and experiment, with the newly added third step of mathematical computation. As a result of great advances in computing capacity, the third step allows us to design mathematical models of systems which are too complex to measure or quantify directly, and to answer those questions which were beyond understanding only a few decades ago [1]. There is another related shift towards the systems-approach [2]. Our efforts traditionally have been to dissect complex phenomena into fundamental and elementary components and then try to understand these components one by one. Assumption is then made that once the components are understood, one can easily synthesize the complex phenomena out of these components. This "fundamentalistic" or "reductionist" approach may not be adequate for many systems where the system itself has certain laws of its own, which need to be combined with the component behavior in order to understand the system. Thus, there is a need for more effective methodology, which may be called "systems" approach. There are many examples which would require such an approach viz:

i. *Strongly nonlinear (chaotic) systems;* examples include: e.g. seismic phenomena, the mixing of oceans and atmospheres, which is far more complex than the normal diffusion process, such as the spreading of ink through water [1].
ii. *Complexity in life sciences;* examples include: e.g. attempt to model by computer the cellular systems, where the interactions between molecules in a cell have feedback effects that increase or decrease the expression of other cells. Such efforts have even created a new cross-discipline – bioinformatics. [1]
iii. "*Social sciences*, where the isolation of components continues to be a utopian goal". [2]

The scientific method also provided a powerful tool for technological research. Its impact on technology became clearly visible after this method was introduced in technological research at the turn of the 20th century.

With the growth of scientific knowledge, there has emerged a very important by-product i.e. practical application of known scientific knowledge for the benefit of man. It is here that we classify scientific research into basic and applied research. One can define basic research as an act through which one simply fulfils his instinct to discover something new, to satisfy his curiosity, to get a sense of excitement and satisfaction of accomplishment, without much thought how it will be used. This does not necessarily mean that results will lack utility, but only that the utility is not the primary purpose. Applied research, on the other hand, is there to improve mankind and to provide material benefits to humanity by exploiting the known scientific discoveries or by inventing new ones. As such, it is done with specific goals in mind.

Applied research can be further divided into two types. In the first type we face a practical problem whose solution we understand and where research will usually involve the application of known techniques. But before we devise a method for solution, we may need a lot of data and its analysis. Here we seldom do anything new. We simply apply the known to solve our problem. This kind of research is very often unattractive for a creative mind. In Pakistan, the problem of salinity and water-logging and its related issues come under this type of applied research.

In the second type of applied research, our research is still directed towards the solution of practical problems, but ones the answer of which we do not understand and in which the approaches likely to be successful are yet undefined. In such problems we encounter new fields and new ideas, in fact we really contribute to the scientific knowledge. This kind of applied research is often indistinguishable from basic research, and in any case, requires attitude and training of basic science.

This second kind of applied research, which I would like to call creative applied research, is rather difficult because here the choice of problem for the investigator is limited, while his approach is undefined. We shall come back to this point and discuss how, in many cases, creative research depends on interaction between basic and applied thinking.

2. POSSIBLE CATEGORIZATION OF RESEARCH

i. Basic or Applied Research

This classification may be useful for recognizing limitation of some kinds of research, with respect to expectations which may not be realizable. “Basic research is that which may take longest time to come to a utilizable fruitation, and must be judged by the scientific criteria of conceptual significance and generality. For applied research, one expects a shorter time of payoff but does not necessarily demand generality or high intrinsic interest”[3]. However, in the prevailing conditions, the time between discovery made in basic research and its fruitful technological utilization is now shrinking. This is illustrated by the fact that, while it took nearly 38 years for radio transmission to reach 50 million users after the first radio station in 1920, Personal Computers (PC’s) reached the same number of users in less than 15 years after 1980, and World Wide Web reached that number in less than 5 years after its invention during the 1990s.

Another important point is that, unlike basic research, which is mainly driven by innate curiosity, “applied research is most effective when it is compelled to “market” that provides an automatic measure of effectiveness of the end product of research. The existence of a market gives a continuous incentive for self-appraisal, which is often lacking for activities performed in the public sector” [3]. This is the reason that many research councils, which were created in Pakistan for applied and/or technological research, failed to make an impact. Apart from budget constraints, the basic reason for their failure is that they could not establish themselves as customers to prospective contractors in industry, utilities and government departments. Unless a customer – contractor relationship, which has a built-in accountability process and research support, is established, such public-sector organizations are not going to be successful. "It is probably no accident that, by and large, government-supported research has been most successful in defense, where the government itself is the customer for the end product" [3].This is true even in Pakistan.

ii. Mission-Oriented Research

The mission may refer to an objective defined in intellectual, technical or social terms. We shall discuss how a research, undertaken for a particular objective has gone in many cases much beyond its original motivation and contributed to creative research.

a. Intellectual

A good example is Fermat's last theorem. Piene de Fermat (an amateur mathematician who published no papers), conjectured that no finite number solution exists for:

$$x^n + y^n = z^n, \qquad n = 3,4,5,\ldots\ldots$$

Written in 1637 (when he came across the Pythagorean equation), most of us learn it in school:

$$x^2 + y^2 = z^2$$

Fermat noted that for any exponent – or a power – greater than 2, the equation could not have solutions in whole numbers. This conjecture was proved only in 1993 by Andrew Wiles and depended on fundamental advances in number theory over a period of 350 years, and especially during the last half century [1] when a new branch of mathematics, called algebraic geometry, which found application in String Theory, was developed. This is an example of intellectually challenging problems, which require new ideas and new techniques for their proper solution.

b. Social

This relates to seeking answers to practical questions for improvement of human health, agricultural crops etc. Some examples are as follows: Louis Pasteur was led to fundamental discoveries about basic biology and germ theory of disease by practical questions from medicine, wine making, and agriculture. Gregor Mendel discovered basic laws of genetics by seeking practical answers to improving agricultural crops.

c. Technical and Industrial Needs

A prime example [4] of peacetime need-driven technology is the invention of the transistor which created a revolution in computers and communications. Mervin Kelly, who was Executive Vice President of the Bell Telephone Laboratories (BTL), reached the conclusion that neither mechanical (relay) nor vacuum tube technology could provide for the foreseeable growth in telephone switching-needs and thus recognized the need for low-power, high-speed, compact switching elements. The recognition of this need led to the formation of a Solid State Physics research group at BTL. This led to the invention of the transistor by Bardeen, Brittin and Shokley, and then to the integrated circuits, programmable microprocessor, LSI, VLSI etc. Thus, the semiconductor electronics was built on basic research, but the driving forces for technological development were the needs, as recognized by certain people at BTL. The other example is that of Dr. F.B. Jewett's recognition at AT&T of the need for audio amplification (again for the telephone system) and the awareness of the high potential for satisfying this need with electron beams. Thus was born the so-called high-technology, using atomic particles, so different from the technologies of coal and iron. Moreover, studies of semiconductor devices opened up whole new areas of basic Condensed Matter Physics, e.g. tunnel diode, which probably would not have been otherwise possible.

d. National Security

Historically, national security has played an important role in deriving technology. Just to give one example, the problem of detecting low-flying aircrafts during the second World War led to the invention of Cavity Magnetron by a physicist, not by an electrical engineer; a small device which powered the microwave radar and gave a crucial advantage to British and American forces. Since this device could be installed in aeroplanes, it revolutionized not only the science of warfare but also the civil aviation. Another example is the Manhattan Project for the development of technology of nuclear weapons, where physicists and those trained in basic research, played a crucial role — for good or bad.

iii. Academic Research

Academic research, including both basic research and applicable (rather than applied), is largely done within the framework of graduate education and faculty in various departments of different universities, with little supporting staff. Traditionally, and most of the time it is [3] 'little science", with relatively small infrastructure and low ratio of supporting staff to researchers, which is done in universities. Some universities now also take part in 'big science' carried out in national and international centers like CERN, Geneva. Big science involves expensive, complex and huge infrastructure and equipment, with large supporting staff. Most important examples of big science are high energy physics, space science, astronomy and astrophysics. Big science involves a different culture and ‘team research”. Important spin-offs of big science, which involve some of the most fundamental investigations in astrophysics and cosmology and elementary particle physics, led to technological and large-scale computing developments that have found other uses of social importance, e.g. in medicine (particularly diagnostic and oncology), climate change, and information-technology like the World Wide Web.

Academic research is essential, since a university has to be not only an effective transmitter of knowledge but also a diligent discoverer of new knowledge through research and innovation, and has to remain responsive to societal and technological needs. As such, higher education and research cannot be separated. Higher education cannot sustain itself without research; research cannot survive without higher education. A university has to produce new generations of researchers. For this purpose, academic research needs patronage and financial support from government, industry and endowments created by philanthropists.

3. WHY BASIC RESEARCH IS NECESSARY?

i. Education and Training

We have already discussed the synergy between graduate education and basic research in the previous section. This does not exclude creative applied research as advanced training in engineering, medicine and agriculture. This may be in the form of research apprenticeship. The basic sciences tend to be a net exporter of people into other more applied fields of science or into technology. It is also essential for the existence of an intellectually vibrant society, and to keep the spirit of enquiry alive.

The way of thinking that a scientist learns is supernally powerful: a scientist learns to solve a problem by analyzing it into small bits, taking care of all the important factors in that problem and to attach to each bit its due weight (the so called scientific method). That is how physicists are going into other fields: finance (for risk analysis), computer software, biology and medicine.

ii. Cultural

Some of the conceptual achievements in science serve for ever as a testimonial to the highest intellectual achievement of mankind. Every new discovery in science changes our vision of the world where we live. Pure science is as fundamental to culture as music, literature or art. Presumably, in laboratory courses and in research projects with his teachers, a student can learn the values of honesty, creativity and full disclosure that are hallmarks of good science.

iii. Social

Applications, which result from basic research, can help in finding solutions to many problems which society faces, such as finding new sources of energy, environmental protection, climate change, earthquakes, water resources, national resources, urban transportation, food sufficiency and improving human health.

According to C.P. Snow, "science is more oriented towards the future than most other disciplines, and scientists are animated by a belief that problems are soluble. Such natural optimism, even when unjustified, is an asset in attacking some problems, such as disarmaments, territorial disputes, which have resisted solution for such a long time" [3].

Science cannot flourish in isolation and scientists have to be in an international environment. That is why they can work in every culture and that is why they can be helpful to each other and to decision makers.

iv. Economic

Importance of technological innovation for economic growth is now generally accepted by economists. To an increasing extent such innovation is dependent upon results of basic research, although the degree of this dependence is difficult to quantify. There is no modern industry that not based on atomic physics or chemistry. There are three ways in which basic scientific research can contribute towards technological innovation [4]:

a. Providing a basis for modern technology.
b. Providing a powerful tool, in the form of scientific method.
c. Through the use of scientists in goal-oriented research and technology.

Furthermore, we need to be aware of potentialities for emerging technologies. It must be realized that when the revolution of new technologies, which would govern the minutiae of living and non-living matter (e.g. biotechnology, nano-structures, new materials, quantum information and computing), is on us by 2020, we should be ready for it. This is only possible if we invest in frontier science now, to reap its benefits later.

v. Entrepreneurship

Here we need academic science, because high technology depends on the knowledge, training and culture provided by it. Science develops new tools and softwares in laboratories for its progress, and trains students and technicians to build them. These tools find uses outside, and some young people become entrepreneurs and launch their own craft industries. In turn, these craft industries grow into big enterprises. This cycle is repeated again and again and it is the rapid progress in science that makes it possible [5]. This is how-high tech. industrialization grows. However, such companies grow around big centers of scientific research, for example, Silicon Valley around

Stanford University [5]. But the Third-World Countries do not have big centers of science. So do they have a chance, or they have lost for ever? I think, the answer lies in linkages with big science-centers in industrially advanced countries.

4. UNITY OF SCIENCE

There are various aspects-integration and unification-within one discipline, another is inter-relationship and interdependence between various branches of science. The latter is relatively recent and one already sees a shift towards interdisciplinary research. In fact derivative science and technology, involving many disciplines, is becoming important. One branch of science can make discoveries which can be adapted and/or adopted to solve problems in another area. For example, physics had great success in creating new tools for research, in its own discipline, that had started revolution in astronomy, biology, computer science, communication engineering, and medicine. Some prime examples are [5]:

i. Crick-Watson revolution (1950) resulting from the use of X-ray crystallography to determine the structure of DNA in biology.
ii. Invention of the transistor resulting in the advent of computers and memory-banks in the 1960's. This has a great impact on society. Electronic data-processing and simulation revolutionized every branch of science, increasing the power of scientific theories to interpret and predict new phenomena. Computers, becoming cheaper and smaller, have become personal and are used for a variety of purposes, from toys to highly sophisticated scientific work. They, together with the invention of World Wide Web, developed at CERN for basic research, have revolutionized the communications and the mode of information and finance.
iii. Development of computer-aided axial tomography (CAT) was invented by A.M. Cormack, an accelerator physicist, and got the Nobel Prize in medicine in 1979. Similarly, MRI is based on a purely Quantum mechanical phenomenon, Nuclear Magnetic Resonance. Both the development of CAT and MRI scanning technology were built upon integrated geometry [1].
iv. The generation of codes for secure transmission depends on the arithmetic of prime numbers, while the design of large and efficient networks in telecommunication uses infinite-dimension representation of groups [1], an abstract subject which nobody could have imagined to have practical application.

Finally to bring out an integration of many activities of science with different aims and character, let me quote V. Weisskopf [6]:

> Science contains many activities of different aims and different character: the several basic sciences, with all their variety of approach from cosmology to biology, and the numerous applied sciences that are spreading and involve ever more aspects of human concerns. Science is like a tree, in which the basic sciences make up the trunk, the older ones at the base, the newer, more esoteric ones at the top where growth into new areas takes

place. The branches represent the applied activities. The lower, larger ones correspond to the applied sciences that emerged from older basic sciences; the higher, smaller ones are the outgrowth of more recent basic research. The top of the trunk, the frontier of basic research, has not yet developed any branches.

Applying this picture to the physical sciences, we would locate classical physics, electrodynamics, and thermal physics at the lowest part of the trunk, with broad branches representing the vast applications of these disciplines. Higher up the trunk we would put atomic physics, with well-developed branches, such as, chemistry, materials science, electronics, and optics. Still higher we would find nuclear physics, with its younger branches symbolizing radioactivity, tracer methods, geology, and astrophysical application. At the top, without branches, so far, we would locate modern particle physics and cosmology. There was a time, only sixty years ago, when atomic physics was the branchless top.

All parts and all aspects of science belong together. Science cannot develop unless it is pursued for the sake of pure knowledge and insight. It will not survive unless it is used intensely and wisely for the betterment of humanity and not as an instrument of domination by one group over another. Human existence depends upon compassion and curiosity. Curiosity without compassion is inhuman; compassion without curiosity is ineffectual.

5. CONCLUSIONS

My thesis is that without 'research' one cannot even talk of applied research and it certainly cannot be sustained without basic research. All basic research done so far has either already been applied or will be applied. The time between a scientific discovery and its application in technology, or otherwise, is shrinking, making the distinction between applied and basic research disappear. In the example of tree given by Weisskopf, one has to strengthen the trunk, a weak trunk will not be able to support branches and would collapse under its own weight. Thus, in my opinion, there is no dilemma in basic or applied research: every country, and more so a developing country, has to support basic research. Those societies that do not contribute to basic science are doomed to subjugation. Furthermore, the promotion of basic research is not so expensive. According to V. Weisskopf, "All basic research, from Archimedes to the present, is less than the volume of 12 days of World's industrial production" [6]. There is no other enterprise which has paid so much dividends, with so little investment. Research and Development (R&D)'s spending in industrialized countries is 2 to 2.5 percent of GNP, 10 percent of this spending is on basic research, the same on applied research and twice as much on R&D related "high technology". The rest is on creating infrastructure for research and training, overheads and "low technology". To conclude, developing countries should at least spend 10 percent of the R&D budget on basic and academic research, mainly in universities. If research in universities, whether basic or applicable, is not good, the research outside cannot be any better.

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CREATION & UTILIZATION OF KNOWLEDGE: RELATIVE IMPORTANCE AND INHERENT LIMITATIONS OF DEVELOPING COUNTRIES

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1. INTRODUCTION

A look at the past reveals that creation and dissemination of knowledge, has always been a constant feature of every society, whether modern or traditional, and this trend continues till date. The ability to generate, acquire and appropriately utilize knowledge and ideas by inventing and innovating products, processes and systems, is what puts societies onto the road of socio-economic progress and growth. Knowledge creates the ground for innovations that serve as a means to improving the standards of living and also as a source for transforming the world around them.

The major difference between developed and developing countries today is the amount of knowledge being produced and utilized by both. While the strategy of production of knowledge and knowledge-utilization (technology) has enabled the developed countries to achieve socio-economic development, the developing countries still remain surrounded by lingering shadows of ignorance. It is quite a well-known fact that nations cannot embark upon the path of development, unless they accept to transform themselves into knowledge-based and information-based societies. The 20th century saw the face of many scientific revolutions. Science provided us with remarkable insights into the world we are living in, as well as gave birth to many technologies, which promise to establish and conquer new grounds. Power, development, and enlightenment are closely linked to knowledge and, it is only through knowledge and its fullest use that one can achieve the state of power, development, and enlightenment. Knowledge being the basis for S&T, makes it necessary here to define knowledge and explain some of its important aspects.

2. WHAT IS KNOWLEDGE?

> *"Our knowledge is sobering and boundless, indeed it is precisely the staggering progress of the natural sciences which constantly opens our eyes anew to our ignorance…with each step forward, with each new problem that we solve, we not only discover new and unsolved problems, but we also discover that where we believed that we were standing on firm and safe ground, all things are insecure and in a state of flux."*
>
> (Karl Popper)

‘Knowledge’ like several other concepts is abstract and not easy to define. The definition of knowledge has gone through a transformation over the years and various scholars have defined it differently. The simplest definition is that, ‘what a person understands of something, or the information he/she has about something’. In this sense knowledge is ‘what is known’. How this is known may vary. It may have been known through incidence, experience, or study and research. Information, learning, erudition and lore, are sometimes used interchangeably with the word ‘knowledge’. Knowledge can be a combination of these overlapping terms, however, it is important to make a distinction between each one of them. ‘Information’ is a collection of facts and data, ‘learning’ implies knowledge gained by schooling and study; ‘erudtion’, is used to describe some profound and often specialized knowledge of a particular domain, while ‘lore’ is knowledge that has generally been acquired through tradition or anecdote.

The acquisition of knowledge is composed of a set of complex processes, involving perception, learning, communication, association, and reasoning. The two key characteristics of knowledge, which allow it to revolutionize the world, are its ‘velocity’ and ‘viscosity’. ‘Velocity’ is defined as the speed with which knowledge is spread. It relates to how quickly and widely knowledge is disseminated and is enhanced by the use of technologies, such as Information & Communications Technology. ‘Viscosity’ is the richness or ‘thickness’ of the transferred knowledge, and is enhanced by the richness of the medium through which it travels. ‘Richness’ essentially determines how much of the transferred knowledge has been absorbed and applied. This transference is only possible through a series of lecturing and hands-on experiences, because these are the only ways in which a recipient acquires large amounts of detailed knowledge over time (DFID, 2000).

The following Figure-1 represents the three contexts of knowledge, in general, and scientific knowledge, in particular, namely self, nature, and social.

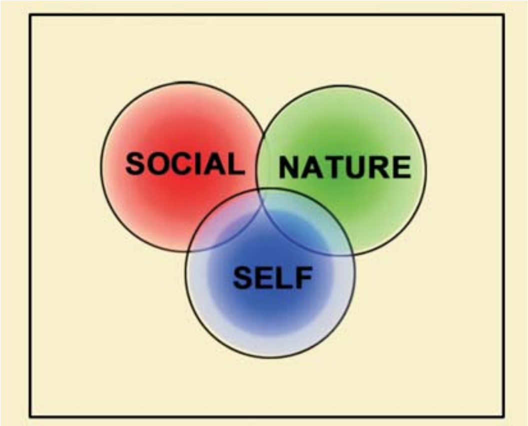


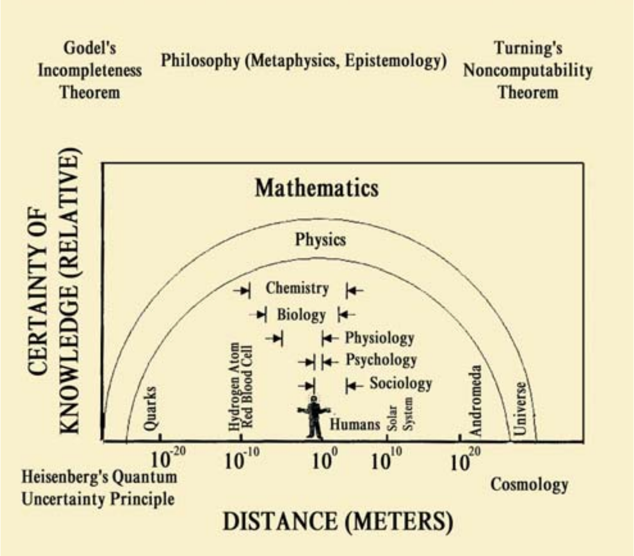
Figure - 1: The Three Worlds of Knowledge

In Figure-1, it is demonstrated that the frontiers of knowledge essentially exist at the boundaries of the worlds of nature, self, and social. These frontiers are also present where each world of knowledge intersects another. Indeed the area where all the three intersect is the most critically important area with regards to knowledge itself (Larry L. Hench).

Limitations of Scientific Knowledge

A particular misconception about science that generally exists in the minds of certain people is that science creates certainty. This is quite an untrue notion, as knowledge is not a limitless phenomenon. On the contrary, it is essentially limited by three key factors, namely distance, time and theory. Figure-2 and Figure-3 depict how time and distance influence the relative certainty of knowledge (Larry L. Hench).

Figure-2 demonstrates the level of certainty of scale, or distance as against the relative certainty of knowledge. This is essentially a hypothetical cross-section of the sphere of knowledge, as against an axis of distance, expressed in meters. This figure essentially illustrates that the level of certainty depends upon knowledge. It says that the level of certainty of the realm of Physics is higher than that of Chemistry, which in turn is greater than that of Biology and Physiology, and so on and so forth. Moreover, the certainty of knowledge of the behavior of very large systems is limited. Although the behavior of individual atoms is not certain, thermodynamic quantities can be defined which are certain.



Source: *Larry L. Hench, "Science, Faith and Ethics", Imperial College Press*

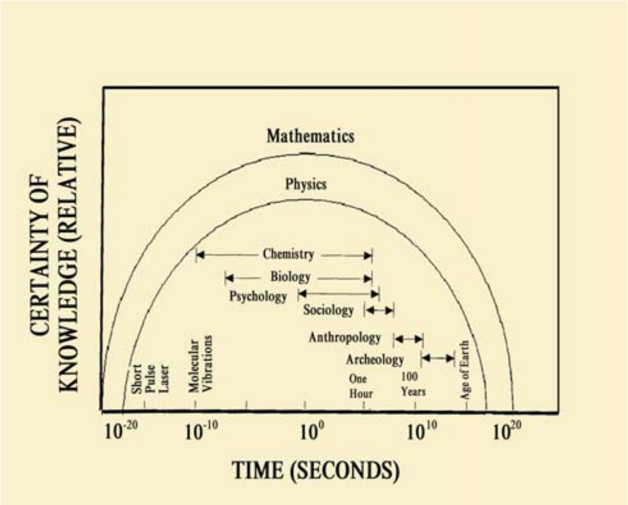
Figure -2: Limits of Knowledge: Effects of Scale

The study of the nature of knowledge, which is called epistemology, further exemplifies the fact that that there is a theoretical limit on certainty of what we know or can possibly know. The problem essentially lies in the process of defining the criterion for judging the truth and falseness of the manifestation of things.

Figure-3 essentially illustrates the effect of time on the certainty of knowledge (Larry L. Hench). It demonstrates that when the duration of time is in the scale of man's general perception, i.e. in seconds, minutes and hours, the certainty of both observation and knowledge is high. But, in view of the circumstances when we extrapolate backwards in time, i.e. the sphere of historians, archaeologists, geologists, etc, the level of certainty of knowledge decreases with the number of years of extrapolation.

A fascinating aspect of time itself is mankind's capability to extrapolate backwards and forwards. Cosmologists freely predict physical events in time backwards by 10^{17} seconds and forwards by equally sizeable increments. As per the figure, the level of certainty of these extrapolations is very low. According to Hawking, time doesn't exist as a fundamental property of the universe. He says that we experience only transitory moments called 'nows'. Indeed, our brains incorporate the immediate 'nows' into what we assume as a continuous and non-stop flow of time, it on the contrary is just an illusion.

As a final thought, it can be said that there are essentially three limits on comprehending the universal nature of things. First, we must not put our trust in knowledge so much that we forget mortality. Secondly, we must always apply knowledge to achieve that which is good, rather than that which is not. And lastly, we



Source: *Larry L. Hench, "Science, Faith and Ethics", Imperial College Press*

Figure -3: Limits of Knowledge: Effects of Time

must not presume to attain the mysteries of God by studying nature itself.

3. IMPORTANCE OF KNOWLEDGE AS AN ECONOMIC GOOD

> *'He who receives an idea from me receives instruction himself without lessening mine; as he who lights his taper at mine receives light without darkening me'*
>
> (Thomas Jefferson)

Thomas Jefferson has pointed out one of the most important and fundamental traits of knowledge – the fact that knowledge is the only resource that does not deplete upon sharing and in effect has the potential to further enrich once shared. Unlike other factors of production, such as capital and labour, knowledge strives to be a non-rivalrous public good. In pure economic terms, once knowledge is discovered and made public, the marginal cost of sharing it with others is zero. Although patents, copyright, and trademarks are barriers to knowledge-sharing, most knowledge is readily available to a large group of users. It is common knowledge today that disparities in the productivity and growth of different countries have less to do with their lack or abundance of natural resources than with their ability to improve their quality of human resources and other factors of production. The World Development Report 1999 states:

> *'For countries in the vanguard of the world economy,the balance between knowledge and resources has shifted so far towards the former that knowledge has become perhaps the most important factor determining the standard of living – more than land, than tools, than labor'.*

4. SCIENCE AS A FORM OF KNOWLEDGE

Having defined knowledge, it is important to mention that science does not constitute the only form of knowledge as such. Science is linked to certain other forms and systems of knowledge. The word 'science' comes from the Latin word meaning 'knowledge'and we generally refer to science as the knowledge that man has accumulated as a result of his quest to understand the world. Science uses observations and expermentations to investigate various phenomena, and to gain knowledge about events in nature. The methods of obtaining this knowledge have been constantly changing and improving, and have been made more objective and reliable over time. Thus, science as it is perceived by all is the body of truth, information, and principles acquired by man through constant learning and investigations. Another way to put it is that science includes processes and a body of knowledge that involves conceptual understanding. Processes are the ways scientists investigate and communicate about the natural world, whereas the body of knowledge includes concepts, principles, facts, laws, and theories. As Einstein rightly said,

> *"The whole of science is nothing but a refinement of everyday life".*

Science and technology are connected. Technological problems create a demand for scientific knowledge and modern technologies make it possible to discover new scientific knowledge. Generally used as a single term, S&T are two different yet overlapping phenomenon. Technology is derived from the Greek word meaning 'art or skill'. It is the application of science that helps us to better adapt to the environment by finding solutions to our problems. The main aim of technology has usually been the achievement of objectives, which are particularly industrial or commercial in nature.

As is commonly known and understood; the end-product of a scientific endeavor is knowledge, both in terms of the scientific papers and related literature. This produce of science is a public good, which is utilized in a fashion of mutual sharing that most certainly implies that "more for one" does not translate into "less for another". All in all, the entire human race benefits from the findings of scientific discovery, without having to pay an extra penny. Given the noteworthy advances in the realms of science-based technology, one cannot help but note that the human adjustment to his habitat, to his preferences, is as constrained as is his understanding and knowledge of physical reality through science.

5. ROLE AND IMPORTANCE OF S&T IN HUMAN DEVELOPMENT

S&T being the outcomes of extensive basic research (knowledge) and applied research (innovation), it seems appropriate here to highlight their importance and dynamic role in shaping human life. Advances in S&T are fascinating and have done wonders for humanity. The contributions of scientific knowledge, and the use of appropriate technologies in the development of modern societies, has made S&T indispensable tools for development.

Science & Technology, together have enabled mankind to overcome, or at the very least, reduce, critical problems like food-insecurity, water-scarcity, environmental degradation, poverty-eradication, and elimination of diseases, to name only a few. In short, the outlook of societies, cultures, nations, economies, environment, and above all life, has been significantly altered by this knowledge.

The continuously increasing need for scientific knowledge in public and private decision-making, including the significant role of science in the formulation of policy and regulatory decisions, has been adequately emphasized and ascertained. It is also agreed and understood that scientific research has always been a major driving force behind progressive development for the betterment of mankind and, that greater use of scientific knowledge is a must for securing our future. The relationship between science and technology has been described by some as mutually dependent. Technology is said to be the mother and the daughter of science. Independent of the proper description of their relationship, there is a mutual debt and feedback between the two that grows with time. As mentioned earlier, one must realize that the road from science to new technologies is not a straight highway, but a kind of spiral of science, enabling new technologies that, in turn, allow new science that again creates new technologies and so forth (Christophorou L.G., 2001; F.N. Magill, 1990).

6. SCIENTIFIC RESEARCH & IT'S SIGNIFICANCE

> *"The process of scientific discovery is, in effect, a continual flight from wonder"*
>
> (Albert Einstein)

The significance of scientific research for the rapid growth of scientific knowledge and emerging technologies is acknowledged by all. The importance of scientific research and the role of S&T in promoting sustainable development, and in transforming our society is a matter that needs no mention. The information-age, in which we are living today, is a result of the breakthroughs in fields of computer- science and communications science.

Scientific research has continuously kept on increasing our knowledge and understanding of worldly phenomenon, inspite of the changes occurring in patterns of sustainable development. Scientific research is the principal tool for human-beings to explore and make use of nature for improving the quality of life. In this context, the emphasis is mainly on two major forms of research, i.e. basic and applied. Although many developed countries are struggling to conquer new arenas of knowledge through scientific research; both basic and applied, yet, in the developing countries this still remains an unaccomplished task. All major forms of scientific research can be broadly categorized as either need-oriented research or curiosity–driven research. Applied research, mssion-oriented research, problem-oriented research, and industrial research can all be termed as need-oriented research, while basic research is essentially driven by curiosity. It is pertinent here to briefly describe these forms of research:

i. Basic Research
ii. Applied Research
iii. Mission-Oriented Research
iv. Problem-Oriented Research
v. Industrial Research

6.1 Basic Research

This is usually termed as 'mother of all inventions', since it provides the required 'scientific capital' for new scientific knowledge and understanding needed for technological breakthroughs. The most commonly accepted definition of basic research (also known as pure or fundamental research), is that it is motivated by a researcher's curiosity or interests in a scientific question. The main motivation is to expand man's knowledge, rather than to create or invent something particular. In other words, it is scientific research conducted without any immediate practical ends in mind. The characteristics of this type of research are:

- It cannot be easily defined operationally.
- It cannot be tested in advance for utility.
- The process of innovation is interwoven with the production of new knowledge.

Some typical questions, which basic research tries to answer, include:

- How did the universe begin?
- What are protons, neutrons, and electrons composed of?
- How do slime molds reproduce?
- What is the specific genetic code of the human-being? (LBNL,Online)

Basic research is that component of knowledge, which does not involve any immediate or foreseen commercialization or commercial viability. The ultimate objective is, therefore, not to serve any pressing need or attend to a current problem, but to aim at discovering knowledge with a universal perspective and a broader horizon. This trait of basic research allows many an invention and technologies to stem from the accumulated reservoir of knowledge built through continued basic research. Informational input attained from conducting basic research is the essence for instigating inventive activities. More specifically, answers to scientific questions are the building blocks for technological innovation and further scientific development, and basic research undoubtedly is the essential means of gathering such answers. Christof Lichtenberg's comment, which he wrote in his diary about 200 years ago, firmly establishes the importance of basic research:

> "To inven*t an infallible remedy against toothache, which would take it away in a moment, might be as valuable as and more than to discover a new planet... but I do not know how to start the diary of this year with a more important topic than the news of the new planet*".

Common examples of basic research include: research on the chemical properties of bacteria, analysis of the interaction of the oceans with the atmosphere, and investigation of neural pathways in the human brain (AAU, 2002). Other examples of basic research include: the understanding of how a protein folds, or how a specific molecule elicits a particular biological response.

Careful studies indicate that basic research serves as a foundation of modern technology. The following important contributions in this regard are worth noting:

1. It provides the required basic knowledge, or acts as a "Scientific Capital" necessary for making the application a reality. It is firmly believed that industrial development would eventually stagnate, in the absence of the supporting basic research. This stage is felt only when the "Scientific Capital" runs out.
2. Broad-based basic research is a prerequisite for solutions to various problems. Solutions are not forced or obtained abruptly. They are preceded by necessary knowledge, often obtained by basic research.

3. Basic research provides the foundation of education and basis of training the people working in industry and technological setups.
4. It cultivates scientific climate conducive to understanding the objectives of technology.
5. Basic research serves as a source of intellectual standards for applied research.
6. It is the net exporter of techniques to industry. Techniques such as, vacuum technology, cryogenics, X-ray diffraction, radioisotopes, with their origin as techniques of basic research, are commonly used in industry these days.
7. Basic research, therefore, must not be taken as a peripheral activity or be forced to provide short-term solutions under excessive pressure and/or limited support.

The Unpredictable Nature of Basic Research: Christophorou L.G (2001), Braben D (1994), Ziman (1976), while talking about basic research, argue that the nature of basic research is highly unpredictable. As discussed earlier, the results of most of the basic research- work contained unexpected practical applications in store. Such is the uncertain future-impact of basic research-work that some entirely wrong predictions were made regarding their practical utilization. History of scientific research contains a number of such instances.

Conversion of Basic Research into Industrial Applications: It is interesting to note that some applied form of research (the products that are developed), can somehow be linked to the fundamental research. Examples can be given in this regard: the transistor was developed as a result of research in condensed matter physics, and Magnetic Resource Imaging technology was developed due to investigations in nuclear magnetic moments. More recently, Frances W. Clarke of the U.S. Geological Survey, in a speech also protested that:

> "*Every true investigator in the domain of pure science is met with monotonously recurrent questions as to the practical purport of his studies; and rarely can he find an answer expressible in terms of commerce. If utility is not immediately in sight, he is pitied as a dreamer, or blamed as a spendthrift*."

The return on investment in basic research is not often so immediate. However, over the long term, it can impact substantially, and often as least expected. Indeed, investment in basic research produces a multifarious payback, a clear example of which is the creation of an entire new economy, based on information-technology (Birgeneau, 2001).

Some of the contributions of basic research in Physics, which have led to its industrial applications, include the following:

- Improvement in accuracy of data and its processing.
- Miniaturization of physical and chemical servicing-devices in health care.
- Real-time imaging and analysis.
- Designing and development of lighter and more robust devices.

- Developments of in-vivo robotic systems, tools for endoscopic surgery and intelligent implants.
- Physics-based surface-engineering in clinical advances (i.e. use of plasmas to improve artificial body parts).
- To reduce the prices, where possible.

The following examples of basic research contributing to the study and understanding of one of the world's most frightening threats, AIDS, are still true and important to further improvement in the knowledge of this area (The Scientist, June 28, 1993, p.7):

- Biologists studying the structure of CD4 (a protein embedded in the cell surface of helper T-lymphocytes) found that HIV invades cells by first attaching to the CD4 molecule (CD4 receptor)
- Immunologists asking basic questions about T-cells (also known as T lymphocytes; a thymus-derived white blood-cell that participates in a variety of cell-mediated immune reactions)
- Geneticists manipulating genes that the virus uses to replicate
- Scientists conducting basic research in the molecular structure of the virus
- Virologists conducting basic research in the genetics of the virus (NCABR, 1998).

The importance of basic research to the control of imminent and re-emerging diseases cannot be over emphasized. Research on emerging diseases, encompasses and engulfs many disciplines, fields and research advances that fall under it; the research will be pertinent not only to specific diseases being studied, but also to a wide array of disciplines, such as vaccinology, immunology, and drug development. Subsequently, research in these areas is crucial to advances in emerging and re-emerging diseases (Fauci, 1998).

Another example, that of Laser-based Technology, is of scientific knowledge lying dormant until scientific advances in neighboring areas and technological needs in neighboring fields made its development inevitable. The name LASER is an acronym for Light Amplification by the Stimulated Emission of Radiation. Indeed, the process of stimulated emission of radiation had been shown to be possible in 1917 by Einstein and thus, since that time, light amplification and the invention of the laser were in principle possible (Bellis [online]). The laser however, was not invented until after WW-II when, as a result of the development of radar, during World War-II and the extension of that work to higher microwave-frequencies, conditions were explored under which laser action can be achieved. Thus, in the early 1950's came the invention of the MASER (Microwave Amplification by Stimulated Emission of Radiation) and in the late 1950's the extension of maser principles to the optical region of the electromagnetic spectrum. By 1960, a number of groups were investigating systems that might work as the basis for the optical maser or laser.

Today, materials for lasers are many and include gases, liquids and solids. Lasers come in many varieties, power levels, wavelengths (infrared, visible, ultraviolet, and possibly also X-ray), and types (continuous or pulsed). In layman's term, lasers are currently being used in daily examples, such as to cut precise patterns in glass and metal and to reshape corneas to correct poor vision. They are also being used in supermarket checkout lines, CD players, and for the transmission of most telephone signals. Among other utilities, they are also used in scientific experiments, to provide intense heat in controlled fusion experiments.

Lasers led to new technology which, in turn, facilitated new science, which again led to new technology and yet again to new science—a continuous interplay that is still unfolding. High-quality lasers and hardware can now be purchased readily, enabling laser-based technology to be used in virtually everything; industry (e.g., cutting, welding), communications (e.g., via satellite, fiber optic, or laser printing), weapons (e.g., directed energy weapons), information storage (laser recording, optical disk storage), remote sensing, and so on.

Laser-based technologies are also used in microstructure engineering, microfabrication, semiconductor processing, material deposition and etching, and a host of methods for altering the morphology of a solid-surface, with special resolution, down to the nanometer scale. Very high-power lasers have a potential application in fusion-energy sources, and short-duration laser-pulses are basic to man's ability to modify and/or switch material properties.

6.2 Applied Research

Applied research is directed at finding solutions to the practical problems of the modern world, rather than to just acquire knowledge for the sake of knowledge. The focus of applied research is on pre-determined outcomes, i.e., to solve problems, to make decisions and to predict and/or control. It is primarily carried out to use findings of basic research to uncover practical ways benefiting human-beings and society.

Applied research is aimed at gaining the knowledge or understanding to meet a specific & identified need, or solve a particular problem. It includes investigations oriented to discovering new scientific knowledge that has specific objectives, with respect to systems, products, processes, or services. Finding a better treatment or diagnostic for a disease is an example of applied research.

The three predominant characteristics of applied research are:

- Generation of knowledge that will influence or improve application, e.g., clinical practice
- Potential for contributing to theory development, and that the
- Researcher has access/control over phenomena being studied

Applied research is carried out to find practical solutions for current pressing needs. In essence, the problems of the society in general, and the industry in particular, are assessed and addressed by applied research, which results in the improvement of a product or a system.

This research is primarily done because the performer "expects to benefit from it in some direct way, such as through a future business return or a direct financial interest" (Lukasik, 2000).

In other words, applied research is work that translates into products, goods, or services, that contribute to the GNP. It is the investigation of some phenomenon to discover whether its properties are appropriate to a specific need or want. It aims to answer real-world problems and not just abstract or theoretical ones. It focuses on solving problems, evaluating projects, and making policy or managerial decisions, and plan and forecast. All in all applied research is that kind of activity whose informational output is an input in productive commodities. General examples of applied research would include using bacteria to inoculate plants against particular diseases, developing computer models of the atmosphere to improve weather forecasting, and creating drug therapies for brain- related illnesses (AAU, 2002).

Applied research is an original research just like basic research, but is driven by very specific, practical objectives. Examples are all researches for the formulation of public policy (on education, health, economic, environmental, etc); research into how industrial development can take place with simultaneous protection of the environment; research into the provision of adequate, cheap housing; and research around finding cures for diseases.

6.3 Mission-Oriented Research

Weinberg A.M (1967), states that, mission-oriented research is simply defined as "a broad-based research, carried out in support of a particular mission or the achievement of a certain technological goal". The 'mission' or the 'technological goal' could be any broad-based programme aimed at the developmental work, for a certain scientific system or establishment of a proper infrastructure/ know-how, necessary to make the project 'Critical' and workable for the aim with which it was initially started. It may consist of different combinations/phases of "basic" and "applied" research project/sub-projects. Some examples of "mission-oriented research" are:

1. Development and establishment of nuclear-energy programme
2. Research leading to the development of radar system, missile programme, space exploration, etc.
3. Research aimed at:
    - Development of X-ray lasers.
    - Understanding the effects of radiation on matter.
    - Development of a cure for cancer, aids, etc.; &

- Controlled Fusion/thermonuclear reactions.

Mission-oriented research focuses on developing new knowledge of direct relevance. It is interesting to note that Mission-oriented research does not deal with only applied research, but has also greatly contributed in the advancement of basic research, with the development of new gadgetry helpful for the generation of new and high-level basic knowledge. Some of the relevant examples are:

i. Basic research in superconductivity greatly benefited from the programme carried out for the development/advancement of new energy sources.
ii. The Space-programme helped (and vice versa) in securing handsome government grants for the advancement of atomic and molecular physics.
iii. Basic research in atomic & molecular radiation, and radiological physics, for example, draw valuable support from Organizations carrying out extensive research/programmes in studying the effects of different types of radiations on living cells.

It is, thus, clear that in Mission-Oriented research, the benefit is mutual, i.e. the applied and basic research help each other. Experience shows that this mutual benefit was a maximum when the interpretation of "Mission Relatedness" of "basic research was not narrowly defined".

6.4 Problem-Oriented Research

Christophorou L.G (2001), states that problem-oriented research is simply defined as 'research work carried out to solve a specific problem arising during a certain research programme'. This is a relatively narrow research activity aimed at some difficulty or hurdle faced during a broad research-activity. It can also be aimed at resolving certain technical fixes. In certain cases, it may be carried out to find a quick / immediate (on relative time-scale) solution to meet certain societal needs. Some specific examples may be as follows:

- Problems relating to public health, pollution, etc.; other immediate community related problems, such as water, energy, transportation, & waste disposal.
- Suitable replacement of useful but hazardous materials – such as PCBs (polychlorinated biphenyls), CFCs (chlorofluorocarbons), etc.

Problem-oriented research is primarily concerned with current issues and problems, as well as the relevant social actors and stakeholders. The primary objective of this type of research is to analyze perceptions of the problems at hand, related models for action and means of knowledge and then to transform these into scientific questions and research-strategies. This research claims to bridge the gap between natural sciences, humanities and social sciences, and uses the impetus on predicaments to reach interdisciplinary and/or transdisciplinary approaches. The fundamental goal is to amalgamate scientific analysis with action, keeping in mind the interests of societal decision-makers and stakeholders (ITAS, 2000).

To achieve the goal of problem-oriented research, the scientific, technical and sociological theories, methodologies and data must be systematically interlinked with the visions of sustainable development or recycling economy, or more specifically visions of a technological nature or those related to ethical standards. By doing this, problem-oriented research focuses more on the relationship between normative determinations and empirical analysis of results. What lies at the heart of problem-oriented research, is essentially the integration of social reflection and the dynamism of scientific knowledge into decision-maker's strategies for action (ITAS, 2000).

6.5 Industrial Research

Schon D.A (1971), states that scientific discoveries coupled with technological developments enable the industrial sector to convert the new knowledge, so gained, to practical applications in an effective manner. Such a conversion of new knowledge into industrial products should preferably take place as early as possible, if an effective edge over other competing industrial set-ups is to be achieved. In addition to this, industry carries out its own research-programme. This research, carried out by industry, under its own programme, is generally known as Industrial Research.

Industrial research predates invention, involves highly knowledgeable men of vision and is aimed at obtaining knowledge and new ways that facilitate the emergence of new technology. It is, therefore, clear that it is extremely important to get new and good ideas, which enable the industry to: (a) improve the quality and usefulness of its products, and (b) make them relatively more durable and inexpensive. It clearly indicates that many industrial set-ups are well aware of the importance of new/basic knowledge, because it acts as the seed for obtaining a better and more efficient product, which will ultimately result in increased profit and more financial gains for the industry concerned.

Experience shows that there seem to exist (a) "time continuums" from fundamental knowledge to usable/marketable industrial products, and (b) "diffusion time", a period necessary for the diffusion of "technological innovations". It is interesting to note that both of these durations seem to be getting shorter and shorter with the passage of time. Superconductivity is also one such area for which Theodore H. Geballe said:

"It took half a century to understand Kamerlingh Onne's discovery, and another quarter to make it useful. Presumably, we wont have to wait that long to make practical use of the new high-temperature superconductors."

7. IMPORTANCE OF RESEARCH-BASED KNOWLEDGE

The relative importance of 'basic' and 'applied' research has been a widely discussed topic for quite some time now. There is still little consensus among scientists and philosophers as to which of the two types of research is more significant than the other, in this rapidly changing scenario. It is important to note that applied research does not always follow basic research, as it is generally believed. There is a common misconception that basic research is supposed to lead to applied research, which in turn leads to industrial development, and then to products. While there are many cases in which this has happened, it is also easy to find examples of advances in technology which have led to advances in basic science, such as that given by George Porter (Nobel Laureate in Chemistry) who pointed out that:

"*Thermodynamics owes more to the steam engine than the steam engine owes to science*".

Similarly the development of large Radar Antennas for applied purposes, led to basic research in Radar Science and Radio Astronomy or the case of the development of pure materials for technological applications, which stimulated fundamental investigations in Solid State Physics. To put it simply, basic and applied research is not a one way process, where one follows the other. Instead basic and applied research is a mutual process where not only basic research leads to applied research, but also sometimes advances in applied research might give way to pure and basic research. Although basic research and applied research are closely interlinked, they have a different orientation from each other. What is important is the way basic research directs and supports applied research that determines the necessity and usefulness of both kinds of research. J.J. Thomson - the discoverer of the electron - in a speech delivered in 1916 differentiated between basic and applied science as follows:

> "*By research in pure science I mean research made without any idea of application to industrial matters but solely with the view of extending our knowledge of the Laws of Nature. I will give just one example of the "utility" of this kind of research, one that has been brought into great prominence by the War - I mean the use of X-rays in surgery...*
>
> *Now how was this method discovered? It was not the result of a research in applied science starting to find an improved method of locating bullet wounds. This might have led to improved probes, but we cannot imagine it leading to the discovery of the X-rays. No, this method is due to an investigation in pure science, made with the object of discovering what is the nature of Electricity*."..
> *pg 198 (Lord, 1942)*

As mentioned earlier, applied research is aimed at gaining knowledge or understanding to meet a specific, recognized need, or to solve a specific problem. It includes investigations oriented to discovering new scientific knowledge that has specific objectives. Recently many of the modern scientists have been arguing about the viability, significance and importance of applied research over basic research. Their arguments are supported by the assertion that global overpopulation, pollution, and the overuse of natural resources, is consistently generating complex problems for the human race, and the focus should be on the type of science that can improve the human conditions by providing practical solutions to their problems, rather than indulging in knowledge-seeking activities only, which have no immediate direction in sight. The process of applied research is usually spread over a large span of time and, normally a large number of people are involved in attaining the invention stage. History contains several examples, where applied research has had a major impact on our daily lives. In many cases, the application was derived long before scientists had a good, basic understanding of the underlying science. This fact is clearly illustrated by envisioning a scientist saying to himself, ”I know it works; I just don’t know how it works!”

Inventions such as that of the transistor was also a revolutionary application of scientific research and proved to be a major milestone for the electronics industry all over the world. It proved to be a starting point for the design and manufacture of integrated circuits (ICs). Previously vacuum tubes were used as the only means (as triodes) in electrical devices (Bindloss, 2003).

It must be kept in mind that applied and basic research both go hand in hand. Niether can be left behind during the process of development. There are some examples in the recent past, where some nations of the world have supported applied research and product development against basic research, and have usually left the production of knowledge through basic research, to other nations of the world. This thought might seem quite effective at first, but the results in the long-run are not very promising. The fact that results of basic research are unpredictable does not mean that economic incentives to find solutions to specific applied problems are futile. But it is important to understand when such incentives are likely to be effective and when they are not. A comparison between economies of Japan and USA in the last two decades is an interesting case in question.

Wong (1996), in his work ‘An Economic Case for Basic Research’, writes that during the 1980s when many science-based markets were lost to Japan, especially in the USA, including very sophisticated areas such as dynamic random access memory, the question was raised whether the US semi-conductor industry could survive at all. Japan (together with Singapore, Hong Kong, and South Korea) was often quoted as a country that had been very successful economically, and captured science-based markets, since it had supported applied research and product development rather than basic research. The US semi-conductor industry did not die out completely, but while critics were predicting its downfall, US researchers were involved in creating revolutionary new markets in biotechnology, multimedia, computer software and digital communications, etc. Meanwhile the Japanese economy has, of course, been in relative decline since 1989. In any case the Japanese Government has no wish to leave basic research to others, and the Science and Technology Basic Plan, published in 1996, foresees a 50% increase in science funding in five years (although the initial rate of increase has not been maintained). Furthermore, earlier arguments based on comparative levels of investment in R & D as a percentage of GDP in the USA and Japan has been re-examined. Data had been used to argue that the larger Japanese investment in applied research and technology was the origin of Japan's economic success in the 1980s. However, the figures for overall non-residential capital investment as a percentage of GDP suggested a different conclusion. The factors that fuel economic growth are the supply of labor and capital. Labor markets having been stable, growth might be expected to be proportional to total investment, and therefore on the basis of these figures some one-and-a-half times higher in Japan than in the USA. In fact, however, sustainable growth is estimated to be 3% in Japan compared to 2.5% in the USA. It, therefore, seems that the Japanese economy is considerably less efficient than the US economy (similarly in Singapore, for example, growth has been three times that in the USA, but investment has been four or five times as large). Reversing the traditional arguments, it has even been suggested that the relative inefficiency of the Japanese economy is due to the facts that there is less emphasis on basic research, and that the universities in Japan are weaker than in the USA. Basic and applied researches are both significant, and neither can be underestimated in its approach and scope. Having said that, we are faced by an important dilemma of prioritizing one type of research over the other. In view of the changing global scenario and increasing number of problems, for both developing and developed countries alike, the focus gradually started shifting from purely basic research towards applied research for achieving immediate results. This trend, it is believed, is forced by the problems resulting from issues such as global overpopulation, pollution, and the overuse of the earth's natural resources. Some basic scientific research probably has no practical value other than "knowledge for knowledge's sake". In such a case it is not advisable for developing countries to spend millions of dollars on conducting research that apparently has no practical value. There is still lack of sufficient evidence to support the unusual assumption that de-emphasizing basic research would be a wise policy for development. However, the fact is that a shift in emphasis away from purely one type of research; either basic or applied, towards a more balanced approach which effectively combines both types of researches, is the need of the hour. The growing importance of applied research cannot be ignored, but at the same time the importance of basic research for the establishment of a powerful science-base can also not be denied; rather a ‘balanced’ approach is required which effectively creates the required knowledge and utilizes it in an appropriate way.

However, this is not possible unless the importance and utility of both types of research is duly recognized by the government, academia, and industry; each has to determine its appropriate role in basic and applied research. This is especially true for developing countries. Although developing countries are moving on a track of achieving industrialization that is being led by the progress in fields of basic and applied research, yet their efforts are not fully capable of bringing about the desired results, due to lack of a strategic approach towards basic and applied research. The role of all three pillars of society government, academia, and the industry is critical for recognizing the importance of knowledge-creation and knowledge-utilization. Each of these institutions, has to identify and perform its proper role.

8. BASIC & APPLIED RESEARCH IN DEVELOPING COUNTRIES: ROLE OF GOVERNMENT, ACADEMIA, AND INDUSTRY

The increasing gap between the socio-economic development of developed countries and most developing countries can be attributed to a number of factors. One of these factors is the extremely important role of scientific (basic) and technological (applied) research which cannot be overlooked. It is no hidden fact that the developed countries of the world have been investing substantial funds and resources for scientific research and development, which has resulted in their current economic strength. Unfortunately, this trend has been missing in the case of developing countries. A good sign, however, is that there now is an increasing awareness, amongst the experts in these countries that scientific and technological research has an extremely important bearing on the sustainability of programmes and policies at the national and international levels. As mentioned earlier, the role of government, academia and the industry, in the developing countries, is critical in this regard. Each of these institutions has to identify and perform its due role. In the current global context, which is characterized by rapid technological changes, innovations and ever-growing industrial applications, lack of attention towards basic and applied research and the maintenance of an optimal balance between both types of researches, is placing a negative impact on the growth and development of the developing countries, and can continue to do so in future if appropriate measures are not undertaken by these countries in a timely manner.

Science & Technology cannot actually contribute to the success of any form of sustainable development without basic scientific and technological capacity. This much needed S&T capacity comes from extensive basic and applied research. It is only through basic and applied research that understanding of complex systems is developed, disciplinary research takes place, ambiguities and uncertainties are removed, integration of knowledge across fields becomes possible, and eventually the capacity for technological innovation is built that is diffused within both the private and public sectors. Shortage of S&T resources in developing countries has always hindered progress in research & development. The need is to organize appropriate R&D programmes, as well as to start new programmes in order to cope with the changing requirements.

8.1. Basic Research as the Primary Focus: Basic research should be supported by governments, as their first priority compared to funding of applied research, and developing countries should not leave this task for others to carry out. Knowledge, which will be produced by academia, will eventually lead to its industrial applications. Any new innovation will not be successful until it has a solid ground, based on scientific knowledge. The simple fact is that applications of scientific knowledge within any society would be much more effective when made on the basis of knowledge rooted within that specific context rather than on the knowledge-base of another society. However; this does not mean that applied research should not be supported at all. As stated earlier basic and applied researches have to go on simultaneously because neither can exist without the other.

The first important step for all is to realize that an active basic research-base sustains and fosters technological development. Basic research is very important for developing countries that are still struggling to achieve economic stability. Yet for them this task is not easy to carry out due to lack of R&D capacity and lack of expertise. Any little basic research which is being produced by these countries in the face of their meager resources is not of great value and is usually placed at sub-critical levels. Universities and academic institutions have to redefine their traditional roles by promoting sustainable basic research, in order to protect the sustainable progress of basic research. Further more the standard of universities and academic institutions should be raised to such a level where these institutions become capable of pursuing intellectual goals and conducting quality research.

8.2. Funding and Support for Research: It is a widely accepted fact that the capacity of many developing countries, including Pakistan, to carry out basic and applied research, is limited and evidence shows that very little work is done in the industry or the nations' universities, and research and academic institutions. This has been generally due to the lack of support from the industries and governments. As a result, most of these institutions lack the required capacity to conduct and engage in advanced basic or applied research and other critical activities required for supporting the development of a globally competitive information, knowledge-based, and high-tech societies. Not only governments but also industries should bear the responsibility of supporting basic research, since their technological advancements are often the result of someone else's basic work. Since the final outcomes of any type of research are extended over a long period of time, therefore industries or the private sectors are least likely to invest in such long-term research activities. Meanwhile the governments should know when and how to support the need-oriented research activity. Since the outcomes of scientific research are too long-term, therefore, private investments particularly in basic research in the areas beneficial to society are least likely. Therefore, governments in most cases, become the sole bearers of the responsibility of funding and supporting basic and applied research.

On the part of the governments, it is required that governments show more commitment in promoting and supporting R&D initiatives to enhance their respective country's capacity to develop and produce a knowledge-based economy. Government should also make best use of ICT products as well as services, as a step towards developing a globally competitive nation. Strong support is required for academic institutions -- universities, R&D institutions, and national laboratories -- as a part of a nation's S&T infrastructure. Governments at the appropriate level should take necessary steps to promote a balanced and effective approach towards basic and applied research with the assistance of international and regional organizations as well as non-governmental organizations, the private sector, academic and scientific institutions,. Once this is done, then steps for improving research activities can be taken by acknowledging the extremely important role of research in training scientists experts, who may later contribute to the industry. Secondly, by enhancing geographical proximity of research centers, an added advantage can be achieved that would be in the form of exploitation of their production and outcomes.

In Pakistan, the R&D Fund is a part of the commitment to meet the needs for sustainable growth in the ICT-sector of Pakistan. The Fund would be the first independently managed organization that would play an instrumental role in the enhancement of R&D culture in Pakistan. The R&D Fund Policy Framework sets out a road map for the development of Pakistan's ICT industry. The development of this policy framework was based on a nation-wide consultative process, involving all key stakeholders in public and private sector and from both industry and academia. The major objectives of various research councils and institutes established by the Ministry of Science and Technology of Pakistan are to conduct R&D work on problems faced by the industrial sector; goal-oriented or applied research, research in the areas of molecular biology; to provide better health to citizens through research in areas of water management and quality of water resources; to maintain linkages through seminars, workshops, publications; to undertake cooperative research with local and foreign R&D organizations and commerce-industrial outfits on projects of national interest; to establish comprehensive scientific and technological information-dissemination centers and promote basic and fundamental research in the universities and other institutions. (National ICT R&D Fund Policy Framework-Ministry of Information Technology IT & Telecom Division Government of Pakistan, pg 6)

8.3 Establishment of University-Industry Collaboration: Another very important aspect is to create the required synergies between industry and the research institutions that are necessary for commercially driven work and its outputs. This is in effect negligible in the developing countries. Academia, which is mostly responsible for conducting basic research, and industry which is usually concerned with applied research (since it cannot simply afford to engage in long-term research- projects due to a competitive commercial environment), have to establish an effective collaboration with each other whereby the research findings can be used for the mutual benefit of both. Universities can lend easy access to knowledge to the industry for conducting applied research. In turn, the technology produced by the industry can be used by the universities to carry out basic research on a more detailed and extended level. Secondly, by enhancing geographical proximity of research centers, an added advantage can be achieved that would be in the form of exploitation of their production and outcomes. Research work is being carried out at universities and within the industries, however, due to lack of collaboration and coordination, the fruits of knowledge produced, are not being fully utilized by either of them. Once these institutions stop working in isolation and provide easy access to their research findings, the combined efforts of both institutions can bring far-reaching results.

Science is increasingly becoming inter- and multi-disciplinary, and this calls for multi-institutional and, in several cases, multi-country activity. Major experimental facilities, even in several areas of basic research, require enormous material, human and intellectual resources, which can be facilitated only through collaboration at both the national and regional levels.

8.4 Bridging the Gap between Developed and Developing Countries: The present level of efforts of developing countries in S&T is much lower than required and this has led to a widening gap between the developed and developing countries. Developing countries are particularly in a dire need to bridge this gap. Developed countries can promote collaborative research programmes in developing countries, to support their research activities in fields of basic and applied research. They can also accelerate the pace of technology acquisition, transfer and adaptation, in order to support basic and applied research in developing countries. A major reason for lack of research activities can be highly attributed to lack of funds and resources to carry out long-term research. Developed countries can play an effective role by providing means of funding for basic research, to the developing countries, which in the long run will ultimately be in the interest of both the developed and developing countries as a whole. Finally the sharing of information is an affective step towards bridging the wide gap between the developed and developing countries. Sharing of information should also be facilitated between the developing countries. Keeping in mind the fact that the capacity to generate new scientific and technological knowledge is mostly concentrated in the developed countries, and is mainly utilized to address their own material needs, information exchange and creation of innovative ideas has to be facilitated between the developed and developing countries, with the help of information and communication technology. As yet, not much of the new knowledge, gained by developed countries, has been used to address the critical predicaments of poor and developing countries:

> *"All the rich-country research on rich-country ailments, such as cardiovascular diseases and cancer, will not solve the problems of malaria. Nor will the biotechnology advances in temperate-zone crops easily transfer to the conditions of tropical agriculture... rich and poor countries should direct their urgent attention to the mobilization of science and technology for poor-country problems." (Sachs, 1999, p. 18.)*

According to Mohamed H. A. Hassan of the Third World Academy of Sciences (TWAS), partnerships between the developed and developing countries can be of great benefit to the South. Strategies of South-South cooperation can help develop and sustain indigenous capacities in science and technology to the developing bloc. A good example in this regard is that of the development of Brazil's space-programme and satellite technology. Brazil set up a National Space Commission in 1961, in order to develop its satellite technology. In 1993, Brazil launched its first resource data-collecting satellite from Kennedy Space Center, Florida, with the assistance of a private US space firm. Ever since, Brazil has pursued two inter-related space programmes. One is the Brazilian Space Mission and the other is the China-Brazil Earth-Resource Satellites programme. These ventures use satellite-technology to address down-to-earth concerns, which include changes in temperature, humidity and carbon-dioxide concentrations in the atmosphere, as well as real-time data on alterations in quality of soil and water. More importantly, the information collected from these satellites has been shared with scientists in other developing countries, through more than 300 Earth-data collecting platforms in Brazil and neighboring countries. Brazil has also offered access to the data, to countries of Africa. Brazil's surfacing space-programme is a premier example of how North-South cooperation can be utilized to further South-South cooperation. This endeavor began with the training of young Brazilian scientists and technicians, primarily in the universities and R&D laboratories of USA. The primary building-blocks of the programme were laid with the help of private firms and public institutions in the North, not to mention the fact that Brazil's first satellite was launched from the soil of United States.

The knowledge and technical skills that Brazilian space-scientists and technologists have attained is currently being put to meaningful use via critical examination of environmental problems, for the benefit of nations throughout the developing world. Simultaneously, the initiative has raised the standard and level of Brazil's overall scientific skills and facilities. Today, a cooperative partnership with China has allowed the country to further advance in the fields of satellite earth-observing, data-collection and communication. Such examples carry the promise of permitting researchers in the South to become partners with the scientists of the North, in projects devoted to global scientific issues (Hassan, 2000).

In a world where the accumulation of scientific knowledge and its technological applications are accelerating at a fast pace, it is a well-known fact that the developing world contributes only meagerly to modern science and technology. Yet, if acquired and utilized appropriately, the new trends in S&T offer tremendous potential for solving many of the problems hampering economic progress in the developing world. Collaboration and cooperation-mechanisms without discrimination and with transparency of activities should provide useful results. Creation of new ideas and their dissemination are one of the many ways by which the purpose of the ongoing global initiatives on sustainable socio-economic development could be advanced. Knowledge, expertise and equipment has to be shared and it is, therefore, important that the developing countries effectively utilize their resources for scientific and technological research, in a manner that would help in addressing their own pressing needs and also promoting scientific and technological cooperation at the regional level for the following main reasons (Kane, 2000):

- There is a need to avoid the duplication of human, material and financial resources in crisis-situations or in the cases of under-development, which are impediments to optimally realizing the scientific and technological potential of developing countries and ensuring its optimization. This is an ailment, common to most of the developing countries, and can be reduced or eliminated through mutual collaboration.
- There are quite a number of similarities in the environmental conditions of the

various developing countries, which give rise to general developmental problems that are similar in several critical sectors of their respective economies. The existence of common problems within the South is undoubtedly the most important reason for cooperation in scientific and technological research. Science and technology are considered to be the likely key-factors in solving critical problems of the South, such as food-insecurity and diseases. Some of these issues have little express impact on the countries of the North, and are thus unlikely to be given high priority in the S&T research-agendas of the North. Cooperation of developing countries, in such areas, could be very beneficial in discovering and disseminating effective solutions.

- Globalization and liberalization of the world economy, followed by the tremendous advances in new Information and Communication Technologies (ICTs) and, most importantly, self-interest in safeguarding the trade-agreements and blocs, are such phenomena that must be tackled by the developing countries, in a collective manner. This is extremely important because, individually, these countries do not stand a chance. While literally all developing countries have been adapting their domestic policies to the new global trade and economic dictation in the recent years, their capacity to protect their own interests in a global epoch, remains restricted due to the lack of capability for institutional and technological innovation - and this is where the role of mutual cooperation comes in. One aspect of globalization, in its present form, is that it forces developing countries, in need of international financial support, to accept imposed conditionalities with respect to the macro-and micro-economic conditions under which they operate. This often leads to reduction in governmental expenditure, with associated pressure on the budgets of the spending ministries, including that of education. Thus, structural adjustment, whether imposed or voluntarily adopted, has put pressure on public funds available for science in these countries.
- There are several large and complex problems, such as environmental degradation and natural disasters, whose solutions can only be found through a collective approach by the entire global scientific community. This firstly calls for greater cooperation in areas of basic and applied research at the regional level, and then at the international level.
- Developing countries must intensify co-operative efforts to enhance their indigenous capacity to generate, manage, and utilize S&T in ways that address its own basic needs. They have to enable their scientists, researchers, and policy-makers to address the problems and to devise a strategy for checking them. They need to train, retain, and promote native scientist and technologists insufficient numbers. Efforts must be aimed at exploring the applications of S&T for economic development, as well as ensuring the sustainability of society and environment by striking a best mix.

For these reasons, the developing countries need to closely work together and build their innovative and creative capacities. As mentioned earlier, no developing country, on its own, has the capacity to shape the processes that can inspire the development of a global economy. However, in adapting local institutional systems to the requirements of the global economic order, every developing country has a lot to gain by cooperating with other such countries. Particularly, those countries that are technologically disconnected can gain from those that have recently transcended to the level of technological innovators. The basis of cooperation amongst developing countries is that, when the wealth of knowledge and capacity in them is systematically assembled and channeled, effective participation between developing countries can be facilitated in the global economy (Kane, 2000).

9. ROLE OF 'CENTERS OF EXCELLENCE' IN ESTABLISHING REGIONAL COOPERATION IN SCIENTIFIC RESEARCH

Establishment of new Centers of Excellence at leading universities, industries and other R&D institutions, specialized in fields of S&T, is also an effective strategy. Centers of Excellence are the key to innovation, and their importance cannot be underestimated. Developing nations should have centers of excellence of local, national, and more importantly of regional, and international status awards to enhance their countries S&T and R&D capacities. These Centers of Excellence should be created, or should be included in the future R&D strategies of every developing nation particularly, in order for its developmental capacity to grow. Such Centers can serve as the main nodes for individuals or groups engaged in enhancing empirical knowledge of national and regional importance. Furthermore, these Centers should have institutional autonomy; sustainable financial support; knowledgeable and capable leadership; international input; also a focused research agenda 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 with talent in Science & Technology. Where such institutions already exist, they should be reinforced or, if necessary, reformed. (IAC Report).

Apart from the establishment of new Centers of Excellence, the developing countries need to establish centers of noble standards such as The Abdus Salam International Center for Theoretical Physics (ICTP). It is very unfortunate that presently there is only one existing center which is fulfilling the R&D needs of so many developing countries. It is urgently required that more centers of such standard be established in various regions of the developing world, probably in Asia and also in parts of Africa that are capable of supporting scientific research in developing regions. These centers should be focused on mainly few fields of scientific interest at one time, for example biotechnology, information technology, etc,. Stepping into so many fields at once will certainly lead the developing countries nowhere and will instead dilute their efforts. Such centers along with other centers of excellence can help in promoting and enhancing world-wide scientific and technological capacity, which will facilitate basic and applied research. An innovative and ambitious initiative would be to compel the already existing Centers of Excellence in developing countries to play their due role effectively in Research & Development activities in their respective countries by:

- Supporting high technology ventures through a collaborative approach among the state, academia, private venture-capital companies, and other private and public sector parties.
- Encouraging rapid commercialization of scientific breakthroughs.
- Allowing coordination and information-exchange between R&D institutes in developing countries.

10. SOME PROPOSALS FOR SUSTAINABLE DEVELOPMENT OF THIRD-WORLD

Having discussed the importance of research-based knowledge and a balanced approach to basic and applied research, especially for the developing countries, some useful and important recommendations in this regard can be put forth as follows:

- It is important to establish international and regional cooperation and coordination between experts in universities, academic institutions, and industry, while carrying out basic or applied research. Centers of excellence and Centers such as The Abdus Salam International Center for Theoretical Physics (ICTP) can facilitate this sort of cooperation. The objective behind these efforts should be to develop collaborative programmes for building the capacity for scientific education and research, and to establish trends of knowledge-sharing through regional alliance among academia, governments and industries, to address real-life problems. The ability of countries to participate in, benefit from and contribute to the rapid advances in science and technology can significantly influence their development.
- Regional efforts must be vigorously pursued. Efforts for Regional cooperation should be intensified and strengthened towards the developing countries' indigenous capacity-building in science and technology, including their capacity to utilize scientific and technological developments from abroad, and to adapt them to suit local conditions.
- Developing countries in this regard need to adopt and pursue policies of non-secrecy to other parts of the developing world. They have to show their willingness to propagate and further the South-South collaboration in S&T. Their commitment to solidarity in the collective augmentation of capacities and acquisition of necessary technologies is indispensable for achieving success.
- Developed countries can promote collaborative research-programmes, in developing countries, to support their research activities in fields of both basic and applied research.
- Developed countries should accelerate the pace of technology acquisition, transfer and adaptation, in order to support basic and applied research in developing countries.
- A major reason for the lack of research activities can be lack of funds and resources to carry out long-term research. Developed countries can play an effective role by providing the means for adequate funding of basic research, to the developing countries, which will be ultimately in the interest of both the developed and

developing countries as a whole.

- The concerned authorities in the developing countries should implement ways to efficiently mobilize and utilize the funds and resources. New and innovative funding-mechanisms need to be established to make available more resources for basic and applied research that will ultimately facilitate the process of sustainable development.
- Each developing nation requires to put up a coherent national framework for actions that directly affect the promotion of scientific and technological research. Such a strategy should be developed by the government, in consultation with scientific, engineering, and medical academies of the country, and the state should learn and benefit from the experiences of other countries.
- The planning authorities, government, industry and research institutions should identify priorities and launch national R&D programmes in areas of basic and applied research, to serve the industrial strategies for the development of technology domains. This will allow concentrated efforts towards improving the overall economic situation of the subject country.
- A sound infrastructural base for S&T is essential, and this can be achieved by building new, and strengthening already-existing, research laboratories, educational institutions, and skilled human resource.
- Developing countries can engage in capacity-building, by outlining their strengths and weaknesses in respective areas of basic and applied research, and then devise appropriate strategies to progressively reduce these weaknesses. Promoting effective cooperation among governments, between public and private sectors, both within and across frontiers should be ensured.
- Research, whether basic or applied, should be carefully planned and executed to produce the results that may, in the long or short term, benefit the humanity at large.

11. SUMMARY AND CONCLUSIONS

In today's competitive world, the key to sustainable development, without a doubt, lies first in the creation of scientific knowledge and second in its utilization. It is knowledge which gives birth to Science & Technology (S&T) and in turn it facilitates the generation of new forms of knowledge. S&T have profoundly influenced the course of human civilization and have stood out as the two main fundamental components aimed at fostering socio-economic development, since the last couple of decades. Meanwhile the scope of sustained socio-economic development has been dynamically shaped in the past and the same can be seen in the present era. Despite the changes occurring in the direction of sustainable development and progress, perhaps the only thing which has remained constant is the creation of knowledge through continued scientific research. Knowledge has always been marked with certain limitations and uncertainties, and the purpose of scientific research has been to overcome or, at the least, reduce them. Scientific research is the principal tool for human-beings to explore and make use of nature for improving the quality of life. In this context, the emphasis is mainly on two major forms of scientific research, i.e., basic and applied.

The usual consensus has been that basic research creates the knowledge which is called science and this science is used for devising applications that is referred to as the technology - essential for addressing problems faced by human beings. In view of the changing global scenario and increasing number of problems, for both developing and developed countries, the focus gradually started shifting from pure basic research towards applied research, for achieving immediate results. This trend, it is believed, is forced by the problems resulting from issues, such as, population explosion, increasing pollution, and the overuse of the Earth's natural resources. The growing importance of applied research cannot be ignored, but at the same time the importance of basic research for the creation of a powerful science-base can also not be denied; rather a ‘balanced’ approach is required. However, the fact is that a shift in emphasis away from exclusively one type of research; either basic or applied, towards a more balanced approach, is the need of the times.

The importance of creation and utilization of knowledge has to be duly recognized by the government, academia, and industry. Each of the above mentioned pillars of society has to determine its appropriate role in basic and applied research. An important strategy in this regard is the establishment of international and regional cooperation and coordination between experts in universities, academic institutions, and industry, while carrying out basic or applied research. In case of regional cooperation, the role of Centers of Excellence is pivotal in promoting South-South and South-North cooperation. Other strategies could include the establishment of university-industry collaboration at the local levels and improved mechanisms for funding and support. Developing countries particularly need to pay attention to these issues, and remove their inherent limitations if they are to practically achieve the targets of sustainable development in its true sense.

Some of the Key Recommendations for Promotion of Science and Technology

- In the context of a radically changing world, which is characterized by a host of pressing challenges, rapid technological change, and globalization, most societies are fast transforming into knowledge-based and information-based societies, for which the importance of research-based knowledge has to be duly recognized.
- It is high time that the developing countries recognize the importance of a powerful science-base and overcome their limitations, if they are to fully participate in today’s world, where traditional economies are fast switching to knowledge-based economies.
- It is generally believed that, in many developing countries, applied research will be more appropriate because of limited availability of resources and scarcity of staff and funds. This might seem to be an effective strategy at first, but it is not very promising in the long-run; therefore cooperative mechanisms, such as South-South or North-South should be made to use.
- Applied research cannot be ignored but, at the same time, the importance of basic research for the generation of pure scientific knowledge cannot be denied; there is a growing need for a strategic approach viz-a-viz research.

- The roles of government, academia and the industry are critical in the process of knowledge-creation and knowledge-utilization; each of these institutions has to identify and play its due role. Governmental efforts must be addressed at supporting and funding research activities and infrastructure at universities and academic institutions, while industry-university cooperation also needs to be established, whereby the research findings can be quickly used for the mutual benefit of both.
- Basic research should be consistently supported by governments as their first priority, compared to funding of applied research. And further more, the research activities of each country have to be necessarily tailored to their particular situation.
- The force and quality of knowledge required to achieve success for sustainable socio-economic development, in a timely manner, has to be galvanized as quickly as possible. Research organizations, universities, think-tanks, world intellectual forums, NGO's and others have to be brought together both from the developed and the developing world, in order to provide a solid foundation on which mankind could build its future strategy and practicable action plans to achieve success.

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FUNDAMENTAL RESEARCH: THE ENGINE OF INNOVATION – EXAMPLE OF PARTICLE PHYSICS

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As one of the missions of COMSATS is to bring about sustainable socio-economic development in the South, it is very much fitting that the centrality of science and technology in the development process be explained again to policy makers. Therefore, I welcome COMSATS' initiative to compile in one book, thoughts on the respective roles of basic research and applied research, even though it is a vast subject that could easily fill more than one single book.

It would be presumptuous on my part to imagine advising developing countries of the South on their research policy. I would rather like to reflect here on the historical role of fundamental research; provide some recent examples from the field I am most familiar with, which is high-energy particle physics; explain how fundamental research drives innovation, and simply express some personal views.

It is generally agreed that one could define fundamental research as the process by means of which science progresses, while applied research is the development of innovations based on the results of fundamental research.

In my view, there should be no real dilemma for any country to choose between fundamental research and applied research. Both are important; however, without fundamental research there is no innovation, and without innovation there is no economic development. I believe that a strong fundamental research programme is the basis for success. Fundamental research requires government funding [1] accompanied by the development of education, as money alone will never create new ideas. It also requires promoting scientific culture so that a large number of the young people, precisely those who can invent new ideas, understand that by developing science they can at the same time enjoy a great adventure and help develop their country. I strongly feel that investing in science is the best way to promote the interests of a country in the long run, and probably the most cost-effective one, much better than investing in weapons. On the other hand, applied research is best funded by the private sector as eventually the result of applied research can be commercialized, thus bringing financial benefits. The detailed mix between fundamental research and applied research does not matter too much, as I do not believe that there is a magical and universal recipe. However, again, without a strong fundamental research programme, a so-called "developing" country will remain, forever, a "developing" country. It is of course understood that sufficient wealth is required to be able to invest in fundamental research, and that the first most cost-effective step is to join international collaborations, which are excellent platforms for the training of young researchers.

Fundamental research is the expression of human curiosity: of the need to understand the structure of matter, life, the structure and evolution of the Universe, which are the main subjects of fundamental research, so that we can decode our past and predict our future. For instance, the laboratory where I am carrying out my research work, the European Organization for Nuclear Research (CERN) [2], unlike what its historical official name might suggest, is entirely devoted to fundamental research, in the domain of high-energy particle physics, even if in practice there is also some applied research occurring at CERN, for reasons which I shall explain below. As I have mentioned already, curiosity is the motivation of scientists; it is also remarkably characteristic of children who need this curiosity to develop, and it is presumably this very curiosity which is at the basis of the evolution of humankind. I could imagine that the evolution of humankind accelerated smoothly as soon as human beings were able to ask questions about their environment.

Both, fundamental and applied research, are directly linked to science, and it might be appropriate to note that, unfortunately, society often confuses science with technology. Robert Oppenheimer once said: “Too often science is being blamed for the misuse of the technology it allows”. Science can be defined as a coherent ensemble of knowledge related to certain categories of facts, objects, or phenomena obeying certain laws and verified by experiment. Therefore, science cannot be bad in itself. One should, however, regret that the traditional goal of science, i.e., to understand nature, the Universe and it’s evolution, is not understood by most people in our society. No wonder that, in making a hotchpotch of science and the political use of science, many believe science to be guilty and socially irresponsible. Therefore, investing in research should only be one aspect of a general programme based on the improvement of scientific education. Science should become a natural part of culture. While the use of knowledge is an ethical matter, the search for knowledge must be absolutely free, and the two should not be confused.

Science represents one of the most noble and ambitious endeavours of human beings who, by trying to discover the nature of the Universe in which they live, are in fact trying to discover themselves and understand their own place in this fascinating and highly puzzling world. Somehow, over the years, science has strongly changed the way human-beings understand their place in the Universe, from ancestral times when the reference frame was the village and its neighbourhood, on to a region, a country, a continent, the Earth, the solar system, the Milky Way (our galaxy), the local group of galaxies (the Milky Way belongs to the so-called Local Group), the Virgo supercluster (the galactic cluster that contains the Local Group) and today the entire Universe. The progress made by humankind is tremendous, however, it is ironical that this progress led us to understand that we still know relatively little. For instance, we discovered that the matter we are made of, mainly baryons (particles such as neutrons and protons which are constituents of atom nuclei), is only a small minority in the Universe, only a few percent of its total contents. What a change of perspective within about half a millennium, when the Earth used to be the centre of the Universe! All this came by steps, with an acceleration of progress starting with Galileo Galilei at the turn of the 16th century, when he used instruments to observe the moon, comets in 1618, and other objects in the sky, such as Jupiter's satellites, to verify the theory of Nicolas Copernicus, establishing that the Earth was indeed rotating and orbiting the sun. New ideas, even scientific ideas, are not always easily accepted by society, and in this particular case they cost Giordano Bruno his life for supporting them. Their revolution was a deep one, as observation became the basis for science and instruments were built that extended the reach of the human eye. It is characteristic of this new era of science how Galileo, armed with one of the first telescopes, was able to settle once and for all, for instance, the issue of the nature of the moon, which had been discussed endlessly by philosophers, as long as society could remember. He immediately realized that the structures he discovered on the moon through his new instrument were reminiscent of our mountains, and that the moon had obvious similarities with the Earth. It was not one of those perfect spheres imagined by philosophers before him.

Today physicists can observe the Universe over distances that vary by 45 orders of magnitudes (a factor 10^{45} between the two extremes), from the smallest distance, reachable at the Large Hadron Collider (LHC) [3] (Figure - 1) at CERN, $\sim 10^{-19}$ m, to the scale of the entire Universe $\sim 10^{26}$ m, reachable with large instruments to observe

Source: *Copyright CERN, Geneva, Switzerland*

Figure - 1: The LHC tunnel between points 1 and 8, showing some of the large superconduction magnets (1232 dipoles with a field of 8.4 Tesla) that constitute part of the 27 km underground accelerator structure

the sky, such as the Hubble telescope or the European Organization for Astronomical Research in the Southern Hemisphere (ESO) Very Large Telescope (VLT) project, which will be the world's largest optical telescope array.

Another important revolution concerning our place in the Universe came with Albert Einstein, at the beginning of the 20th century, when he described an unexpected relation between space and time. It came as a great shock that two individuals could age differently, if one of them travelled. This completely changed our understanding of the Universe. Today, relativity is with us even in everyday life, when we observe, for instance, muons produced by primary cosmic-rays in the higher layers of the Earth's atmosphere, 100 to 200 km above us, reaching sea-level, which implies that they must have lived 100 to 150 times longer than a muon at rest, which lives only two microseconds on average. Even closer to everyday life, with the advent of new technologies, the Global Positioning System (GPS) would be totally unable to locate a car within a few metres without relativity corrections.

Einstein's revolution was soon followed by another one, made possible both by the understanding of the red shift of the light coming from distant galaxies, and by the availability of better telescopes, when Hubble realized, in 1929, that the Universe was expanding. Everyone remembers that it was even a shock to Einstein himself, who had desperately tried to find a static Universe solution to his general relativity equations. It is very ironical that today, with the observation that the expansion of the Universe is actually accelerating, cosmologists are tempted to include again in the equations the cosmological constant term ( ) which Einstein had taken out of his equations of gravitation [4], reproduced here because of their incredible conciseness, which some scientists refer to as "beauty":

$$\left(R_{ik} - \frac{1}{2} g_{ik} R\right) + \Lambda g_{ik} + \quad T_{ik} = 0$$

Despite my natural bias towards physics and cosmology, I should not forget to mention Darwin's contribution with his theory of evolution by natural selection, which gave a new perspective of the place of humankind in the history of life. More recently, in the early 1950s, Francis Crick and James D. Watson, discovering the double helix structure of deoxyribonucleic acid (DNA), the fundamental molecule of life, bridged biology and chemistry, and opened the field of molecular biology. This actually gives me the opportunity of making an important comment on how various fields of science interact. There is often cross-fertilization between fields. Francis Crick and Maurice Wilkins, who shared the Nobel Prize in Medicine with James D. Watson in 1962, were physicists. The microscope, X-ray imaging, more recently gel electrophoresis which plays an important role in the study of genomes, integrated circuit techniques to study gene correlation with cancer cells, computers, large databases, etc. are all coming from physics and have allowed molecular biology to progress in a very spectacular way in the past sixty years. This pleads in favour of a diversified research programme, which will create a general scientific environment that will stimulate all areas of research.

For politicians, it is not always easy to understand why they should invest in fundamental research. The practical results of fundamental research are not predictable, and the benefits often come on a long time-scale. It is certainly easier to explain to constituencies investing in the transportation system, or in the building of a new football stadium, rather than investing in research to discover the nature of dark matter in the Universe.

Actually, my own experience shows that when scientists make the effort of explaining their own research to the public, it always triggers a lot of interest and enthusiasm. CERN is currently submerged by visitors, and is foreseeing more than 60 000 visitors a year during the LHC era. Not that visitors can actually see much of the LHC itself, which is buried on average 100 metres underground, but because they are intrigued by the mysteries of high-energy physics, the scale of the experiments needed to tackle some of the smallest objects we were able to imagine as constituents of matter so far, and also because they are fascinated by the paradoxical connection between understanding the world at the smallest dimension scale and understanding the history of the Universe, described by the Big Bang model at the largest dimension scale.

The example of Michael Faraday, the prestigious English physicist of the early 19th century is an ideal case to illustrate the difference between fundamental research and applied research. His government had asked Faraday to also spend time doing “useful” things, whereby they meant “applied” research as opposed to “fundamental” research, which to them seemed a waste of time. Faraday was asked to solve the problem of lighthouses along the coast of England. England was at that time, and still is, heavily reliant on shipping for trade and could not afford the heavy losses due to shipwrecks when lighthouses failed. Michael Faraday took up the challenge, and with his brother, an engineer, understood that the main problem was the soot produced by the candle that was deposited on the lenses and on the light reflector. They invented a clever chimney system that controlled the soot and they took out several patents, which allowed them to make some money out of their invention. However important that contribution was at that time, today, if we remember the name of Faraday, it is because in his laboratory he was puzzled by the fact that when drawing an electric current through a conducting wire, it had an action on his compass needle. Faraday was curious and he spent his life studying this type of phenomenon, which led to the invention of the electric transformer, the electric motor, and made possible the deployment of electric lighting, etc. The impact of his fundamental research turned out to be far more important than improving candle lighting.

Today, the realm of fundamental research is broader than ever. The study of life in general expanded from botany and biology to molecular biology and to the search for extra-terrestrial life. The study of the Universe can take so many forms, from the observation of the microwave background (COBE, WMAP, etc.) to the observation of type II supernovae to map the expansion of the Universe to accelerator experiments at the CERN LHC: ALICE [5] will explore the early Universe state of matter known as Quark-Gluon Plasma (QGP), that is presumed to have existed only during the first 10 microseconds after the Big Bang; ATLAS [6] and CMS [7] in addition to searching for the Higgs particle to explain the origin of mass, will try to find out whether supersymmetric particles could account for the dark matter that constitutes about 23% of the contents of the Universe; LHCb [8] will study the violation of one of the main symmetries of fundamental interactions, the product of charge conjugation by reflection in a mirror, so-called CP symmetry which might be related to the fact that the Universe is almost entirely made of matter, as opposed to equal amounts of matter and antimatter. Not only is the realm of fundamental research broad, but the possibility of building instruments today which are infinitely more powerful than ever before, makes the enterprise of fundamental research so exciting that I believe this might be one of the most gratifying occupations and a continuously exciting adventure for a man or a woman on our planet. Again to take my own field as an example, I believe that the Large Hadron Collider being commissioned at CERN has the potential for being one of the greatest scientific adventures of our times.

Besides satisfying our thirst for knowledge, fundamental research plays a very important role in society. History shows that it is fundamental research that drives the development and progress of a society and that the success of a civilization depends on its support of science. Examples are numerous but I shall mention only a few here: the Greek civilization of the 5th century BC, the first one to attribute value to the search for knowledge. I have always been impressed by Empedocles (492-432 BC), who, two thousand and five hundred years ago, was already asking the very same questions we are asking at CERN today: what are the ultimate or fundamental constituents of matter? What are the forces through which they interact? Of course, even though Greek Scientists invented the concept of the atom, they could not possibly get the right answer. To the first question, they answered that there were four fundamental elements, earth, air, fire and water, and that there were two fundamental forces, love

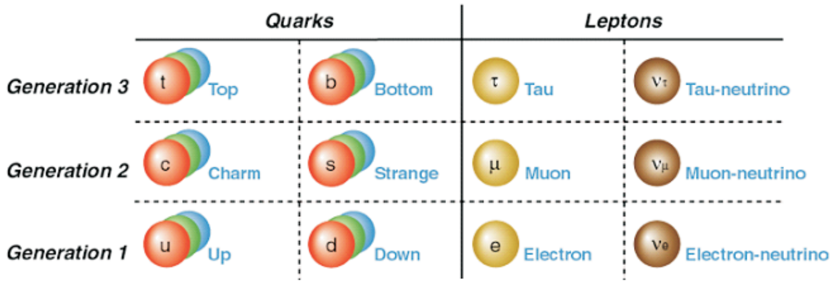

Figure - 2: Today's Three generations of fundamental building blocks of ordinary matter. In addition, for each particle of matter there exists a corresponding antiparticle

and strife, engaged in an eternal battle for supremacy. Today we know of 24 elementary building blocks of master: 18 quarks and 6 leptons (Figure - 2), and of three forces: the electroweak, the strong and the gravitational forces, which are mediated respectively by the $W^{\pm}/Z^{0}$, the eight gluons and the graviton (yet to be discovered). A relatively simple and consistent picture well described by the so-called Standard Model of elementary particles and their interactions. The LHC will be searching for the ultimate piece in this construction, the Higgs particle, the quantum of a scalar field that might be generating the masses of the quarks and gluons.

The other well-known example is that of pre-medieval Arabic civilization, which was flourishing and of great influence throughout the world. Just at the time when they were supporting science: they had great mathematicians, astronomers, doctors, etc., but for various reasons, their enquiring spirit died and left modern Arab society greatly impoverished. Another interesting example is that of the 15th century Chinese civilization. The eunuchs wanted to explore the world, and Admiral Zheng had assembled, what would be the largest fleet for another five centuries, 300 ships, some of them 130 metres long. However, the confucianists won the debate: why explore the world, as nothing in their mind could be better than China, what was the point of going elsewhere? As a consequence, the fleet was destroyed. That was the time when the first Portuguese boats were sailing along the coast of Japan. Most likely, if the enquiring spirit had prevailed, Europe would have been discovered by China, and surely our history would have been quite different.

The fact that fundamental research drove innovation was even truer in the 20th century. Prof. Hendrik Brugt Gerhard Casimir, a physicist who became research director at the Philips Research laboratory, in a symposium on Technology and World Trade in 1966 listed a number of spectacular examples:

"I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsense it has been my fortune to stumble upon.

Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in, and had not contributed to, wave mechanics or the quantum theory of solids. It so happened that the inventors of transistors were versed in, and contributed to, the quantum theory of solids.

One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the thirties by physicists dealing with the counting of nuclear particles, because they were interested in nuclear physics.

One might ask whether there would be nuclear power because people wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps – only it didn't happen that way.

One might ask whether an electronic industry could exist without the previous discovery of electrons by people like Thomson and H. A. Lorentz. Again it didn't happen that way.

One might ask even whether induction coils in motor cars might have been made by enterprises which wanted to make motor transport and whether then they would have stumbled on the laws of induction. But the laws of induction had been found by Faraday many decades before that.

Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz who emphasised the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of twentieth century innovation which is not indebted in this way to basic scientific thought."

In practice, there are two basic ways in which fundamental research feeds innovation: (a) directly, as was for instance the case with Faraday's research which led to direct applications; (b) indirectly, from the tools developed for fundamental research. CERN provides many spectacular examples. A first image from a PET camera was made at CERN in 1977, in collaboration with the Hôpital Cantonal of Geneva. CERN ISOLDE provides hospital with radioelements for diagnostics. CERN patented the TARC idea to produce locally new radioelements, which would considerably reduce the dose to the patient, simply by using shorter half-life nuclides produced in the vicinity of the hospital where they will be used.

In the accelerator domain, the most spectacular development at CERN is the proposal by Carlo Rubbia to use a proton accelerator to drive a new type of nuclear fission reactor. It is subcritical, uses thorium-based fuel as well as transuranic elements from PWR spent fuel. Such a system would be very proliferation resistant, designed to remain subcritical under all circumstances, making a Chernobyl-type of accident impossible. It would moreover be able to destroy existing nuclear waste. It is in my view the only reasonable way we can imagine deploying nuclear energy today on the large scale needed to provide developing countries with the huge energy increase they need, while at the same time fighting global warming. At the time of writing of this book, Norway is showing interest in building the first prototype of such a system, which Carlo Rubbia named "Energy-Amplifier" [9]. Today, more than half of the particle accelerators of the world are used for medicine. For instance a proton cyclotron built by a physicist who trained at CERN is now used with spectacular success, for treatment of retina cancers, at the centre Antoine Lacassagne in Nice, France.

It also happens that innovation comes as a total surprise, as for instance in the case of the World Wide Web. Tim Berners-Lee, at CERN, for the need of the large experimental collaborations carrying out experiments at the LEP collider (the predecessor of the LHC), combined personal computers, networks and hypertext technologies into a global information system that was easy to use. As the Economist put it when awarding their innovation prize to Tim Berners-Lee: “the World Wide Web has changed forever the way information is shared”; this contribution from CERN is having a huge impact on the entire society, but in 1954, when a few European member states created CERN, nobody could have predicted that such an important innovation would come out.

With the LHC in preparation, the needs for computing resources (storage and CPU power) are such that CERN abandoned the idea of constructing the required computing system at CERN. Instead, CERN is participating in the development of the GRID, to allow its physicists to tap resources distributed throughout the world, in a way somewhat analogous to tapping electricity from the electrical grid.

There is an interesting feedback mechanism between fundamental research and innovation. Innovation allows the construction of new and much more powerful tools, thereby allowing the exploration of new research territories. For instance, pixel detectors massively used by LHC experiments, were made possible by progress in semiconductor physics, and then developed by the microchip industry. Today, they are used at the LHC to improve the precision in the detection of charged particles produced in proton-proton collisions. The computer technology was based on elementary circuits invented by physicists. It was then developed by industry to provide processor chips to the public, imbedded in sophisticated toys or in personal computers. For comparison, CERN at the end of the 1970s had the most powerful computer in Europe, the CRAY/XMP, a very spectacular water-cooled machine. Today, the SONY PlayStation 2 uses a processor 2.5 times more powerful than the old CERN CRAY! These new generations of processors, developed by industry, are allowing molecular biology, particle physics, astrophysics, etc. to process amounts of data which would have been impossible to handle merely 10 years ago.

We can be sure that the new fundamental research projects, made possible today by the progress of technology based on previous research projects, will in turn produce their share of innovation, as has always been the case in the past.

How can we hope to increase the public’s awareness of the true nature and virtue of science? I believe that this cannot be accomplished quickly, but is a long-term goal, which can be achieved mainly by a better education system. Science must become an integral part of the general culture. Unfortunately, an insufficient number of students are going into the sciences these days (at least in the western world), maybe because science requires a particular effort, but mainly because our society is not fully appreciating the role science should play in our culture. For the large majority of people, believing in science is only a matter of faith. It is ironical that, while our society depends more and more on technological development, hence on science, scientific education seems to be decreasing drastically. The Russian Academician Lev Borisovitch Okun, in his address at the International High-Energy Conference in Marseille in 1993, remarked very correctly that:

“The more illiterate people are, the more they hate the spirit of scientific curiosity, the

more irreversible the process of intellectual degradation will be."

It is, therefore, our most important duty to foster education, while at the same time using every opportunity we have, to explain why science is such an exciting adventure and why we should share with the largest number of people the unique excitement which knowledge can bring to us. It is our duty to write about science in popular newspapers; to talk about science on the radio; on television; to use every modern medium to convey our enthusiasm for science, so that the young people may learn that science offers hope for them and that the future may be bright. Scientists certainly have an overall moral obligation to inform.

In this context, I believe that COMSATS could take the initiative, and use its unique access to a large number of developing countries to act in the area of scientific education. In Pakistan, an educational effort is already taking place under the leadership of Dr. Ishfaq Ahmad, who was the main initiator of collaboration between Pakistan and CERN. CERN has a lot to offer in matters of education, as a place to carry out Ph.D thesis research, a place with various graduate and undergraduate student programmes; a unique summer student programme, and a unique physics teachers training programme. International collaboration, in particular with CERN, can strongly boost scientific education in developing countries. Clearly, Pakistan has the opportunity to take a leading role in this area.

I would like to conclude by citing Dr. E. Sylvester Vizi, the President of the Hungarian Academy of Sciences, who wrote in 1993 [10]:

"In the next century, more than ever before, the world will be shaped by science. Knowledge, primarily scientific knowledge will be the engine of modern society, it will provide the new raw material for prosperity of mankind. Science is able to change the world for the better, to improve the quality of life, but it is also true that its application can have adverse effects on the world. Therefore, the moral duty of the scientists is to call the attention of the governments to the actual problems and to help them in their attempts to find solutions for political, economical, ecological, social and moral problems."

The energy problem may well be among the foremost challenges to our civilization, because it is crucial to the prospects for sustainable and harmonious development. How can our civilization meet present and future energy needs without jeopardizing the ecological balance of the planet? How can we be sure that acceptable energy resources are distributed equitably among all nations, including developing countries? This is certainly a challenge for scientists to take up, as the solution can only come from innovation. Furthermore, a significant part of this challenge for scientists lies in providing politicians with the proper guidance, which is certainly not easy. It is rather clear that energy savings and maximum use of renewable energy sources will not be sufficient, by far, and that we must free ourselves, as soon as possible, from the use of fossil fuels, because of their strong environmental impact (chemical pollution

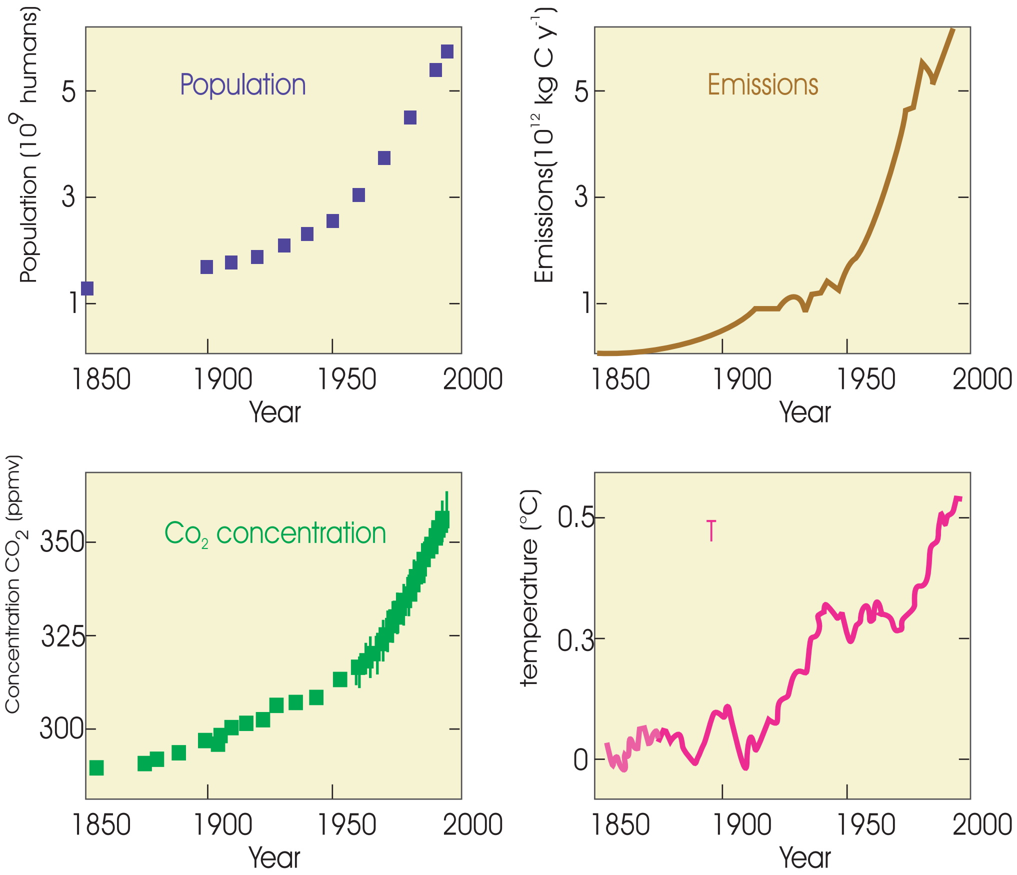

Figure - 3: Historical increase of the world's population, the industrial emissions, CO_2 concentration in the atmosphere, and the increase of global temperature from 1850 onwards. This illustrates the correlation between human activities and the global atmosphere parameters relevant to global warming

and release of global warming gases). Therefore, the ball is more than ever in the scientist's camp, they must find a new non-polluting energy source that can provide the huge energy production increase required on a relatively short time scale (≤ 50 years) to avoid catastrophic and perhaps irreversible consequences for our planet and for our civilization. I strongly believe that the Norwegian Prototype of an Energy Amplifier for Clean Environment (PEACE) initiative is a very significant step in the right direction, and I hope it will soon turn into a global project that will associate developing countries, in particular COMSATS countries. Warming of the earth's atmosphere is a global problem (Figure-3) and it must be faced globally.

CONCLUSION

It is vital for any country to strongly support fundamental research. This is a message that China has recently understood well. If the United States of America leads the world today, it is mainly because independently of which party is in power, their enquiring spirit has always been encouraged, offering some of the best research facilities in the world. As a result, today the pool of American researchers is dominated by foreigners. Encouraging fundamental research is a task of and must be a priority for governments, as it is not in the interest of private investors who require short-term profits, and who most naturally can invest in applied research.

In addition to cultural and educational contributions, to the innovations generated, fundamental research presents a universal character, which contributes to promoting peaceful international cooperation beyond cultural and political barriers. In my view, this is in itself a strong enough motivation for developing fundamental research, both on a national scale and on the international scale. Therefore, it makes sense for developing countries to contribute at the forefront of research, whatever the field, and nothing less than the forefront.

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R&D IN DEVELOPING COUNTRIES: CASE FOR APPLIED RESEARCH

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APPLIED RESEARCH: A CASE STUDY FROM U.S.A.

The excellence that the United States of America (USA) has achieved in science and technology, owes much to the vision of Vannevar Bush. Trained as an electrical engineer, he contributed considerably in advancement of technology used for the defense of USA during World War-I. In 1939, when he was appointed President of the Carnegie Institution of Washington, with large sums of money at his disposal for research grants, he was able to influence the direction of research in the country. Perhaps because of his experiences in World War-I, he was particularly biased towards the military projects.

Upon his appointment as the Chairman of the National Advisory Council for Aeronautics (NACA), the precursor of National Aeronautics and Space Agency (NASA), he was able to convince President Roosevelt to establish the National Defense Research Committee (NDRC). As Chairman of NDRC, Bush appointed four of the following leading scientists of his time as members, and assigned them clear objectives:

a. *Karl Taylor Compton:* A prominent American physicist (President MIT, Chairman AIP), was the head of Division D, which was responsible for assembling a group of academic and industrial engineers and scientists that would study primarily Fire-Control, RADAR and Thermal Radiation.
b. *James Baynant Conant:* A Chemist (President of Howard University) was to look after development in chemistry and explosives. Together with Bush, he gave strategic direction to the Manhattan project.
c. *Frank B. Jewett:* He received a PhD in Physics from the University of Chicago, and was put in charge of the armor and ordnance development. In 1917, Jewett had presented a paper at an AIEE meeting, stating that industrial and academic research laboratories were "very closely associated and must grow together and with the same vigor if the best interests of civilization are to be served". He cautioned, however, that universities should not themselves enter into industrial research but help the industry in training of manpower and conduct of pure-research, providing an adequate supply of capable and highly trained researchers for boosting the industrial development.

d. *Richard C. Tolman:* He was a mathematical physicist and physical chemist. Being an authority on statistical mechanics (Dean of Graduate School at CALTECH), he was to advance the issue of invention and patents.

Later, the NDRC was merged into the Office of Scientific Research and Development (OSRD) with Bush as its Director. With a workforce of 30,000, OSRD was responsible for the development of a number of weapons that could be considered critical in giving the Allies an upper hand in World War-II. It should not be surprising to note that in its initial years, the Manhattan Project was controlled by OSRD, and later transferred to the military, for security reasons, in 1943.

In spite of his illustrious career, in what may be called Applied Research, Bush surprisingly considered Basic Research to be the key to his nation's survival. After a bitter fight with a number of high-profile politicians, right up to the level of President Truman, Bush was finally able to get the National Science Foundation (NSF) established, with himself as its first Chairman. Earlier, while he was still at OSRD, at the request of President Truman, Vannevar Bush, in 1945, authored the Seminal Report "Science: The Endless Frontier", which laid the foundation of Basic Research in Universities and of Application & Innovation in the industry.

Even before the end of the war, with the possible dissolution of OSRD in view, Bush had envisaged the establishment of an equivalent peacetime national research and development agency in its place. Convinced that basic research was the key to his nation's survival, Bush in 1945 proposed the setting up of a national agency called 'National Research Foundation'. In the same year, two pieces of legislation came before the US Congress. The Magnum bill echoed Bush's ideas to give the control of scientific activity in the country to a panel of top scientists. The panel would have the authority to appoint the executive directors of the Foundation, with a mandate to focus on basic research.

The competing Kilgore bill proposed a single-service administrator, appointed by the US President, with heavy emphasis on applied research. A compromise bill was passed by the Senate in 1946. Not being happy with this situation, friends of Bush put forward a new bill along the lines of the original Magnum bill and, thus, the compromise Kilgore-Magnum bill was again in jeopardy when it reached the House of Representatives.

In February 1947, the bill for the creation of National Science Foundation was introduced in the US Senate being passed by it in May. The bill was passed by the House of Representatives in July the same year. On presentation to the President, it was however, vetoed and the matter was delayed for a few years until the Foundation was created by the US Congress in 1950.

Before proceeding further let us see what "research" is and how are Basic and Applied Research and Development defined. The word 'research' is derived from the French recherché (pronounced ruh-sher-hay) which means to search closely, or to investigate thoroughly. A circular issued by the Office of the Management and Budget of the White House in 2006, lists the following definitions:

- *Research and Development (R&D)* activities comprise creative work undertaken on a systematic basis, in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of stock of the knowledge to devise new applications.
- *Basic research* is defined as the systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. Basic research, however, may include activities with broad applications in mind.
- *Applied research* is defined as the systematic study to gain knowledge and understanding necessary to determine the means by which a recognized and specific need may be met.
- *Development* is defined as systematic application of knowledge or understanding, directed towards the production of useful materials, devices, and systems or methods, including design, development and improvement of prototypes, and new processes to meet specific requirements.

The question of whether to prefer basic research over applied research, was certainly not new. It had always been an issue of bitter debate for over a century in many US federal and state agencies. One of the best examples of the polarization of this kind is the rise and fall of the Geological Survey office of the State of California. The office, called 'California Survey' was established in 1860 with Joseph D. Whitney, an outstanding geologist, appointed as State Geologist to lead the organization.

Although Whitney did consider his assignment to have two facets – one of exposing the general geological structure of the state and the other of providing information to the entrepreneur of direct practical utility - as a scientist he considered the farmer to be more important. In fact, he planned to undertake the second part after completing the first in ten year's time!

Meanwhile the state government hoped that the survey reports would be of direct industrial value, producing immediate practical results. The first report published in 1864 was, however, devoted to the study of fossils as a purely scientific pursuit. This angered the state politicians so much that they became openly hostile to Whitney.

Fueled by the geological prospecting for oil, to which Whitney was opposed, things started to go from bad to worse; so much so that in 1867, the state senate refused to approve the budget for California Survey. Research was continued by Whitney, through philanthropic donations for some years. In 1871, a decision was made by the state government to finally shut down the office and, in 1874, California Survey was officially abolished. The work done by Whitney and his team, resulted in six reports on paleontology, geology, ornithology and botany and numerous maps. This work was of immense scientific value, which in later decades would serve its purpose. A prime reason for the abolition of California Survey was the lack of clear perception of its task by those who established it and those who ran it. For the state government, research was a means to an end only, with the academic goal of more efficient exploitation of the natural resources. Whitney, a proponent of basic research, on the other hand was not bothered about producing immediate practical results or the need to be fraternal with his financial backers.

Even these days, the American Congress has a strong influence on what types of research gets funded and, generally, not very keen to see much funds going to basic research, which in all probability may not lead to applied work for quite some time. Super Conducting Super Collider (SSC) project was abandoned in early nineties under the same philosophy. Similarly, the Heavy-Ion Linear Accelerator (HILAC) and the Bevatron at Lawrence Berkeley National Laboratory (LBNL) could not be kept functional.

As seen above, basic research (also called fundamental or pure research), has the advancement of knowledge as its primary objectives. It is investigative in nature and is essentially motivated through the curiosity and inquisitiveness of the researcher. It is very often conducted without any practical end in mind, although the results may be put to useful practical applications many decades later.

Science: The Endless Frontier served as a template for scientific development in USA in the middle of the last century. A lesser known but a far more comprehensive and thorough and perhaps more important, report came out in 1947, less than a month after Bush had submitted his report to President Truman.

Earlier, impressed by his academic and other skills, President Truman had appointed J.R. Steelman as an Assistant to the President. Steelman, an Economy and Sociology Professor, the first ever holder of this position in the White House, was tasked to undertake a thorough analysis of the research activity in USA. As a result of his untiring efforts, just ten months later Steelman produced a six-volume document titled "Science and Public Policy: A Programme for the Nation"..

Traditionally, basic research was considered as an activity that preceded applied research, which in turn preceded development into practical applications. Basic research was characterized by the prevalence of basic scientists with doctoral degrees, concerned with making fundamental contributions to their fields. Applied research was undertaken by scientists with doctoral degrees and also by engineers with doctoral degrees, as well as by engineers with masters and bachelor's degrees. Work in this area is product- or process-oriented. At the level of 'development engineering' very few Ph.D.'s, particularly with physical science background, are to be found. With the recent developments in the fields of biochemistry, electronics and information technology where fundamental discoveries have been made alongside development of new products, these distinctions have started becoming blurred.

From 1945 to 1980, the attitude of funding basic science was generally favourable in most of the developed nations, as there was wide acceptance of the ideas promoted by Vannevar Bush, in his report mentioned earlier. This report argued that money spent on basic research would, in the long run bring about improvement in the socio-economic status of the people of a country. As long as enough cash was available, this idea prevailed. With added economic pressures, however, things started taking a turn about two decades ago, so that the emphasis now lies on research and development with definite end-objectives in view, while not abandoning basic research in its truest sense. A case in point is the decision by the Japanese Cabinet in 1996, which stipulates that the government will promote R&D activities, focusing specifically at the following socio-economic factors:

i. Invention of original and innovative technology, contributing towards the improvement in economy and establishment of new industries.
ii. Solving growing problems, related to environment, food and energy
iii. Contribution to prevention and treatment of diseases and handling natural disasters.
iv. The cabinet, however, also re-iterated that it supports basic research because:
    - the discovery of new laws and formulation of original theories contribute to the advancement of culture and provides a sense of pride to the people, and
    - discoveries in basic research sometimes bring about a technological revolution, and spin-offs are frequently very beneficial.

Gone also are the days of the Bell Lab and Xerox Corporation's Palo Alto Research Centre (PARC). The emphasis with the companies, today, is on development rather than investing large amounts, in term of manpower and resources, and more importantly time. When the big firms essentially had little global competition, they could afford this kind of luxury, but now in every field the race is on, not only to discover new ideas but to bring these ideas to fruition through practical applications with financial gains in a very short time. This does not mean that basic science is not being done; what has happened is that the Research and Development phases have merged. The researcher, also being involved in the development of applications, has to focus on the solution of immediate problems. It is argued that this fusion of research and development may solve the central shortcoming of Vannevar Bush's plan, i.e., how to turn useful ideas into commercial innovations.

SOME EXAMPLES FROM DEVELOPING COUNTRIES

Considering applied R&D as the backbone of industrial development, the countries of the Gulf Cooperation Council (GCC) have been actively involved in such activities, through universities and specialized research-centers, such as King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia and Kuwait Institute for Scientific Research (KISR) in Kuwait. While these institutes are playing a leading role in supporting the industrial research in their respective countries, some of the major oil and gas companies also have in-house R&D centers to support their research work, such as Saudi Basic Chemical.

King Abdulaziz City for Science and Technology (KACST) was founded in 1977 in Riyadh (Saudi Arabia) as one of the premier institutions for the development of science and technology in the Kingdom of Saudi Arabia. Its main activities are in the areas of applied S&T related to energy, industry, natural resources, remote sensing and seismology. KACST conducts applied research in numerous fields, including:

- *Solar Energy:* Photovoltaics, solar thermal systems, solar-hydrogen production, renewable-energy resources, buildings and energy.
- *Atomic Energy:* Radiation protection, environmental radiation measurements, science and nuclear technology.
- *Natural Resources and Environment:* Food resources, arid and semi-arid lands, earth sciences, environmental pollution, water technologies, spatial information.
- *Petroleum and Petrochemical Industries:* Industrial waste disposal outside the industrial cities, pre-feasibility studies of selected petrochemical industries, industrial survey of Saudi industries.
- *Astronomy and Geophysics:* National observatory project, lunar observatories, laser observatory project, national seismic network.
- *Remote Sensing:* Receiving information from space satellites and recording it, processing and analyzing remote sensing information, using remote sensing information in the exploration of minerals, geothermal studies.
- *Electronics and Computers:* Production of speaking boards for impaired children, advisory services, production and distribution of software in local language.

The Directorate of Technology at KACST offers consultancy services, to the local industry, on the transfer of appropriate technologies. For this purpose, the Directorate has developed a database that contains more than 55,000 technologies drawn from 30 countries in various fields of science and technology.

Founded in 1967, Kuwait Institute for Scientific Research (KISR) is one of the oldest institutes of its type in the GCC. Its activities are involved in the area of applied sciences and technology dealing with energy-construction, environment, agriculture, water and petrochemicals. It has a total staff of 735 members, including 127 research professionals. It includes the following research divisions (departments/ programmes):

- Engineering Division (Energy, Systems and Controls, Civil and Buildings)
- Environmental and Earth Sciences Division (Environmental Sciences)
- Food Resources Division (Agriculture, and Fisheries, Biotechnology, Food Technology)
- Petroleum, Petrochemicals and Materials Division (Oil Production, Petroleum Refining, Polymers and Petrochemicals, Corrosion and Materials Science)
- Techno-Economics Division (Economic Policy and Planning, Economic Studies)
- Water Resources Division (Water Desalination)

Adapting to the global change, Hong Kong University has lately reviewed its Vision and Mission as follows:

The emphasis placed by the University, over the years had predominantly been on "basic" or "fundamental" research. This led to a number of original research successes, with the resulting international publications, adding to the universities stature. Realizing the importance of contributing back to the society and community in a more useful way the University reviewed its vision and mission in 1998. The University is now committed to broadening the scope of its research to encompass applied research and development work, by working in close partnership with the industry, to bring about desired benefits to the society. The goal is to produce results of relevance to the community. More importantly the so-called "upstream" research work aimed at advancing the frontiers of human knowledge is to be extended to "midstream" and "downstream" research for technological development and industrialization.

As has been argued above, the traditional view that spin-offs from basic research lead to useful innovations for human kind is being abandoned even in the developed countries. For developing countries, the issue has to be viewed in a completely upside-down perspective.

As such, for developing countries, universities and the R&D organizations need to develop most of their resources to solving practical problems. Researchers participating in industrial research would not only have the satisfaction of achieving a goal, but the scientific importance could also gain visibility. The creation of knowledge and expansion of horizons would naturally follow.

As discussed below, for a country like Pakistan, this would certainly fit in very well with the policies in vogue. In Pakistan, a comprehensive Science and Technology policy was adopted in 1984, with the essential theme of achieving self-sufficiency in food and energy, improving national growth and providing support to the industrial sector. The subsequent Technology Policy also aimed at obtaining technology-based development by industry, using the latest technologies, in order to gain an edge in indigenous industrial growth.

Pakistan inherited a small scientific and technological infrastructure at the time of independence in 1947, with hardly any worthwhile scientific research taking place in the country. In 1959, a National Commission on Science & Technology was constituted which identified energy, agriculture and health as the priority areas of research. As a result of the recommendation of the commission in 1965, the subsequent fourth five-year plan, for the first time, carried a chapter specifically devoted to science & technology.

In 1970, a Scientific Review Committee and Professor Abdus Salam (Nobel Laureate) identified "Universities and Planning & Development Organization not being involved in research relevant to the Country's need" as one of the three fundamental defects of scientific research in the country.

The 1993 National Technology Policy (NTP) and the Technology Development Action-Plan ((TDAP), aimed at achieving the following objectives:

- To bridge the gap between international and local industry's technology practices
- To bridge the gap between the best and the sub-standard local industrial technology practices
- To improve and develop technology, and
- to develop technical manpower

The Science and Technology Vision for Pakistan identifies the goals as:

- To acquire world-class capabilities in scientific & technological research
- To use S&T as an engine for economic growth
- To improve quality & productivity in industrial processes
- To absorb proven technologies, to meet national needs

Chapter 30 of the Mid-Term Development Framework (MTDF) issued by the Ministry of Planning concludes with Government of Pakistan's commitment to intensify efforts towards innovation and technology-led development in order to meet the requirements of a knowledge-based economy. In order to keep pace with the technology advancements, the private sector has been urged to bring about an expansion in its R&D capacity.

Although the Steelman Report, like the Bush Report, identified basic research as the major support-well for the U.S. government, it went further and proposed what portion of finding it should receive. For example, the report suggested progressive increase in science funding so that, over a decade, it would reach 1% of the GNP, with the contribution to different sectors as follows:

- Basic Research - 20%
- Health & Medicine - 14%
- Military Research and Development - 22%
- Other Revenue & Development - 44%

John Horgan, the author of "The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age" is of the view that, because of the work of the scientists in particle physics, astronomy, and microbiology, etc., a general map of physical reality has come into being, which is not likely to change much in times to come. In his opinion, given how far science has already come, any further resulting addition to the knowledge already generated, would be a miniscule part of the whole. Moreover such additional knowledge in pure science is likely to be created by people working in highly sophisticated and well-equipped scientific centers, very expensive to establish and run.

There is, thus, an argument for the scientists, particularly in the developing countries, to pay more attention to applying the existing knowledge for practical applications. Along the way, however, they might make new discoveries filling in the small gaps in the established theories.

As we have seen, the debate has been raging with respect to basic and applied research in both developing and developed countries. Developed countries are fortunate to have enough funds to support basic research through universities, or dedicated research centers with effective transformation to commercialization, through industrial involvement, which is constantly looking to improve its products. In developing countries, however, where industrial participation in research is non-existent, it is difficult to direct funds towards discovery of new knowledge and mechanism to remaining at par with developed countries is lacking. This makes it a challenge to develop a competent high-tech community, to get international recognition, through publication in well known international journals carrying high impact factor that has become one of the most important benchmarking parameters to evaluate the performance of the researchers and the institutions worldwide. All developing countries are facing this dilemma of trained manpower that can bring the benefit of R&D spending to common man. India has been fortunate to capitalize through IT technology while Far Eastern countries took the advantage of breakthrough in steel making process and heavily invested in manpower to create highly skilled workforce who could compete in better products at lower cost and became the manufacturing hub of the developed countries.

The only hope for the developing countries is to invest in its manpower right from their primary schooling all the way to university education to give them better understanding of basic principles of science and its application instead of just rote learning for the sake of degrees and employment. Good understanding of the basic principles, at the graduate level, would result in better application towards applied research where its fruit can be harvested through solving the day to day problems of people. From this will emerge quality research and publications worth publishing in high impact journals while benefiting the society in general.

SUMMARY AND CONCLUSIONS

The debate about the relevant importance of basic and applied research is not new. In the United States – the world leader in, among other things, science and technology, during the nineteenth century, many state and federal institutions suffered due to alienation between the supporters of the two thoughts. Globally also, things are changing very rapidly. With increasing international competition, it is now being considered important to develop the scientific ideas into marketable products at the earliest possible moment. The culture of white-coated lab research, with no practical applications in the foreseeable future, is gradually disappearing in big corporations. The governments in Europe, as well as other developed nations are now reassessing their priorities. The universities all over the world are also revising their visions of research and related missions, giving due importance to applied research.

There is thus, a strong case for the developing nations to support research activities whose results could be put to practical use in a reasonably short, say period of 10 years.

With limited financial resources at hand, it is becoming increasingly important for developing nations to set right their priorities regarding the allocation of resources to basic and applied research. Starting with a historical review of the century-old debate about this issue, with special reference to USA, this chapter discusses the changing global perceptions, within the governments, and the large corporations and the universities etc. about financing pure research on a continued basis. Drawing upon these examples, the another concludes that developing nations should primarily invest in research activities likely to yield practical applications within a decade or so.

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BALANCING BASIC AND APPLIED SCIENCE AND RESEARCH: A DILEMMA FOR DEVELOPING COUNTRIES

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INTRODUCTION

We have seen great strides in development, through innovations in science and technology (S&T), during the past century. Much of that development was spurred by advances and focused on both basic research and applied use of knowledge that gradually led to enhanced application for betterment of human life.

Basic research is driven by scientists' curiosity or interest in a particular topic or subject. The main motivation here is to expand the knowledge-base and not to invent something. The invention that follows the cues arising from basic research, forms the applied component. As Dr. George Smoot of LBNL says: 'people cannot foresee the future well- enough to predict what's going to develop from basic research. If we only did applied research, we would still be making better spears" . Applied research is undertaken to solve practical problems of the world and to improve the human condition.

According to Dr. C. H. Llewellyn Smith of CERN, the connection of science and technology is neither linear nor anti-linear, but infact highly non-linear. Holton et al. (1996), claimed that the historical study of successful modern research has repeatedly shown that the interplay between initially unrelated basic knowledge, technology and products, is so intense that far from being separate and distinct, they are all portions of a tightly-woven fabric.

In times of rapid economic changes and often stagnant support from the public-sector, countries need to look at how ensuring investments into basic research does not lose out to supporting applied research, using the argument that applied research is more directly relevant to the people and society of today. One noticeable phenomenon in recent years is the diminishing division between basic and applied research.

In several countries there is a criticism that research, in general, is receiving less government support by which the results of such actions are made available to society, as against private-sector support that determines priorities based on markets and economics. Several countries started responding to this. In the US, the National Science Foundation told scientists that if their research does not address the connection between results and effects in the society, their proposals will be rejected.

However, the results of this norm were never encouraging, as it was often difficult for scientists and researchers to understand or estimate the effects of science and technology on society at all times and all levels.

But a lot of criticism disregards the potential benefits that one could gain from having a proper mix of basic and applied research that can contribute to local economies, creating high-quality jobs and revenues.

Today, whether it is basic or applied research, science and technology institutions as well as individuals practicing this have undergone significant restructuring and reshaping. The competition in the knowledge-market is growing very rapidly bringing forth the changes.

Two developments in the recent years are spearheading this change. Firstly, in many countries, government funding for basic research is either stagnant or reducing and in addition a significant portion of such support is coming on a contract basis. Such contracts are conditional on specific and measurable short-term objectives, thus, impinging on academic freedom and creativity. This concern is voiced by almost all research establishments across the world. Secondly, the entire work-culture of sharing information and knowledge among peers is seen to be getting eroded. As said earlier, scientists have moved away from the 'publish or perish' rush to 'patent or perish' dilemma. Increasing competition to secure funding is one of the reasons for this. This definitely is a big blow to basic research that works on issues of equity and society.

Scientists and researchers are still at a loss regarding adjustment or reaction to these changes. A right balance of basic and applied research priorities, development-appropriate guidelines for collaborative and sponsored research with private-sector, enhancement of skills to be food at cultural arguments, are critical for today's science to progress.

Given for this background, heavy investments in science and technology by several Asian countries are increasing. According to a recent survey conducted by the National Science Foundation, Asia has surpassed European Union's research and development activity, in 2002 itself. US-based multinational corporations nearly doubled investments in science and technology in Asia – doubling from a USD 1.5 billion in 1994 to USD 3.6 billion in 2002. The following table provides some indications of how the business-sector is booming in Asia, while the research and development expenditure in education and non-profit sectors are diminishing in Asia, as compared to other regions.

This makes the need for policy-makers and economists to sit back and address the issue of how to deal with increase in investments into science and research in the Asian region.

Table - 1: Research and Development Expenditures, by Performing-Sector and Selected Region and Country/Economy: 1995 and 2003–04

Percent distribution		Business	Higher education	Government	Private nonprofit
Asia	1995	62.9	17.9	15.6	3.6
	2003	69.8	12.2	16.8	1.3
EU-25	1995	62.1	20.8	16.3	0.9
	2003	64.1	22.0	12.7	1.2
United States	1995	70.5	12.3	14.0	3.2
	2004	70.1	13.6	12.2	4.1

EU = European Union

Note: Asia includes China, Japan, Singapore, South Korea, and Taiwan.

Source: *Organization for Economic Co-operation and Development, Main Science and Technology Indicators (2005) (www.lbl.gov).*

PUTTING BASIC RESEARCH AGAINST APPLIED RESEARCH

Even a topic like the above in our opinion is a misnomer. One could consider discussing basic or applied research, if they belong to a linear model according to which basic research leads to applied research, which in turn leads to product development contributing to the needs of our society. However, history shows us that this is not always true. As said by George Porter (Nobel Laureate in Chemistry), "thermodynamics owes more to the steam engine train than the steam engine owes to science". This in turn does not mean that we should subscribe to an anti-linear model where one argues that basis science has no contribution to make towards economic development (Kealey, 1996) . This is where we agree with the proposition of Llewellyn Smith (2006) where he opines that the connection between basic and applied research is neither linear nor anti-linear but non-linear .

It is in this context that we propose that one should move away from arguing about basic or applied research and begin focusing on 'Strategic Research' – where research is undertaken with some level of curiosity but with an interest to develop products. As suggested by J. J. Thomson, (credited with the discovery of the electron), in 1916, that applied science leads to improvement in old methods, while pure science leads to new methods .

HOW TO SUPPORT SCIENCTIFIC AND TECHNOLOGICAL RESEARCH?

For industry and private-sectors, with their deep pockets, taking care of applied research, who should fund and support basic research remains a critical question for policy makers and educationists / academia. Obviously, it should be the government through its public sector allocations. Since basic science is important for society as a whole, governments are responsible for supporting the same. Governments should support basic research not just for the benefits of acquiring knowledge but also for the spin offs they provide, the human resource capitals they develop as well as on ethical and cultural grounds (Smith, 2006). In his book tilted "The Price of Truth", David Resnick (2006) argues that modern science is intimately tied with the business world and with financial incentives.

An analysis published by CERN in 2006 highlights the dynamics of the Japanese experience in dealing with basic and applied research. It is argued that Japanese investment in applied science and technology was the origin of Japan's economic success in the 1980s. However, the figures for comparing the levels of investments in R&D as a percentage of GDP in the US and Japan indicate that Japan spends 2.9% in GDP on R&D while 81 % of it comes from private sector leaving little investments in basic research. In the USA the R&D expenditure is 2.7% of GDP with 53% of this coming from private sector. Considering the weakness of its support to basic research which might spur another set of economic benefits, the Japanese government prepared the Science and technology Basic Plan in 1996, committing a 50% increase in science funding for basic research. But figures are scant to gauge the delivery of this commitment.

WHERE SHOULD THE FOCUS BE - BASIC OR APPLIED RESEARCH?

We come across several arguments where economic, social and cultural considerations lead to support that public funding should be directed mainly towards basic research. However, it is difficult to forecast that all basic research will lead to societal good and result in applied research. One could argue that could a government do better if Mendel, who pronounced basic understanding of genetics, could not foresee development in genetic engineering?

If we assume that results of basic research are unpredictable this does not mean that economic incentives to arrive at applied solutions are futile. One cannot make generalizations with respect to supporting basic science research. The background to subject-area, the understanding gained, possible knowledge based solutions the research could bring in- all need to be carefully assessed. Prioritizing basic research in physical sciences cannot be based on same principles as in biological sciences, for example.

When one looks at applied research, it will be clear that advancements are many times driven by market dynamics that come with a backing from the private-sector and industry. Take for instance, advances in genetic engineering in agricultural crops. Most of the commercially available varieties are crops that were modified with agronomic characters having economic potential and market value- such as insect resistance, herbicide tolerance etc. Much of the commercially available crop varieties that are genetically modified are results of research from commercial ventures and private-sector. It is very hard to find private sector investing in crops that have very high consumption value than commercial value. However, almost everyone agrees to the fact that the success in genetic modification owes much to research in basic understanding of genetics and environment.

The above arguments brings in a dilemma – how to prioritize support to basic and/ or applied research? The answers can be as simple as: prioritization be context specific and time specific. For example, in 1978 the OECD Science and Technology Outlook found that the objectives for science and technology are not centrally defined and scientists decide priorities in fundamental science themselves. This, however, changed in 1993, when the UK Government prepared a White Paper on Science and Technology which was based on the premise that science and technology should support wealth creation leading to a "technology foresight" programme development. Through this, multi-disciplinary teams worked with multi-sectoral groups to come up with a list of topics that needed attention to tap markets and technologies.

One cannot agree more in today's science governance systems that the 'strategic planning' and 'strategic research' priorities are being completely revisited and redesigned to find a balance between public supported funding and private sector funding, between basic and applied research, between ethics and profitability and between society and science.

FUTURE SCENARIOS

The following broad priorities will define the future support for science and technology in the coming decades:

- Knowledge and skill base
- Basic research excellence
- Infrastructure
- Funding
- Responsive policy making
- Cooperation and consideration
- Networking and technology transfer.

We have to agree that basic science is good and important and that funding to continue basic research be secured. However, increasingly governments and public-sector institutions are running out of money. Where can they get support from?

This is where we need new and strategic science policies to be developed. Such policies should be pragmatic. Consider the above-mentioned broad priorities – policies supporting these priorities be flexible and open to change as experiences of implementation come in and be supported by not only scientists but also by economists and sociologists.

How shall such “Innovative Science Policy” look like? We propose the following options taking on from the outcomes of the Millennium Development Goals Task Force Report on Science, Technology and Innovation (2005) .

- **Improve Policy-Environment and Support Better S&T Governance**

Experiences from countries such as India, Malaysia, and China demonstrate that national science and technology missions – endorsed by their respective Prime Ministers or President – could be an effective way to deal with better governance of S&T related research, as well as, development of policy instruments to support development of specific areas of focus. Priority could be accorded to strategic areas of research such as biotechnology, nanotechnology, taxonomy, ICT, agriculture, healthcare, education and rural empowerment.

Each of these mission shall have a national and where relevant regional outlook, supported by a panel of eminent experts in the area of study, NGOs, community representatives, media and private sector. The mission shall have specific outlook on enhancing partnership approaches, better management of knowledge and skills besides being responsive to local needs and investment options.

- **Reinvigorating Research in Public-Sector Institutions**

A recent report published on the internet quotes Jeffrey Sachs, the advisor to UN Millennium Project, saying ‘ even today Africa is not touched by the three key drivers of green revolution in Asia, namely improved high-yielding seeds, availability and application of fertilizers and extension services’. It is a bit disheartening to note that Africa, in spite of its rich soil and crop resources is lagging behind in per-capita food production. One of the main reasons for this is the lack of support to public sector agencies and institutions that hold primary responsibility to securing food in Africa. While biotechnology and related research areas are being promoted vehemently in Africa, basic research into agronomy, physiology, post-harvest technology and agricultural extension is lagging behind.

This should change now. Governments should be encouraged to use the experiences of successful results of green revolution in Asia. If this has to be achieved, public sector and basic research needs strengthening. Probably some of the old and out-of-fashion areas of research such as plant breeding should be re-invigorated. Such a need also exists in other areas of human development such as primary healthcare and sanitation, water supply.

‘Innovation villages’ should be established where traditional and modern technology blends should be tried (such as participatory plant breeding; using GIS technology to deal with fish and water resources). Such centers of excellence should be nationally recognized and internationally supported. Innovative income generating options (but not alternate livelihood options) could be tried using options such as ‘development market places' of World Bank or the 'Biovillage' concept of government of India.

- **Build National Human-Capacities / Support Human-Resource Development**

In a recently published article by the National Academy of Sciences, USA, Micheal Teitelbaum (2006) confesses that the demand for more science trained workers seem to be real . The report also cites the increasing trend of employers not just to look for specially trained students (such as those with PhD) but also for postgraduates. Recent reports from academies of science reveal that employment opportunities are better for those with broad understanding of relevant disciplines, those with capacities to be a part of interdisciplinary teams, those with skills in computers and computing, project management and communication.

These scenarios drive home the point that in order to progress in research – teaching and training in schools and universities need to change. Entrepreneurial skill development and focus on enhancing talent that combines creativity, education, skills and knowledge is very important in research (Andreas Solimano, 2006) . Training in basic and applied research should be components of postgraduate degree programmes to equip students with better employability and to ensure that neither of the areas of research suffers.

- **Reaching the Unreached**

Though there is a lot of discussion about public-private partnerships in research and development, little seem to change the challenges basic research faced with. On one hand the private sector feels basic research is not being responsive to its needs while public sector continues its discourses on its role and responsibility to kindle human quest and curiosity, It has been proven beyond doubt that neither of them could do better in isolation, Public policy should support and encourage private sector investment in basic research,. Private sector should increase its focus on using basic research as an engine for its development and growth. Private sector does have a responsibility to see beyond the boundaries in terms of prospecting human and natural resources capital and be responsible to deal with local needs and support basic research and development. Successful partnerships such as from the US need to be replicated as far as possible.

- **Support Innovative Thinking and Action**

The future of both basic and applied research is very much dependent on the emergence and use of innovative actions and exploration of suitable policy options. Supporting technology transfer, technology incubation backed by public and open access to intellectual property rights, provision of alternate intellectual property models, exploring increases in venture capital investments, are some options that need careful consideration. Experiences from around the world on how science led policy development (such as space science) and policy led technology development and deployment (such as information and communication technology) need assessment and replication.

CONCLUSIONS

What we have attempted in this paper is to provide readers with various arguments and different scenarios. One should be cognizant of the fact that there is little than can be gained from either favoring basic or applied research. We need strategic research now that will help us bridge the increasing technological and knowledge divide. Our society needs both basic and applied research but how one ensures correct balance and support to carry on the research is critical and will depend on basic research being relevant and flexible and applied research being responsive.

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SECTION B

SOCIO-ECONOMIC DIMENSIONS FOR APPLICATION OF RESEARCH

BASIC AND APPLIED RESEARCH: ROLE IN ECONOMIC PROSPERITY

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1. INTRODUCTION

In examining the role of basic or applied research in economic prosperity, one first needs to consider different factors and the relative contributions of each component in the development of any nation. One specifically needs to focus on the crucial role of science and technology in achieving economic prosperity. Whereas there are several different ways in which science and technology impacts national development, one can illustrate this by using the example of available natural resources. There is, firstly, the need to identify the existing available national resources, and then to exploit those in an effective and optimal manner. Related closely to this, is the ability to use available knowledge and presently the well-known and globally accepted concept of knowledge based economy. These interacting factors can be graphically depicted as follows:

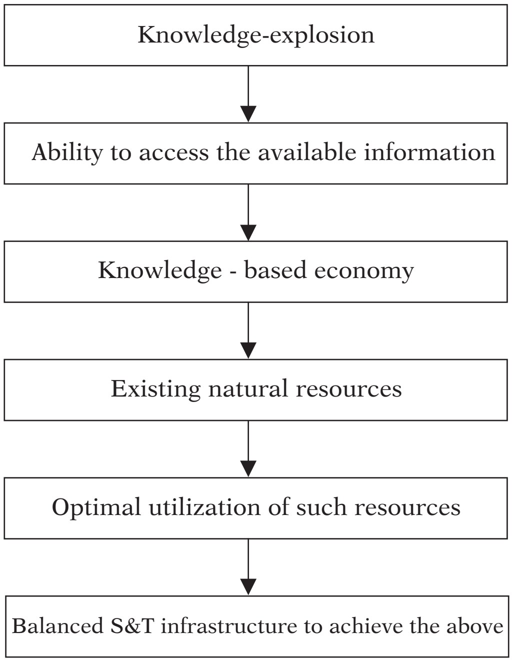

Figure - 1: Factors Contributing to Development

In this chapter we will try to find an appropriate approach that can lead to economic prosperity, and will answer some crucial questions such as: How poor countries can develop? The kind of research, would basic or applied or both should be adopted? Why poor countries are poor? What are the basic factors that usher nations to prosperity?

2. RESEARCH IN DEVELOPING COUNTRIES

The observations outlined above provide the conceptual framework to examine the role of basic and applied research and, hence, comment on the dilemma that developing nations must face and resolve.

In this discussion, taking into consideration the available natural resources, there is a need to use the example of countries like Japan. This example will clearly demonstrate that with a strong commitment and use of innovative technologies, a high degree of success is achievable, even in the absence of abundant excessive natural resources. In contrast to this, there are examples of countries blessed with rich natural resources and, yet, due to lack of a well thoughtout policy and innovate technology, they end up with much lower GDP. Even if natural resources are in abundance, this does not necessarily lead to economic prosperity. The following table compares total GDP of oil exporting countries' with the economic performance of a single knowledge and technology-based country, i.e. Japan.

In terms of the ultimate objectives at which the developing countries should aim meeting the Millennium Development Goals (MDGs) can serve the purpose. Among the eight stated goals, at least five can gain significant benefits from an integrated programme of basic and applied research in biotechnology and genetic engineering. Here we can examine Finland's example, which indicates that one major success can lead to economic prosperity. Finland produced Nokia mobile phone sets and generated huge amount of revenue, to the time of .....

Table- 1: Comparison of total GDP of Japan and OPEC Members from OIC Countries

OPEC Members from OIC Countries	GDP (US$ Billions)
Algeria	84.6
Indonesia	257.6
Iran	163.4
Kuwait	55.7
Libya	29.1
Nigeria	72.1
Qatar	20.4
Saudi Arabia	250.6
UAE	104.2
Total	**1037.7**
Japan	**4,622.8**

Source: *Human Development Report 2006*

a. Strategy

To examine the question of the relative emphasis on basic and applied research and the manner in which these two are inter-related, the examples from biotechnology and genetic engineering will be critically examined. Biotechnology is not a new technology, but it has brought a revolution in the development process of several countries. Many countries have excelled in this technology, examples are Cuba, China, Brazil and India. We compared the basic components of biotechnology related policies of these countries and found no significant difference. Primarily, there is a focused and well-defined approach, with emphasis on production of industrially useful pharmaceuticals and transgenic crops. Developing countries can follow the policies prepared by some of the countries mentioned above. It, however, needs to be emphasized that any such approach has to be country-specific. Hence, the starting point always has to be to clearly define the needs and priorities of the country in question. This concept can be called "borrowed vision", which leads to the conclusion that enough has been said, done and written on this and now it is time to reap benefits from that existing knowledge by an effective implementation.

Thus, another important consideration is that any future strategy has to be "country-specific". The ability to undertake basic research is largely determined by the existing infrastructure and available skilled manpower. This once again is "Discipline-specific". It is obviously much easier to work on plant tissue-culture than on electronic engineering or computational biology. Such choices become an integral part of the determination of national priorities.

A prerequisite to this is the in-depth analysis of the needs of a country. This is best illustrated by two very impressive reports by Dr. S.T.K. Naim, dealing with Maldives and Nigeria. These reports present the country-profile, national sources, earlier studies and resulting recommendations. So, the first task is to have a national strategy based on a sound scientific policy. The effective use of basic research would obviously require public-private partnership. Dr. S.T.K. Naim has prepared S&T policies for Maldives, Nigeria, as well as S&T policy for industrialization.

1. ***Maldives:*** The report provides policy-guidelines for S&T policy-consultants. It identifies priority-areas, where government's intervention is required and key technologies, of particular relevance to Maldives, where research efforts need to be supported. For donors' support, the issues identified in the S&T Master-Plan in each of the sectors are highlighted. Some priority projects have been proposed for building Maldivian scientific, technological and innovation capabilities. The list of international organizations/banks/agencies that provide scholarships for training of manpower or research grants for addressing local problems of developing countries is also attached.
2. ***Nigeria:*** S&T policy for Nigeria provides a selection of concrete steps towards a successful national S&T policy appropriate to the current challenges for socio-economic development in Nigeria and based on an in-depth survey of

the international experience of successful S&T policies in countries in the developed, as well as developing world. These two elements – the combination of international experience, as well as, in-depth knowledge of the Nigerian context – are characteristic of the team that has produced this report as it is based on both Nigerian as well as international experts in the area of S&T, education and economic development. The report is not merely an abstract, it is not aiming at building an Utopian long-run plan for developing an Utopian S&T policy in an Utopian country. On the contrary, it starts from Nigeria's experience and then prioritizes steps that should be taken tomorrow.

b. Implementation

For developing countries, one of the major causes of failure is the highly ineffective implementation-mechanisms. Now, seems to be an appropriate time to carry these discussions further with a greater sense of seriousness, dedication and commitment. This is not to imply that searches for cures of our ailments have not been talked about earlier. In fact, strategies have already been discussed and the priorities clearly stated. One, therefore, does not need much imagination to conclude that the real rate-limiting-step in this series of chain-reactions is the actual implementation of the known remedies. We must therefore, understand that mere lip-service, empty pronouncements, verbal commitments, unfulfilled promises and half-hearted measures cannot cure the deep-rooted and serious malaise. What we need is a firm, honest commitment to endeavor to resolve problems with sincere devotion, at the earliest. One observes this in many of our international symposia and conferences where the prevalent end-result is NATO (no action, talk only). It is about time that we realize that this formula has now been tried and practiced for a longtime and does not lead to any tangible achievements.

3. BASIC AND APPLIED RESEARCH

A historical and objective review of the traditions of science and technology will clearly illustrate how basic and applied research are so closely related that any attempt to separate those into two distinct categories would be futile and meaningless.

"Traditionally, basic and applied research were seen as activities of a different nature, carried out by different institutions and financed from different sources. But in the 1970s and 1980s, the information and communication technologies, later reinforced by biotechnology, started a trend in which it became increasingly important to turn scientific research into concrete products. Whole industries were built around the notion of developing new commodities and services from basic research, as quickly as possible. As a result of these new economic developments, the strict division between basic and applied research in those fields has weakened, until the boundaries have become obsolete and sometimes artificial." Table - 2 shows three typical examples from Biotechnology.

Table - 2: The Conversion of Basic Research into Applications

Basic Research	Application
Polymerase Chain Reaction (PCR) **PCR** is a biochemistry and molecular biology technique for exponentially amplifying DNA, via enzymatic replication, without using a living organism (such as *E. coli* or yeast). As PCR is an *in vitro* technique, it can be performed without restrictions on the form of DNA, and it can be extensively modified to perform a wide array of genetic manipulations.	PCR technique is being used in medical and biological research labs for a variety of tasks, such as the detection of hereditary diseases, the identification of genetic fingerprints, the diagnosis of infectious diseases, the cloning of genes, paternity testing, and DNA computing.
Plant Tissue Culture also called micropropagation, is a practice used to propagate plants under sterile conditions, often to produce clones of a plant.	Micropropagation is widely used in forestry, floriculture to conserve rare or endangered plant species, to produce large numbers of identical individuals, to cross distantly related species by protoplast fusion and regeneration of the novel hybrid.
Stem Cell Research **Stem cells** are primal cells found in all multi-cellular organisms that retain the ability to renew themselves through mitotic cell division and can differentiate into a diverse range of specialized cell types.	Stem cell therapy has the potential for treatment of human diseases for example heart and liver repair. A number of adult stem cell therapies already exist, particularly bone marrow transplants that are used to treat leukemia. Medical researchers anticipate being able to use technologies derived from stem cell research to treat a wider variety of diseases including cancer, parkinson's disease, spinal cord injuries, heart diseases and muscle damage, amongst a number of other impairments and conditions.
Recombinant DNA **Recombinant DNA** is a form of artificial DNA which is engineered through the combination or insertion of one or more DNA strands, thereby combining DNA sequences which would not normally occur together.	These techniques are widely used to produce Insulin or even antibiotics.

continue...

...Table-2 Continued

Plasmids A **plasmid** is a DNA molecule separate from the chromosomal DNA and capable of autonomous replication. It is typically circular and double-stranded. **Ligation** **DNA ligase** is a particular type of ligase that can link together DNA strands. **Restriction enzymes** A **restriction enzyme** (or **restriction endonuclease**) is an enzyme that cuts double-stranded DNA.	
Cloning **Cloning** is the process of creating an identical copy of something. In biology, it collectively refers to processes used to create copies of DNA fragments (molecular cloning), cells (cell cloning), or organisms.	Production of Insulin, Interferon and Growth Hormones

Basic research has very often led to concrete applications. Biotechnology, Molecular Biology, and Genetic Engineering provide the best recent example of how basic research has led to revolutionary economic prosperity. Fermentation, restriction enzymes, DNA sequencing, Polymerase Chain Reaction (PCR) have all led scientists to bring changes in the structure of DNA. These techniques helped in diagnostics, finding cure for infectious diseases and crime detection. How basic research very significantly impacts industrial progress and economic benefits is best illustrated by using the example of new biotechnology and genetic engineering.

It is important to emphasize that good basic research can not be without purpose. Curiosity driven research with a defined mission is highly-likely to be useful for society. For example searching the causes of cancer and finding cure for this deadly disease. It is however important to point out that it is difficult for the developing countries to do highly sophisticated and expensive basic research because they do not have state-of-the-art laboratories to conduct such research. Researchers in the developing world must remain conscious and aware of the recent knowledge, and they must develop skills to apply existing knowledge to problems which have high national priority in their homeland. This need itself is a major challenge and would require consistent and continuing efforts focused on capacity building.

Here we would like to make a specific strategy related suggestion for the manner in which scientific research should be carried out in developing countries. Developing countries must very clearly understand that any significant change in the present conditions would require drastic changes. Whereas this approach would need a large number of different initiatives; the one that stands out as the very first step is to examine and reconsider the system currently prevalent for distribution and award of research grants. A new system developed and implemented by a group of experienced, visionary and eminent scientists working under a national organization like science foundation, or planning commission should identify mega national projects. This choice obviously will be dictated by the needs and national priorities of any nation. Such projects could then be assigned to a core group of research scientists; each one assigned a well-defined role. This kind of commitment and collaborative mode of action must become a precondition for award of any major research grant.

The entire research system should be guided by either a committee of experts, an organization or a national group of experienced eminent scientists who can provide the outlines and specific mega national projects. Such selected projects can then be assigned to different groups of qualified scientists. Once such projects have been chosen in the light of national priorities, researchers should collaborate in an effective and interactive manner. Funding of such major national projects should be only made available to those prepared to work as a team. This will result in the much needed collaborative effort which unfortunately is lacking in developing countries. To effectively implement this policy there is a need to strictly emphasize and insist on making joint collaborative projects. Failing to do so should then lead to lack of any financial support or funding by government organizations.

So our basic view is that it is neither plausible nor required to make an unnecessary distinction between basic and applied research. A successful national strategy is to aim for and end up with an "optimal blend" of the two in the light of well-defined national priorities determined on the basis of both national resources and needs. This is the kind of visionary approach that has led to success stories like Japan, Korea, Finland, Cuba, India and Brazil. One can find many examples of how this national commitment has resulted in major and highly visible achievements. The sequencing of Rice genome in China is one such example.

One can illustrate the above suggestion by using the example of Pakistan's. Economy based on agriculture.

For an agricultural country like Pakistan the emphasis on research in the area of "agricultural biotechnology", is an appropriate approach. The impact of earlier basic research and techniques on the production of transgenic crops like Bt Cotton is a very good example to illustrate the relationship between basic and applied research.

For Pakistan, mega-national projects in the area of agriculture, transgenic crops, curl leaf virus resistance would be best example. Research activities cannot be left to the individual scientists moving along their own "solo flight" approach and failing or refusing to become part of a national collaborative effort. In this approach there is of course extreme care needed to leave enough room for the expression and fulfillment of individual creativity. Within the framework of national needs every one could positively contribute using given skills and capabilities. This suggested proposal would also require rigorous and continuing monitoring and accountability. All these projects will be critically peer reviewed by experts.

4. KNOWLEDGE-BASED ECONOMY

Today around the world countries are striving for “knowledge based economy”. The dilemma of the developing countries is that no adequate infrastructure to meet the requirements of knowledge based economy exist.

Hence, the smart approach is to develop the capacity and ability to keep up with and assimilate new knowledge. This again is not an easy task. In the absence of prestigious and outstanding universities and research institutes, it is absolutely unthinkable to expect to benefit from knowledge-based economy. This is no small task and the magnitude and dimensions of this challenge can be appreciated by looking at the current programmes of Higher Education Commission in Pakistan.

Knowledge-explosion has occurred; knowledge is being doubled at yearly basis in different fields of studies. Now there is a problem for developing countries how to keep up with this. One among many new initiatives is establishing digital libraries as has already been achieved in Pakistan.

There are a few basic realities and accompanying notions that need to be stated. Firstly, the pace at which new knowledge is being generated has indeed no parallel in early history. The ease with which one can access available information is just as impressive. It has been estimated that whereas the total knowledge pool in other areas will double in six to seven years, for life sciences such doubling time is estimated to be nearly three years. This new scenario provides not only an extremely rich and almost unmanageable store of data but also poses a serious challenge for an effective and meaningful approach towards a focused discussion.

Thus, there is a dire need for scientists, academicians and policy makers to realise that computers and other highly sophisticated devices have dramatically changed our ability to acquire, store and retrieve information. So how do we cope with this knowledge explosion? Internet, ISP’s enable us to download enormous amount of data in no time – that fact alone poses a serious challenge of how to manage, coordinate, analyse, draw conclusions, develop guidelines and then formulate effective strategies to cope with future challenges.

In all such discussions it has to be clearly understood that there are no secrets or mysteries underlying the causes of success. We can find many examples of successful countries such as Japan, Korea, Finland and USA. These countries did not use any mysterious powers which were unknown to other countries that are underdeveloped or called developing countries. Successful countries set well defined goals and strive to achieve them and thus succeeded in their endeavors.

There are really no new ideas that have not been talked about or documented. Prof. C. Auerbach (my Ph.D. supervisor) used to say "If you read all the papers that H.J. Muller (two times Nobel Prize winner) has written, you will come to the conclusion that there is no idea or concept in biological sciences that H. J. Muller, two times nobel prize winner did not think of". Using the knowledge that is already available with special skill, capacity and training can help poor countries to develop. At the very beginning, poor countries do not need to bring new knowledge and breakthroughs into the existing pool; for just taking off they should strive to benefit from the existing knowledge and traditional practices. This imply taking what is available within the country and making the best use of it, to begin with.

5. CONCLUSIONS

In view of all the above considerations, the reality that emerges is that the most important distinction is between meaningful, well thoughtout and well-planned versus adhoc approach to scientific research. This distinction and the relevant decisions are obviously dependent on the intellectual capability of the decision-makers. As is often stated, "A journey well begun is half done".

It is this crucial beginning that will bring in a balanced and optimal mix of basic and applied research, closely related to the country-specific ground realities of any community. The example of research in new biotechnology clearly demonstrates that good basic research effectively feeds into applications that result in tangible economic benefits.

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GOAL-ORIENTED RESEARCH: A RECIPE FOR ECONOMIC DEVELOPMENT

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1. INTRODUCTION

Linus Pauling, winner of two unshared Nobel Prizes in Chemistry and Peace, referred to academic research in 1950, as "that which is carried out in an effort to increase our understanding of the nature of the world in which we live. It does not have, as its primary purpose, the solution of any practical problem; but it is fundamental to practical progress, since the discoveries made by the workers in pure science, of one generation, provide the basis for the great industries of the next generation".

The Twentieth Century has been the century of many fundamental discoveries in natural sciences; the majority of these discoveries could be regarded as an outcome of academic or basic research, which at the time of discovery were not required to solve any practical problem. However, all these discoveries had a far reaching affect on the development of science & technology for industrialization and economic development. This phenomenon is well demonstrated by the discoveries in life-sciences during the early 20th century. The elucidation of the structure of DNA was the beginning of unraveling of a series of secrets of life. All these, at the time of discovery, were still pursuits in fundamental research without any initial application. All these findings resulted in the award of series of Nobel Prizes and resulted in development of modern biotechnology, which is now considered to be the most important tool for the development of agriculture and the healthcare industry.

In all these developments, the contribution of the developing world is minimal. It is now well-established that the countries that have invested heavily in science and technology have been able to achieve rapid economic growth. The examples of Korea, Malaysia, China and Singapore are worth mentioning. The situation in other developing countries is now improving, due to a strong realization that without building a strong science-base, it may not be possible to even use the already available scientific information. It is with this rationale that an impressive investment in science and technology and human-resource development is being made in Pakistan. Several institutes of science and technology and universities are being established that are primarily entrusted with the job of not only creating new knowledge, but also to use the globally existing information for developing technologies suitable for benefit of the public, thereby contributing to economic development.

Thus, the debate about basic versus applied research becomes irrelevant in the existing *scenario of many of the developing countries, where we would like to use science for direct economic development and the alleviation of poverty*.

In order to have a direct impact of science on society, it is essential to have goal-oriented research, which is directed towards solving a certain problem. Such an approach assumes that, if necessary, a certain amount of 'basic research' has to be carried out for solving the selected problem. Whether basic or applied, the methodology and quality of research cannot be compromised. The findings of these researches have to be published in peer-reviewed journals, presented in scientific conferences, etc., in order to ensure the quality of research. This is the only internationally accepted methodology for conducting proper scientific research. Generally in developing countries, science managers of R&D institutes, and even rectors of the universities, do not give due weightage or due importance to publications because (for them), delivery of a product or a process is more important. This tendency results in half-baked products and erroneous processes. Therefore, it is essential, while undertaking goal-oriented research, to subject the results to peer review, through publications and presentations in scientific meetings.

Since we have been involved in biological research related to agriculture and biotechnology, I would like to elucidate this approach by giving a few examples from our own research projects, which we carried out over the last 30 years at the Nuclear Institute for Agriculture and Biology (NIAB) and National Institute for Biotechnology and Genetic Engineering (NIBGE), in Faisalabad.

2. DEVELOPMENT OF BIOSALINE-AGRICULTURE TECHNOLOGY

Salinization of soils and ground-water is a major soil degradation problem that is growing steadily in many parts of the world. Salinity is reported to affect about one billion hectares, particularly in arid and semi-arid regions. In Asia, Pakistan and India are among the worst affected countries and the situation in China also is not different. Salinity has adverse social and economic effects on communities, resulting in poor living standards. Finding ways to make saline wastelands productive, will permit better land-use and will lessen risk of further degradation. The decreasing fresh-water resources, coupled with increasing demand for food and raw materials, is a problem common to many areas of the world.

In Pakistan, the total salinized area consists of 5.83 million hectares of arable land; 1.25 million hectares falling in the canal-commanded area while 4.58 million hectares is outside it. This salinity has adversely affected the soils' chemical and physical characteristics, making it unfit for conventional crop-production. Of all the salinized lands, 1.95 million ha is saline, 1.74 million hectares saline-sodic and 0.0029 million hectares sodic. The salt-affected soils are not only saline, but also impermeable, devoid of organic matter and biological activity, and their physico-chemical characteristics have been altered making these 'dead' or 'sick' soils.

It seems that a durable solution of the salinity and water-logging problems may take a long time and we may have to learn to live with salinity and to find other ways to optimally utilize the affected lands. In order to achieve this goal, a series of studies were conducted, which included the following:

- *Biology of saline-soil was studied.* It comprised of studies on the isolation and characterization of microflora from these soils and their role in decomposition of plant-residues and other biochemical activities (1,2,3,5,8,9,10,11,12,13).
- *Physical and chemical properties of such soils and changes due to plant-growth were studied.* This included the studies on changes in hydraulic conductivity and bulk density due to plant-growth (6,7,19,21,26,28,29,30,31,32,33).
- *A large collection of germplasm obtained from different countries was screened* under uniform conditions for their ability to tolerate various levels of salinity. The information, thus, obtained was validated in the field. This resulted in selection of various grasses, shrubs and trees for different salinity levels in the soils (4,17,20,27)
- *Physiology and ecology of most promising salt tolerant plants was studied.* This included studies on agronomy of these plants so that these could be cultivated on large areas of salt affected soils (14,15,22,29,34).
- *Studies were carried out* on various uses of the biomass produced on saline-soils with a view to increase the income of farmers (16,18,19,23,27,34).

All the above-mentioned studies resulted in a series of research papers published in various refereed journals. Such studies gradually evolved to develop a Biosaline-Agriculture Technology, which has now been defined as 'the profitable and integrated use of genetic resources (plants, animals, fish, insects and microorganisms) and improved agricultural practices in order to obtain better use from saline land and saline irrigation-water on a sustained basis. A schematic illustration is presented in Figure-1.

Majority of these studies, if seen in isolation, could be termed as academic research, resulting in increase of our "understanding of the nature of the world we live in". However, all these studies combine to achieve the goal of utilizing salt-affected soils through an integrated approach.

In order to transfer this technology to the end-users, a 'Farmers Participatory BioSaline Agriculture Project' was launched in 2002 at 5 locations, covering nearly 25,000 acres of salt-affected land. The approach was to transfer the technology through community-mobilization and by establishing demonstration-sites. Based on the results of this project, a National BioSaline Agriculture Program has been launched, at a cost of Rs 800 million, in 13 districts that are predominantly saline.

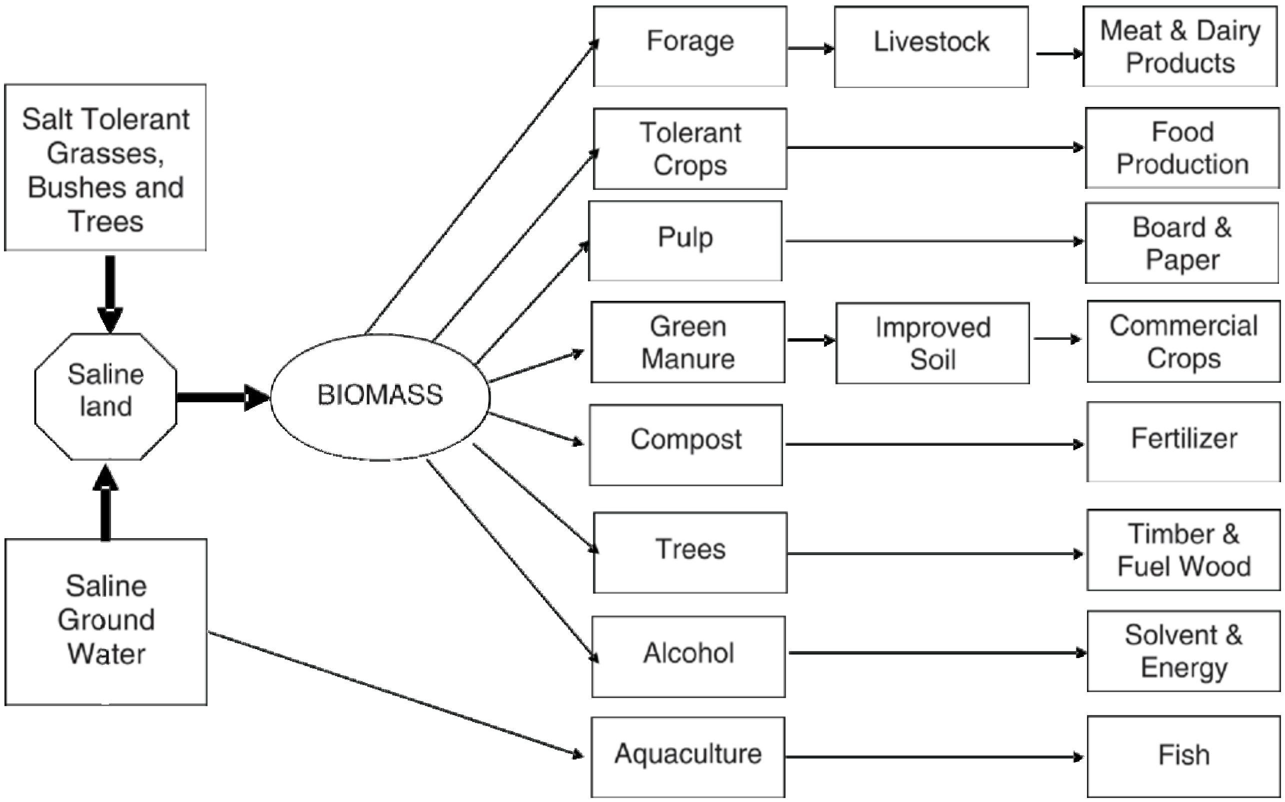

Figure - 1: Schematic Presentation of Integrated Biosaline Agriculture Approach

3. DEVELOPMENT OF ABIOTIC STRESS-TOLERANT CROPS THROUGH GENETIC ENGINEERING

Salinity and drought are the two major abiotic stresses, that account for more losses in crop productivity, than any other factor, and a constraint to food production. Pakistan is located in arid and semi-arid regions of the world. Salinity is becoming a serious problem in canal-irrigated plains of Punjab and Sindh provinces, and in some parts of NWFP and Balochistan. Pakistan is facing severe shortage of irrigation water. Low rainfall in arid regions affects the seed-germination and subsequent stages of plant growth. To maintain high yield under drought (no/low water) and salt-stress is the most persistent problem. It is now much more importance to grow stress- tolerant plants for sustainable food production.

Studies on biology of saline soils and physiology and ecology of salt-tolerant plants, gave us insight into the mechanisms of osmoregulation (salt-tolerance) in some of the salt-tolerant plants (37) and some bacteria isolated from the rhizosphere. This led us onto the detailed studies of osmo- regulation, discovery of different osmoproectants in these plants and their role in osmoregulation. These studies lead to many interesting findings. For example, a bacterium was isolated from the roots of Kallar grass (a salt tolerant grass) and was identified as Klebsiella Sp NIAB-1 (36). It was shown to harbor a plasmid, which conferred salt-tolerance (35). Similarly some yeast were isolated from saline soils and were found to tolerate up to 15% NaCl and 50% glucose in the culture medium. These microorganisms have proved to be excellent model-systems for studying osmo-regulation and, identifying various genes involved in imparting osmo-protection (38,39).

With the incorporation of transgene technology, breeding of stress-tolerant crops will be possible with far fewer target genes than has been anticipated before. In addition, a number of salt and drought-related genes have been identified and cloned by different laboratories around the world. Some of these genes are listed below, with their functions related to salt and drought tolerance:

i. AtNHX1:- This gene is a sodium proton-antiporter isolated from Arabidopsis thaliana. This gene has been cloned at NIBGE.
ii. Na^+/H^+ antiporter from Kallar grass:- The homologue of AtNHX1 will be cloned from Kallar grass.
iii. AVPI:- This is a vacuolar pyrophosphate H^+ pump. Transgenic plants show enhanced tolerance to salinity and drought stresses. This gene is available at NIBGE.
iv. CtHSR1:- This gene encodes a transcription factor related to heat-shock family and isolated from Candida tropicalis, which confers salt-tolerance in Yeast and Tobacco.
v. HKT1:- This high-affinity potassium-transporter gene regulates the K^+ and Na^+ transport (symporter) across the membrane. It will be cloned from wheat.
vi. MtSK1:- MtSK1 is a serine threonine kinase that is involved in signal transduction

(SOS pathway).

vii. DREB1:- DREB1 is a transcription factor and it's over-expression increases drought-tolerance in plants.

viii. Trehalose: Engineering stress tolerance in sugarcane by over-expressing yeast gene.

ix. Proline: Genetic engineering of ornithine to proline pathway in oilseed Brassica for improved drought-tolerance.

These genes are being introduced into crop plants, after careful evaluation of the above-mentioned genes in the model system (tobacco). Transformation-systems in various crops (cotton, rice, sugarcane, brassica) have already been developed. We have made considerable progress in development of transgenic plants of cotton, rice, tobacco, etc., through Agrobacterium as well as Biolistic process. Recent successes include the development of synthetic insect-resistance genes and development of broad-spectrum insect-resistant plants.

In spite of the availability of such genes and some successes in introducing stress-tolerance, our ability to improve plant stress-tolerance remains limited, due to our lack of understanding of the inherent complexity of stress-signaling and adaptation process. Understanding the role of reactive oxygen species and scavenging mechanisms, gene-expression profiling through micro-array analysis, study of stress-inducible promoters and transcription factors and proteome reference maps will allow a global view of how plants integrate salinity and drought-tolerance response. These are the areas where more 'fundamental or basic or academic' research is needed. Results of all these studies will be of immediate benefit to the project with the 'Goal' of developing salt and drought-tolerant plants.

4. DEVELOPMENT OF COTTON-RESISTANT TO COTTON LEAF CURL VIRUS (CLCuV)

Cotton is our most important cash crop, being grown on nearly 3 million acres. Nearly 60% of our export is dependent on this crop. In 1992 there was an outbreak of CLCuV disease, which resulted in drastic reduction in production. During the first five years of its outbreak, this disease resulted in a loss of more than 7 million bales of cotton with an estimated value of US$ 5 billion. The symptoms of the disease include upward and downward curling of leaves, with thickening and darkening of both main and lateral veins. These thick dark veins often differentiate into cup-shaped leaf-like structures on the underside of the leaf. The disease results in stunted plant growth, with loss in yield.

In order to combat this problem, a project was designed with the goal to develop virus-resistant plants and devise strategies to manage this disease. This is a typical project where role of basic information, regarding the virus, its molecular characterization and genetic diversity was crucial for making a strategy for developing virus-resistance in cotton through genetic engineering. It has been shown that the disease is transmitted by whiteflies from cotton to cotton and to other alternate hosts. It was also found that temperature, light intensity and whitefly biotypes significantly affected transmission efficiency (41).

This project was carried out systematically with the following steps. The results thus obtained were published in internationally refereed journals. The editorial comments and reviews of our research papers helped us to adopt a proper scientific approach for achieving our goal.

- Isolation of CLCuV gaminate particles from infected cotton-leaves (40)
- Molecular characterization and genetic diversity in CLCuV collected from different cotton-growing areas of Punjab (41,42, 43, 44,45-53)
- Molecular epidemiology of CLCuV (54,55,56,57)
- Development of cotton transformation system (58)
- Construction of recombinant DNA constructs, derived from viral genome (59,60,61)
- Development of other strategies, such as, antisense RNA, RIP and RNAi for imparting resistance (62)

These studies resulted in development of several transgenic lines of cotton cultivars, which are now undergoing various stages of evaluation and subsequent seed multiplication.

This project resulted in four PhD and several MSc/MPhil theses; more than 50 International research publications in good refereed journals, several presentations at scientific meetings and the establishment of international collaborations. While undertaking such Goal-Oriented Research project, the distinction between basic and applied research seems to vanish, as each study is contributing to the understanding of the nature of things and also helping to achieve the main goal of the project.

5. BIOLOGICAL NITROGEN-FIXATION: DEVELOPMENT OF A BIOFERTILIZER

Nitrogen is the nutrient that most frequently limits agricultural production. Global agriculture now relies heavily on N-fertilizers derived at the expense of petroleum or gas, which in turn is vulnerable to political and economic fluctuations in the oil/gas markets. Nitrogen fertilizers, therefore, are expensive inputs, costing agriculture more than $ 45 billion (US) per year.

In the soil, nitrogen is recycled through the activities of several types of micro-organisms. Conversion of atmospheric nitrogen to ammonical forms, which is useable by plants, is mediated by some of the bacteria, generally referred to as nitrogen-fixing bacteria, which perform this function with the help of an enzyme called ‘nitrogenase’. In the industrial production of nitrogenous fertilizers, N from the atmosphere and hydrogen from methane gas is combined, under high temperature and pressure, to form ammonia (Haber-Bosch Process), which is then further converted into a fertilizer, may it be urea or ammonium sulphate. The nitrogenase enzyme of these bacteria practically do the same conversion, but without the input of huge energy.

The phenomenon of biological nitrogen-fixation is well studied in legumes, where Rhizobium, a nitrogen-fixing bacterium, forms root-nodules (which is the site of nitrogen-fixation) through which the legume derives its nitrogen. This is referred to as 'Symbiotic Nitrogen-Fixation'.

During our studies with Leptochloa fusca (Kallar grass) growing in saline-soils, it was observed that, in spite of a very low fertility of soil with negligible soil-nitrogen, the grass was growing luxuriantly. This led to the investigation of its rhizosphere for the presence of root-associated nitrogen-fixation. Using various techniques, we were able to demonstrate, for the first time, the presence of nitrogenase-activity associated with its roots (63,64) and were able to isolate a number of nitrogen fixing bacteria from the root-surface and its interior (68,69,70,71). This led us to screen several plants growing in saline soils for similar nitrogen-fixation associated with roots of these plants. It also enabled us to isolate bacteria with greater diversity. Various studies were carried out to quantify the nitrogen-fixed using N15 stable isotope.(65,66,67,72,75,80).

The growth habitat of kallar grass is similar to lowland rice. Thus, basic information and knowledge obtained from nitrogen-fixation associated with its roots could be directly applied to rice, which is grown on a much larger area, where substantial amount of nitrogenous fertilizer is applied (84,85,87). With the objective of developing a biofertilizer for cereals, detailed studies on all the isolated bacteria were carried out. It was found that certain bacteria have properties in addition to nitrogen fixation that can be useful for growth of plants. Therefore, all such bacteria were systematically screened for:

i. Nitrogen-fixation,
ii. Phytohormone production,
iii. Phosphorous solubilization,
iv. Zinc mobilization, and
v. Bacteriocin production

All the screened strains, which showed some of these properties, were considered as Plant Growth-Promoting Rhizobacteria (PGPR) (86,88,89,90,91,92,93) In order to further elucidate their role in the rhizosphere, serological studies were carried out, using fluorescent antibodies prepared for the bacteria being used as inoculum. In addition, electron-microscopy and fluorescent in-situ hybridization (FISH) was carried out, to observe colonization of the root-surface, root-tissues and presence of bacterial cells in the intracellular spaces.

As a result of these studies, a biofertilizer has been developed that is presently being marketed under the trade name of "BioPower". Biofertilizers are defined as preparations containing live, non-pathogenic micro-organisms, which are beneficial to agricultural production in terms of nutrient-supply. Developing a beneficial bacterial strain into a biofertilizer needs several steps. In addition, the strains suitable for producing biofertilizers must possess some, if not all, of the following properties:

- Ability of survival in a wide range of environments
- Competitive ability
- Nitrogen fixing, phosphorous-solubilizing and plant-growth promotion
- Infectivity and efficiency in the presence of soil N
- Ability to multiply in liquid-culture
- Survival on the seed-carrier
- Survival under adverse environmental conditions
- Tolerance to pH changes, agrochemicals (pesticides), and
- Genetic stability during growth and storage

After selection of the strains, an appropriate consortium has to be developed, which should include the requisite properties and should be crop-specific. For this purpose, appropriate quality-control and methods for monitoring of the inoculated organisms is essential. Several methods, including serological techniques, tagging of the strains with detectable markers and PCR based 16sRNA probes, are being developed.

Some of the steps that are essential for the development of a commercial biofertilizer are as follows:

- Selection of the strains,
- Large-scale production of the selected strains,
- Carrier selection and its preparation,
- Mixing and curing,
- Maintenance of appropriate number of bacterial cells, and
- Stringent quality-control

Following all these steps, Biofertilizer produced under the trade-name of BioPower has been extensively tested on the following crops in the greenhouse, in the fields and on the farmers' fields, for rice, legumes (chick pea, mung bean, lentils, pea, Medicago), wheat, cotton, and maize. The provincial agriculture-extension department of Punjab also independently evaluated BioPower for rice.

This project on biofertilizers, which started with the discovery of nitrogen-fixation associated with roots of kallar grass, about 25 years ago, culminated into a commercial product. During this period, numerous publications were made, 6 PhD theses have already been produced and some are still in progress. The R&D work still continues for the improvement of biofertilizer with the introduction of new, more active bacterial strains.

5.1 Issues Concerning Commercialization

It is generally observed that all the processes, products or technologies developed in the Universities and R&D Institutes are not made available to the end-users, may it be the industry or farming community. Even in Agriculture, where extension departments are well established, transfer of technology and its effective utilization is not easy. Such problems are encountered in many developing countries. In our experience, the onus of transfer of technology and commercialization lies with the Senior researchers who have to go an extra mile to make sure that their technology reaches the appropriate end users. There is a general tendency among the scientific community or academia to be satisfied by publishing their results in scientific journals. It is also the duty of academia/researchers to transform their own published results into a useable/commercial product. This can either be done independently, or in collaboration with industry or progressive farmers. In the developing countries, it is seldom that an end user (industry/farmers) comes to academia. It has to be the other way round. This is a job that developing country scientists have to do if they want credence for their knowledge and technology.

6. SUMMARY & CONCLUSIONS

The debate regarding basic, fundamental or academic research versus applied research has been a popular topic among science-managers, economists and politicians. Such issues crop up especially when funding of scientific research is to be decided. This scenario is prevalent in virtually all developing countries, where science is generally regarded as an abstract-entity, which has no real relevance to the economic development. However, the situation is changing fast, because of several reasons, including globalization and a realization that transfer of technology from North to South is not as smooth as it should be. Therefore, many developing countries are rethinking their developmental strategies and are making S&T as the corner stone of their policies. It is in this context, that the relationship between basic and applied science is discussed.

The purpose of describing these goal-oriented research projects was to highlight the importance of all phases of research and to emphasize that it cannot be compartmentalized into fundamental, basic or applied research. Each phase has to contribute to the solution of a problem. As is evident from the examples given above, all projects had a goal, and efforts were made for the dissemination of the technology or the product.

Another important aspect of scientific research is its funding. Unlike other departments, scientists are required to solicit financial support for their projects. They have to write proposals and compete for funds, which are always limited. This is a normal practice internationally. The success in getting research-grants is an indication of the validity of the idea or hypothesis on which the proposal was based. All examples of goal-oriented research that are presented here have been funded through several national and international competitive grants. Governments are required to provide good infrastructure and basic facilities for doing research. The funding of research should be through competitive research-grant system, for which enough funds should be made available to various science-funding agencies. It is needless to say that the approval of grants has to be based on merit, absolutely transparent and through proper peer review.

Presently in Pakistan, there is a feeling of optimism as science & technology is being liberally supported, and slowly a true culture of doing good science is emerging in our universities and other R&D institutions.

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PUTTING ONE'S MONEY WHERE THE MOUTH IS

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PREAMBLE

With the transition into the 21st century, mankind has witnessed the emergence of a new world-order that is global, yet not so integrated in the sense that it is an order that puts most of the world's populations in contact with one another. But still there are some barriers between different groups of countries and between peoples within the countries. The diversity of changes and trends in economy that can be observed as a consequence of the new world order indicates that an accelerated, segmented, and uneven process of globalization is underway at present. To-date, the major transformations taking place in the patterns of world-economic interdependence are mainly due to advances in communication and information technologies, globalization of financial markets and changes in trade-patterns. The scientific advances and technological innovations have acted as enabling-factors toward globalization. Ofcourse these changes have created both opportunities and challenges for young researchers, especially those in the developing countries.

A brief examination of these transformations may help us to appreciate the extent and depth of the transformation in the global order and to establish the background against which the Commission on Science and Technology for Sustainable Development in the South (COMSATS) has selected the substantive theme namely "Basic or Applied Research: Dilemma of Developing Countries", in order to reveal some common threads running through this theme.

Since World War II, the products of scientific research & development and technological innovation have deeply enmeshed in all aspects of human activity. There have been several modifications in the way knowledge is being generated, investigated and used. Only about 4% of the world's expenditure is on research and development (R&D) and about 14% of the world's supply of scientists and engineers are in developing countries, where more than 80% of the world's people live. The role that knowledge is now playing in the process of development is so critical that development needs to be redefined in terms of the capacity to generate, acquire, disseminate and use both modern and traditional knowledge. Infact, the presence or absence of this capacity marks a crucial division between the developed and developing nations. It appears that two aspects of S&T further attention during the transition into the 21st century: the changes in the way scientists are conducting research; and the merit are worth increasingly systematic character of technological innovation.

In the above-mentioned contexts, this chapter provides an economic context for basic and applied research in developing countries. Three main areas of concern are discussed briefly: (a) concepts and trends in basic and applied research, (b) strategic way forward for developing countries to adopt appropriate basic and applied research for socio-economic uplift, and (c) selected contributions of the Pakistan Atomic Energy Commission (PAEC) in the development and commercialization of nuclear (radiation and isotope) technology for socio-economic uplift in Pakistan. As such, an attempt is made to facilitate some insight into how researchers, governments and the economic advisors in developing countries need to view R&D and likely trends in funding. It also discusses some possible changes in the policy and funding of the government for R&D institutions that may influence the balance required for sustainability in doing a mix of basic research and applied research.

BASIC AND APPLIED RESEARCH

Concept of Basic and Applied Research

At the outset, it is important to understand and follow the concept behind basic and applied research. In basic research, the researcher mainly stresses on investigating the structure of the knowledge. At a given time, one person may have well-defined research goal(s)/idea(s) to investigate, or question(s) to answer. It is the type of questions which infact distinguish basic research from applied research. Basic questions often start with a question like "why", while applied questions often start with reservations like "how". A typical basic question is: Why do we see this response or behaviour? How did the life begin on this planet? A typical applied question is: How can we use this principle or ideology to achieve some specific results (for example, for implications of scientific ideas, for boost-up of the national agricultural, health, and warfare status) …. How can we treat this specific cancer-type? Basic research is driven by a researcher's interest and/or curiosity in the scientific question. Thus, basic research is characterized by the type of questions to be resolved. In short, the main motivation behind basic research is to expand man's knowledge and not to invent something purposely, while in applied research, the researcher is involved in improving current products and services and in conducting specialized research for the use and benefit of clients in the public and private-sectors. Nevertheless, it is important to note that in many cases, one has to do both basic research as well as applied research at the same time. Many scientific and technological projects naturally reflect the research aims of the project leader, but among the project team, the individual researcher directs his own work. However, patent applications originate from both basic or applied projects.

To date, competition on the knowledge market is growing very rapidly. However, the developing nations in South Asia, South America, Middle East, and Africa are still at the forefront of scientific progress, and their historical strength in scientific research is even more 'volatile' than ever before. There is a dire need to collect database on the emerging trend in the type of research activity, funding and expenditure, as it greatly concerns many researchers and scientists in developing countries. It appears from this discussion that the developing countries need to put concrete efforts in deciding about the type of research to be pursued and strategies to be developed, for optimal use of research grants for basic and/or applied research with the objective of socio-economic development in the country. This calls for creative thinking about the type of research activity to be followed in view of the research grants at hand, the national needs, the regional needs and the national-capacity, to deliver for a specific S&T work.

Dilemma of Developing Countries viz Science & Technology

Today, in developed countries, the basic and applied scientific research is an essential investment in the long-term planning for welfare [1]. In universities, highest priority is assigned to stimulating and nurturing of scientific and technical talent, and to the concomitant training of students. What is emerging from this priority is the close association of education and economic growth. Accelerating the rate of growth and rate of productivity can basically be accomplished by stimulating and supporting scientific education in universities. Unfortunately, contrary to this attitude in developed countries, science has been treated as a marginal activity and perceived as an ornament [2]. Specially, for countries in the South, the problems of development extend far beyond the issues of economic strategy alone. Market forces that promote particular science and technology in the developed country do not exist in poor countries. There is a deficiency of science and technology that is crucial to addressing the critical problems of countries of the South. There is an absence of sound decision making. Indeed, most of the developing countries do not realize that their situation can only be rectified with the blend of modern science and technology into their societies. Although some of the developing countries are aware of the importance of science and technology, this awareness does not necessarily make it easy to develop and popularize science. More importantly, the inadequate scientific infrastructure is a critical factor which retards the advancement of S&T in developing countries.

The main change over the last decade has been an increased economic motivation for the public funding of science. Scientific research is recognized as a major driving force behind the knowledge-based economy. Present day public-funding, is motivated mainly by its economic importance. It is measured as a percentage of the states national budget, and correlated to economic growth etc. In this regard, developing countries, in general, have several shortcomings in their mechanisms of funding and supporting scientific infrastructure. Further, the critical size of human resources and infrastructure, viz-à-viz the amount of investments in these two areas in developing countries, shows how science and technology are so much neglected in developing countries. There is a lack of will towards strengthening of human resource development sector and developing vision to allocate science funds in proportion to GNP for socio-economic development. For example, industry and universities in Turkey have been facing shortages of researchers - 10 for every 100,000 of the population compared with 280 in US, 240 in Japan, 150 in Germany and 140 in the UK [1]. In 1984, in Turkey, non-defense research expenditures were 0.20% of the GNP [10], while these were 2.74% in the US, 2.65% in Japan, and 2.54 % in Germany [1]. Compared to technologists, economists, and planners, the extent to which scientists are allowed to play a role in nation-building is another important problem. Few developing countries have formulated such a policy of allowing scientists to play their roles [3].

Again, in developing countries, the national science-policy can pose strong impacts on initiatives and outcomes of basic and applied research initiative. The economic arguments for science dominate completely. Accordingly, researchers need to look at programs, which help to develop their ideas to work on the topic that they feel is of vital importance w.r.t. national domestic, agricultural, health, industrial, power, or defense sector needs etc. It appears that there must be a smart thinking in seeking research grants for socio-economic developments in the developing countries and that the developing nations need to dwell science-policy that is more encouraging, less strict and controlling. A science-policy of this kind will keep talents in science, because they feel appreciated and important. More results can be expected, because this will appeal to the ambition of the people. There is a need to narrow the gap between the scientist and the policy-maker in this manner. Good concepts of basic or applied research in the context of science-policy must be inspiring for the individual scientist in any research group. Briefly, the basic problems of developing countries are, the weak science-policy resulting in a weak educational and scientific infrastructure, and a lack of appreciation of the importance of research as an essential ingredient of economic and social development. The social and economic growth of the developed countries thus, depends upon essential emphasis on education, science, and technology.

THE STRATEGIC WAY FORWARD

1. Develop Quest for Knowledge-Economy

The quest for knowledge-economy relates to strengthening knowledge for innovation. During the past three centuries, sustainable development in science & technology has brought significant revolution in the mechanisms that boost economy. Figure-1 shows a stepwise transformation in economic evolution viz-à-viz change in the industrial growth, knowledge, and socio-economic structure. It appears that during the 18th century, the agricultural revolution boosted the economy. During the 19th Century, industrial revolution brought significant revolutions in technical advancements which transformed the evolution of economy from an agriculture-based economy to an industry-based economy. The industrial revolution, from the seventeenth to the nineteenth century, gave birth to the steam engine, textiles, printing press, etc. Countries that underwent this industrial revolution became developed, as machines took over some of the work from man; while countries that did not undergo industrialization remained underdeveloped and agrarian. This Industrial revolution had no direct linkage with science. Today, advancement in socio-economic conditions in developing countries is closely linked to the development of new technologies and their transformation into an economically-viable operating industry. Accordingly, the

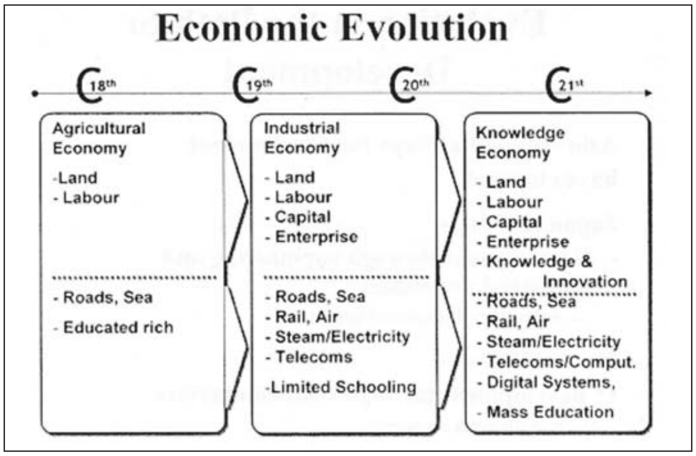


Figure - 1: Sequence of Transformation in Economic Evolution [4]

20th century has witnessed a knowledge-based economy which has revolutionized the socio-economic conditions in the developed countries. Examples of these are: nuclear technology, space technology, biotechnology, information technology etc.

Knowledge and technology go side by side. New technologies always help to generate new knowledge, which further breeds newer and finer technologies, thus leading to an explosive growth in science and technology. Nevertheless, policy-makers and researchers in developing countries need to visualize that the adoption of technology needs a certain indigenous capacity for appropriate development of human resources and the S&T infrastructure. Each modern technology casts a definite impact on all sectors of development such as agriculture, human-health, water resources, energy, etc.

Accordingly, the developing countries need to strengthen scientific knowledge both in the basic sciences, as well as applied technical sciences. This attitude not only brings innovation but it inherently supports efforts for socio-economic uplift and growth. Knowledge has always been an important economic activity. The development of the appropriate mechanism, whereby economic value can be extracted from knowledge, brings about the concept of innovation. The capacity to produce, select, adapt and commercialize knowledge, is critical for trade, competitiveness, and for the sustained growth of the economy [5]. This concept is critical for developing countries to adopt as such. Therefore, for developing countries, an effort is certainly required to bring about evolution in the path of development. Again, policy-makers and researchers in the developing countries need to understand that appropriate investment in development of knowledge is a key to wealth. Research in specific domain(s) of science, selected in view of resources and trained-manpower in a country would provide the drivers for innovation and knowledge-economy. Figure - 2 shows a comparison of investment in knowledge by some developed & developing countries.

Knowledge is a Key to Wealth
Investment in Knowledge (R & D + Software + Higher Education)

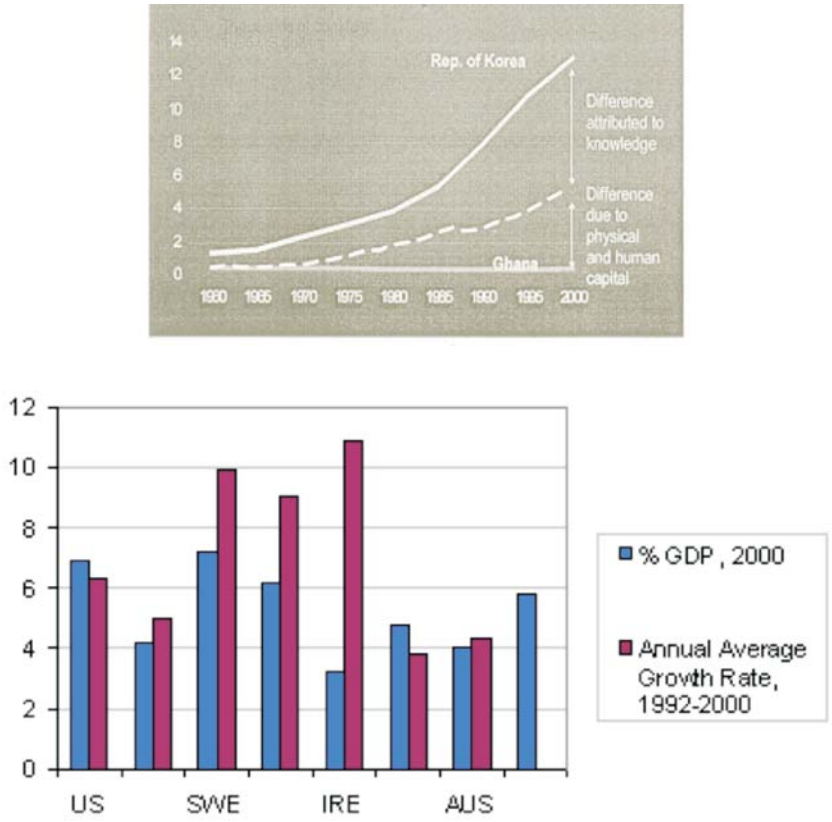


Figure - 2: Scenario of investment in knowledge by developed & some developing countries

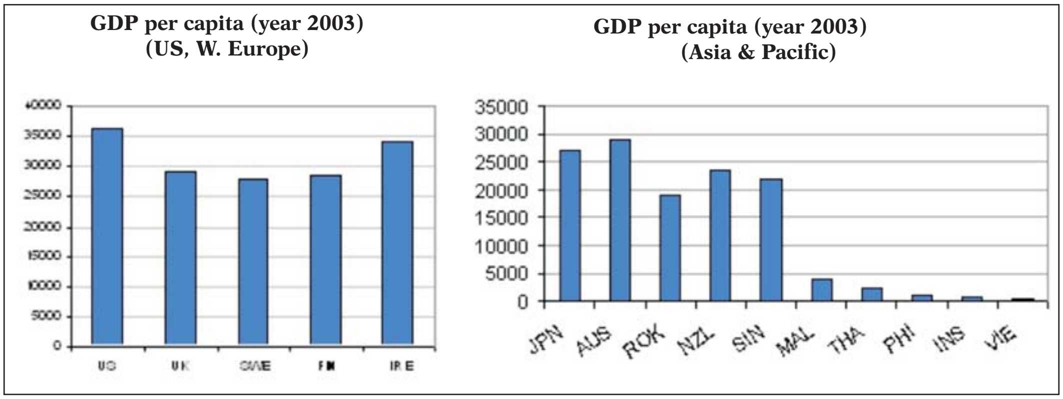
Today, wise developing countries are investing in knowledge for R&D, for software and for higher-education. Although, the knowledge-economy favours countries that are already advanced (such as US, and Japan), yet it also benefits developing countries that have large economies (such as India, China). Many less advanced and smaller countries are falling further behind as the knowledge economy gains speed. It appears that developing countries must act in a smart and timely manner to dig for knowledge based economy for socioeconomic uplift and to compete the developed countries. Examples of efforts of socioeconomic uplift in different developed and developing countries are well documented in literature [4 -11]. For example, the socioeconomic uplift in Finland has resulted from adoption of such an approach. Finland (in 1980s) started as an economy based on agriculture. This country was 76% forest with raw wood exports contributing 5% of GDP. The country made investment in technology added value (paper, paper products, forest products machinery). Accordingly, forestry exports in Finland climbed to 20 % of GDP. Finland continued expansion of exports and GDP and in 1990s, it managed huge investment in knowledge and IT through Nokia. Japan (1970s) initiated development through engineering and industrial processes i.e. through a smarter industrial economy. Korea (1980s) initiated development through semi conductors - a high-tech economy. India (1990s) made initial progress based on industrial technologies but in the years following 2000s, so India has been managing faster and newer progress based on biotechnology and information technology (IT). Growth opportunities in India are now becoming more focused on high-tech. and more knowledge-based technology options.

2. Assess National Wealth and Investment in Innovation

Before making huge investments to build up status of science and technology as well as R&D, the developing countries may use a number of measures of wealth and investment in innovation. The most critical or key parameters that can be used to gauge wealth and innovation are as follows:

- GDP and GDP/capita
- Gross expenditure on R&D (GERD)
- GERD (% GDP)
- Average annual growth-rate in GERD
- Number of scientists
- Internet connectivity/ Electronic Networking and Outreach

Figures 3a to 3c highlight the impact of these measures of wealth and innovation among developed nations like USA, Western Europe, and developing countries in Asia



GDP per capita (year 2003)
(US, W. Europe)

GDP per capita (year 2003)
(Asia & Pacific)

Figure - 3a: GDP per Capita for US, Western Europe, Asia and Pacific (for 2003)

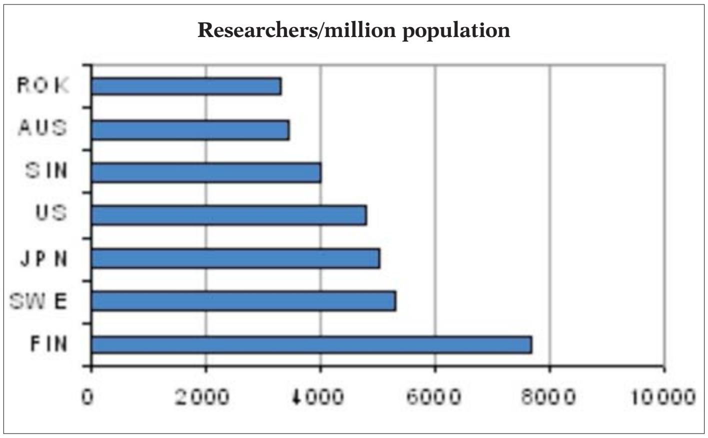


Figure - 3b: Comparison of trends in researchers per-million-population in some developed countries and developing countries in Asia & Pacific

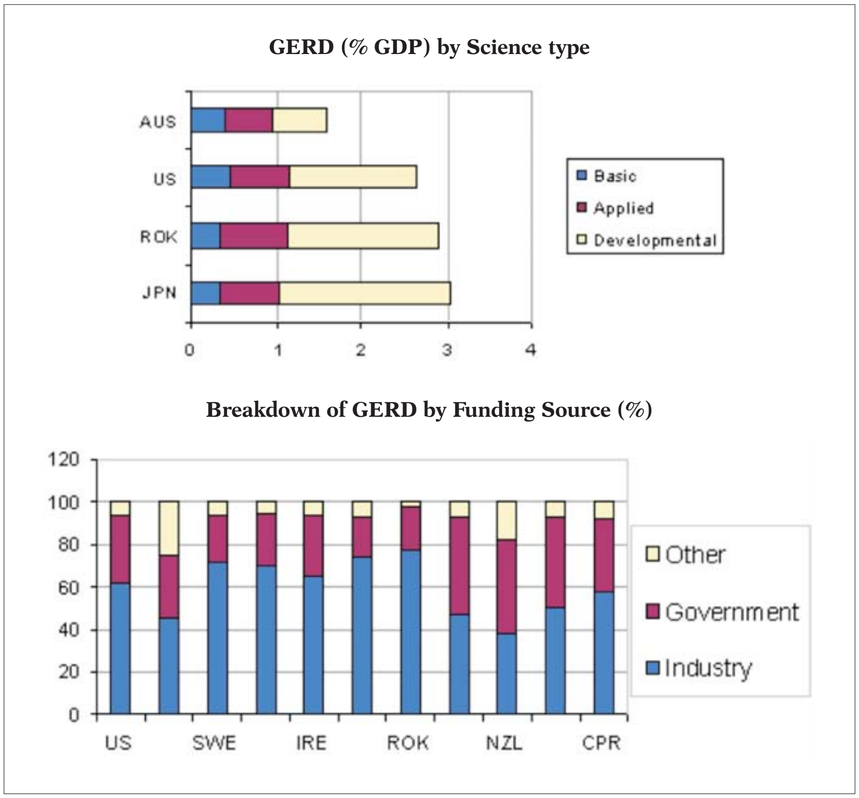


Figure - 3c: Comparison of trends in Gross Expenditure on R&D (GERD) as % of GDP by type of Science and by funding source (lower) some developed countries and developing countries in Asia & Pacific

& Pacific Countries, mainly, Australia, New Zealand, Malaysia, Philippines and Vietnam [4 – 13].

3. Assess and Develop Knowledge-Database

For developing nations, one of the long-term goals is to assess the development of a knowledge-database that draws on the most advanced techniques of artificial intelligence. There is a need to statistically evaluate the knowledge-pool and resources of the developing nation. Through the appropriate use of artificial intelligence, the developing nations can aim at the ultimate combination of objective and subjective analysis or expert-analysis. The availability of full texts in machine-readable form will enable this process to become fully algorithmic.

4. Focus on Multi-Disciplinary Problem-Oriented Research

Basic research is one facet of the national research resources. The other facet is what can be termed as multi-disciplinary, problem-oriented research, which of course involves basic research, but it also involves engineering and applied work. As developing countries are to meet major challenges of the global-age, research focused on solutions to problems has to be well-organized and sensitively managed.

All scientific inquiries are not of equal value. Policy-makers in developing countries must not decide priorities giving the push to research on the verge of a socially-beneficial breakthrough. The scientific community must improve the articulation along the route from basic research to technological application. There is, ofcourse, a continuum between basic and applied, although it seems to vary from discipline to discipline. For too long, developing countries have lived (and some are still experiencing) with an overly strict dichotomy between the basic and applied sciences. With the rapid S&T developments, a new kind of research enterprise may likely emerge in the coming age whereby large scale operations designed to grapple with problem focused, rather than discipline focused, issues. Thus, policy makers in developing countries must learn how to mobilize and manage such enterprises. The wise steps are that some aspects of problem oriented research leading to socioeconomic development can best be handled by universities, others by federal or federally supported laboratories, and still others by the industry. For developing countries with medium-scale economic resources, it is important to direct their research budgets towards core areas of competence (for example, UK has invested in pharmaceuticals, Nordic countries have invested in renewable energy and Pakistan is investing at present in nuclear-power technologies to overcome the electrical energy deficiency for domestic/industrial purposes).

5. Identify Lead Research Institutions

The developing nations must identify and establish lead institutions or consortiums of institutions that are capable to handle the needs and requirements of innovative research of societal importance. On the surface, it might appear that the lead institution concept will strengthen the major universities in the developing nations. nevertheless, quite contrary to it, it is possible that one small university in the country, which has a special research strength can also become a lead institution in a particular area. Accordingly, a laboratory in the public/private sector R&D institution or university or the industrial-sector may be assigned responsibility for research and development on a manageable segment of a societal or socio-economic problem. Ideally, the university should be the focus for both basic and inter disciplinary research on long-range issues. Federal laboratories, corporations, and special university institutes and centres may be held responsible for the short-term approaches closer to practical applications. Such an approach will not monopolize research efforts in a specialty, but foster coordination of research efforts throughout the developing countries. The socioeconomic projects may be very large projects and will cost considerable money. It is essential that there be stable funds for a set period of years (say 10) with an in-depth review after the first 3 to 4 years. If progress is satisfactory, additional forward funding may be granted by the funding agencies.

6. Create Viable Research Groups

Developing countries need to realize the importance of strengthening viable research groups. There is a need to nourish the creative minds in the developing countries with the importance of deciding about doing basic research and applied research when required. It appears that the most ambitious researchers would seek to have such a group around them which can hold the clue to a good research policy. The group does not need to keep basic research from applied research. On the contrary, progress in basic research has often been promoted by difficult problems posed by industry. Thus, universities need to reframe their research programs and devise mechanisms to form, strengthen and fund their research groups which can take up a mix of basic and applied research for socio-economic development. If the governments/funding agencies, R&D institutions & universities can develop such a criteria, and provide good working conditions, it will certainly lead to creation of viable groups for innovative research.

A proper mix of basic and applied research in developing countries can lead to large contributions in local economies, specifically, through creation of high-quality jobs as well as revenues for R&D institutions, universities and the society. The impact of both R&D expenditures and of academic research in 125 regional statistical entities so called 'Metropolitan Statistical Areas (MSAs)' in the USA, has been investigated [12]. It indicates that R&D employment in industry has a positive effect on the innovation output of each region. Also, university-level research in a region can only have a positive effect on that innovation-output if there is sufficient interaction between academic research and a flourishing industry or entrepreneur of high tech ventures and startups. Thus, the strength of a research group to launch and execute projects with innovative thoughts for basic and applied research bears great significance for developing countries.

Three measures of innovative success

- Numbers of Patents
- Technology Balance of Payments
- Trade Balance and Export Market Share for High- Tech Industries

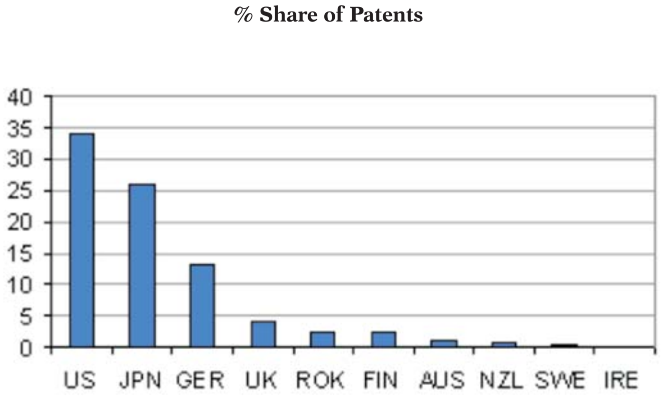


Figure - 4: Measures of innovative success and comparison of % share of patents in developed countries & Asia-Pacific countries

7. Evaluate Level of Innovative Success

Once a developing country has made significant investments in the S&T sector for socioeconomic uplift, it is mandatory to evaluate success in terms of results of investment into innovation. Figure-4 illustrates the measures of innovative success and % share of patents as published by the patent organizations (PO) in the USA (USPTO), Europe (EPO) and Japan (JPO) [4].

Very clearly, the comparison of % shares of patents in developed countries vis-a-vis developing countries reflects gaps and fissures in appropriate thinking of governments and policy makers in the developing countries to opt for appropriate technologies for socioeconomic uplift. This situation can be remediated by constructing R&D plans on the four pillars of innovation and providing a conducive environment for innovation through involvement of the government-sector, the private sector and the R&D institutions, so that investments in R&D for an opted R&D work can bear fruit (Figure-5).

Four Pillars of Innovation

- Policy & Institutional Framework
  - Facilitation
- Innovation Systems
  - RDIs, Universities, Companies, Think Tanks
- Education & Training
  - Skilled Workforce
- ICT/e-Development
  - Information Flows

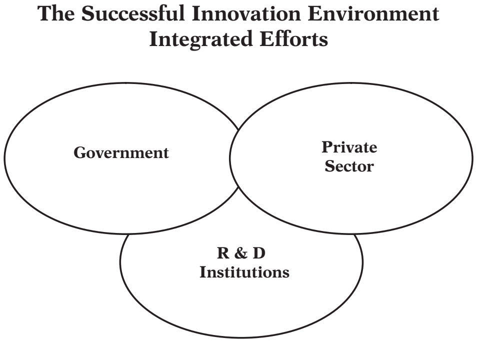


Figure - 5: The pillars of innovation in relation to innovation environment [4]

In this regard, the governments and the private-sector of a developing country has an important role to play in facilitating innovation because knowledge is not appropriate, early stage R&D is high risk and there are economies of scale and synergies from a large nationally supported R&D base. Accordingly, the governments in developing countries must adopt the following schematics in facilitating innovation [5]:

- Put in place policies, regulations, processes conducive to innovation
- Provide access to knowledge and skills
- Restructure R&D institutions
- Promote collaboration between industry, universities and R&D institutions
- Provide incentives for upgrading of skills
- Set a conducive framework for commercializing of R&D outputs

Similarly, the private-sector in the developing countries has the following role to play in facilitating innovation. As such, it supplies –

- Demand-driven focus
- Market awareness
- Efficiency and management capability
- Investment

Nevertheless, the Governments in developing countries may assist the private sector involvement through the following strategy:

- Public-private partnership
- Small-medium enterprise startup
- Technology parks
- Matching grants
- Tax-incentives: loans: partial
- Guaranties: risk sharing

At the outset, one must not expect large increases in government investment and government policies, for research-funding now aims to encourage private sector funding of R&D. Further, the science policy makers in the developing countries must ensure that applications for applied research must show a 'route-to-market' and preferably an increasing probability of funding by the private-sector. In this regard, the policy makers and researchers must follow the following future strategies of EU Lisbon 'Declaration':

- By 2010, GERD is to be 3% of GDP
- Two-thirds of the GERD will come from the private sector (presently in the EU, one-third comes from the private sector, on the average)

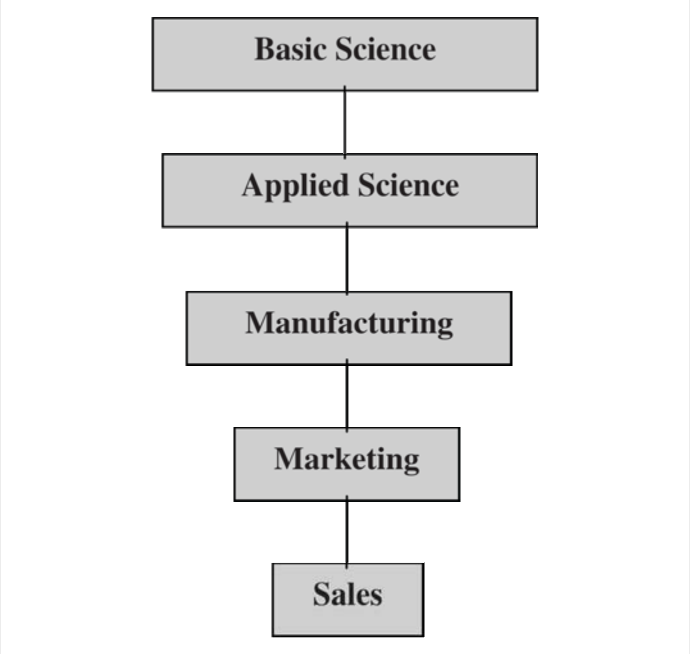


Figure - 6(a): The Linear Model for Innovation [14]

8. Adopt a Fruitful Approach for Transfer of Knowledge for Innovation

Appropriate and viable approaches or models need to be adopted for adequate transfer of knowledge between academia and the industry for innovative purposes. In the past, research councils in some developing countries have been following the linear model of innovation [14]. The Linear Model offers a straightforward approach to innovation, in which researchers working in the basic and applied research domains, are not put together as one group and knowledge is transferred or handed over in a step-wise manner from basic groups to applied groups and ultimately to the development sector, say industry [Figure- 6a].

Although, the linear model may help to obtain a better return of the research investments yet, when one compares the linear model to the activity and the motivation of typical research groups, there is clearly a mismatch in the sense that different research groups are placed not only as an isolated link in the chain, but these are found in fact out of contact with the others. As such, in the linear model approach, each group works on both basic as well as applied subjects. Eventually, this strategy retards the speed of innovation.

A better option for developing countries is to follow the Coupling Model or the Blending-Model approach of innovation. Those countries which have succeeded in boosting socio-economic conditions have infact abandoned the linear model approach

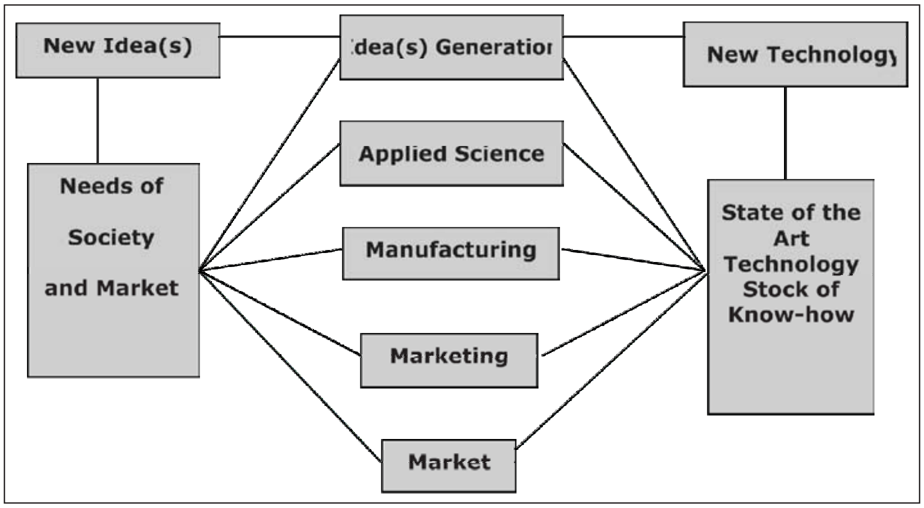


Figure - 6(b): The proposed coupling or mixing model for socioeconomic motivation in developing countries [14]

and adopted the Coupling Model or the Blending Model approach of innovation, in which, the different actors in basic and applied research are put together in one group [Figure-6b]. The organizational level in such a model bears a promises of fruitful common environment for both the basic and applied research groups. Thus, developing countries should opt the coupling model of innovation for socio-economic growth and the link between academia and industry must be strengthened by the third party i.e., the government.

PAKISTAN'S PARADIGM IN NUCLEAR RESEARCH

In many developing countries today, nuclear technologies are established dynamic components of the national economy. As such, the nuclear technologies (isotope and radiation technologies) are used for power-generation; make food more abundant and safer for consumption; diagnose and cure diseases; optimize sustainable water-use; and protect the environment. Hence, it is worth-spending in nuclear-technology research.

Pakistan Atomic-Energy Commission (PAEC), is playing a pivotal role in socio-economic uplift of the country by investing in basic as well as applied research. Over the years, PAEC has established premier scientific research & development centres in the country to carry out basic/applied research and application of nuclear technologies in the water sector, agricultural sector, health & environment sector as well as in nuclear power generation. The selected contributions of the Pakistan Atomic Energy Commission (PAEC) in the application of nuclear technology are depicted in the following section:

(i) Pakistan Institute of Nuclear Science and Technology (PINSTECH)

Pakistan Institute of Nuclear Science and Technology (PINSTECH) is the mother organization of the Pakistan Atomic Energy Commission. After the PINSTECH Nuclear Research Reactor (PARR-I) went operational in 1965, PINSTECH emerged as a major research laboratory in the region for basic and applied research in the fields of nuclear-physics, nuclear-chemistry, nuclear-materials, nuclear-engineering and radioisotope-applications, in the first phase. In the second phase, new disciplines were added with major emphasis on applied research to support the nuclear program in the country for peaceful application of radiation and isotope technology. In the development of indigenous fuel cycle facilities, PINSTECH made appreciable contributions towards fabrication of reactor fuel for the Karachi Nuclear Power Plant (KANUPP) and for production of Zirconium metal for use as cladding material for the reactor fuel. Similarly, research carried out in various disciplines of physics and chemistry was applied in the field of food and agriculture, health, water resources and industry, all of which are essential components of sustainable socio-economic development in the country. The following section presents some success stories of R&D achievements of PINSTECH in basic and applied research.

Water-Sector Applications: There is an increasing awareness in the world that fresh water is a precious and limited resource. All over the world and in Pakistan, groundwater-aquifers are shrinking due to over exploitation, or are being lost due to degradation of water quality from pollution caused by human activity. Worldwide, the demand for water is increasing due to increase in population and higher standards of living. Global warming issue is putting additional increasing demands on water requirements. Sustainable management of freshwater resources requires appropriate technologies. Isotope techniques, based on stable and radioactive isotopes offer effective tools for assessment and development of water resources. Isotope hydrology is the only tool which can identify the source of water in different aquifers and thus identify safe aquifers. Isotope techniques can also identify the sources of pollutants. Sediment and seepage tracing, through isotope techniques, is being used to study dam stability and calculations of its life. Over the years, the Isotope Applications Division (IAD) at PINSTECH is playing a lead role in the establishment of world recognized Research Laboratories in Pakistan in the fields of Isotope Hydrology & Isotope Ecology for environmental implications. IAD has made significant contributions in the indigenous development of mass spectrometers and one of the most efficient and capable analytical facilities for isotope analyses in the region achieving international standards. These laboratories host valuable working facilities for full spectrum analysis of key environmental isotopes [2H, 13C, 15N, 18O, 34S, 3H, & 14C], inorganic/organic chemical analysis, and radioactive tracer applications to address national and regional issues related to environment, hydrology, industry and Life Sciences. At the regional and inter-regional platform, the RCA (Regional Co-operative Agreement) and the IAEA (International Atomic Energy Agency) have declared these laboratories as a Regional Resource Unit (RUU) to provide analytical services, training and expertise to member states as well as for hosting regional training courses in the field of “Isotope Hydrology, Isotope-Ecology and Marine Coastal Pollution”. At the national level, apart from services to various departments of Pakistan Atomic Energy Commission, these laboratories are strongly collaborating and extending services to various organizations such as National Institute of Oceanography, Water & Power Development Authority (WAPDA), Pakistan Council of Research in Water Resources (PCRWR), Irrigation Research Institute (IRI), International Waterlogging and Salinity Research Institute (IWASRI), International Irrigation Management Institute (IIMI), Oil and Gas Development Corporation, universities etc. for isotopic analysis of hydrological, geological, biological and environmental samples, environmental pollution monitoring and up-gradation of research facilities and training at these centers. Today, the Isotope Applications Division at PINSTECH is receiving requests from a number of public and private organizations for investigation of their specific problems through the use of nuclear techniques on cost basis. This has provided an excellent opportunity to commercialize isotope hydrology and isotope ecology related research activities.

Laser Land-Leveler: PINSTECH has established state of the art high resolution laser spectroscopy laboratories to carry out both fundamental and applied research in physics. As a spin off, these laboratories have indigenously developed laser land leveler system (Agro-Laser) which helps in water savings by more than 30 %, increase in crop yield by more than 25% in addition to savings in the labour cost and time (Figure-7). By the year 2006, PINSTECH has fabricated and sold 432 Laser Land Levellers to various clients in the country.

Figure - 7: A View of Agro-Laser based land leveling of agricultural field

Industrial-Sector Applications: Industrial non-destructive testing (NDT), is an integral part of quality-control and quality assurance requirement in a modern industrial plant. Nuclear NDT services are being used in a number of industries, including oil refineries, fertilizer and other chemical plants, hydroelectric as well as thermal power-plants for evaluation of defects of materials and weldments. Table-1 highlights the contributions of PINSTECH in facilitating public and private sectors for NDT evaluation of their industrial products and materials.

Radiotracers and Nucleonic Control Systems facilities are also being provided by PINSTECH to a number of industries for industrial process optimization and trouble shooting studies. Radioisotope technique is very powerful tools for industrial process investigation and troubleshooting. Though the technology is applicable across a broad industrial spectrum, the Petroleum and Petrochemical Industries are the major beneficiaries of radiotracer applications. The search for oil and gas resources, oil product intensification, transportation of crude oil & natural gas by pipelines and processing in petroleum refineries & chemical plants offers extremely diverse radioisotope applications in the petroleum industry. The Industrial Application Group of the Isotope Application Division, PINSTECH has established unique field/laboratory scale facilities and developed expertise to provide radioisotope based services to national industries. Presently, the Radiotracer technology services are being extended to oil companies in Pakistan to assess increased oil production during secondary recovery process by providing important information through detection of: high permeability channels, barriers & fractures; communication between layers; evaluate the fraction of injection water reaching each production well; determine break-through times; find out different stratifications in the same layer and determine preferential flow directions in the reservoir. Human Health and Nuclear Medicine: Radioisotopes find applications in various fields such as nuclear medicine, diagnosis and cure of diseases, hydrology, sedimentology, agriculture and industry. Production of radioisotopes started since Pakistan Research Reactor (PARR-I) went critical in December 1965. Typical radioactive products developed by the Isotope Production Division-PINSTECH are shown in Table-2. Radiopharmaceuticals are defined as radioactive drugs that, when used for the purpose of diagnosis or therapy, typically elicit no physiological response from the patient.

The Isotope-Production Division (IPD) at PINSTECH is among the few laboratories in the region that has achieved unique status through the distribution of radiotracers and radiopharmaceutical products and services all over Pakistan. Initially, a clean laboratory for the bulk production of diagnostic radiopharmaceutical freeze dried kits was established in IPD, PINSTECH under IAEA Technical Cooperation Project (PAK/6/012) with financial support of US$ 100,000 during the year 1989-1992. Regular production and supply of the kits was then started. Now IPD is producing diagnostic radiopharmaceutical freeze dried kits for the visualization of different body organs e.g., heart, kidneys, brain, bone, liver, renal organs, hepatobiliary, red cells etc. These kits include DTPA, MDP, DMSA, DISIDA, MIBI, MAG3, Pyrophosphate, Phytic Acid, Heptagluconate, HMPAO etc. (Table-3). All these products are being supplied to

Table-1: Non-Destructive Testing Services extended by IAD/PINSTECH to various departments and industries in Pakistan

Industrial sector/client	Type of NDT services provided	NDT techniques used
WAPDA	i) Radiography of welded joints of boiler tubes at Thermal Power Station, Quetta. ii) Radiography of bus-bars at Terbela Power-Station. iii) Radiography of Aluminium welding joints of Imperial construction Company at Tarbela Dam. iv) Radiography of turbine blades for gas Turbine Power-Station. v) Radiography of Super-Heater header at Steam Power-Station, Faisalabad. vi) Radiography of Aircraft propeller for WAPDA, Walton-Lahore. vii) Ultrasonic testing of high-pressure heater at Steam-Power Station, Faisalabad. viii) Thickness measurement by ultrasonic testing at Steam-Power Station, Faisalabad.	X-ray radiography and gamma-ray radiography Ultrasonic flaw-detector Ultrasonic thickness gauge
Pak Army/ DESTO/ POF/ GHQ/ ARDE	i) Radiography of Air craft Propellers at Qasim Army Aviation Base Dhamial, Rawalpndi. ii) Examination of critical areas of the blades of Helicopter at Qasim Army Aviation Base, RWP. iii) Radiography of Morter Gun base plates for Armament Research & Development Establishment at PECO Lahore and PINSTECH. iv) Radiography of Helicopter frame and other components at Qasim Army Avn. Base. v) Radiography at Pakistan Ordinance Factories, Havalian. vi) Radiography of Steel pipes, tubes, columns, Welded joints for DESTO. vii) Radiography of special sample received from GHQ. viii) Number of Specimens of special significance from Defense were critically radio graphed. ix) Radiographic inspection of TT straps (Jet range helicopter) from Central Ordnance Aviation Department.	X-ray radiography and gamma-ray radiography
Heavy Mechanical Complex, Taxila	i) Radiographic examination of three hot-rolled steel shells. ii) Radiography of test plates of welding.	X-ray radiography and gamma-ray radiography

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Heavy Rebuild Factory Taxila	Radiography of slings and crane hooks.	X-ray radiography
Attock Oil Company	Radiography of L.P.G. Cylinders.	X-ray Radiography
Sui Northern Gas Pipe Lines, Faisalabad	Radiography of bursted parts of pipelines through DNF&M (PAEC).	X-ray radiography
Pioneer Steel Mills Ltd. Lahore	Radiography of bursted parts of pipelines through DNF&M (PAEC).	X-ray radiography
Imperial Chemical Industry, Khewera	Thickness measurement of reaction vessels by Ultrasonic testing.	Ultrasonic thickness gauge
Ravi Engineering Ltd.	Radiography of 300 meter long S.S. and M.S. Welded shells and Nozzles.	X-ray radiography
Pakistan Air Force	Interpreted 200 radiographs received from PAF Base Chaklala.	X-ray radiography
Ittehad Chemical Ltd.	102 radiographs were taken to find out the soundness of the circumferential as well as seam weld of chlorine storage steel pressure vessels.	X-ray radiography

Figure - 8: Sterile PAKGEN 99mTc generators developed at IPD-PINSTECH

Table - 2: Radioactive Products developed by the Isotope Production Division-PINSTECH

Sr. #	Radionuclide	Chemical form	Maximum activity per Batch	Application
01	Iodine-131	Sodium Iodide (^{131}I) ^{131}I-MIBG	~7Ci/259 GBq 20mCi/0.74GBq	Diagnosis/ Therapy Diagnosis
02	Molybdenum-99	^{99m}Tc-Generator (PAKGEN)	~1Ci / 37 GBq	Diagnosis
03	Sodium-24	Sodium carbonate (^{24}Na)	35mCi/ 1.3GBq	(R & D)
04	Phosphorus-32	Sodium phosphate (^{32}P)	>1Ci/ 37GBq	Therapy, Agriculture
05	Sulphur-35	Sodium sulphate (^{35}S)	10mCi/0.37GBq	β^- source (R&D)
06	Chromium-51	Sodium chromate (^{51}Cr) EDTA-^{51}Cr Complex	100 mCi / 3.7 GBq 100mCi / 3.7 GBq	Diagnosis, Hydrology Diagnosis
07	Iron-59	Ferric chloride (^{59}Fe)	5mCi / 0.185 GBq	R & D
08	Cobalt-60	Metal (^{60}Co)	10mCi / 0.37 GBq	γ source (Educational)
09	Selenium-75	L-Selenomethionine (^{75}Se)	10mCi / 0.37 GBq	Diagnosis
10	Bromine-82	Potassium bromide (^{82}Br) Ammonium bromide (^{82}Br) Dibromobenzene (^{82}Br)	~1Ci / 37 GBq ~1Ci / 37 GBq ~1Ci / 37 GBq	Industry, Hydrology Industry, Hydrology Industry, Hydrology
11	Silver-111	Silver chloride (^{111}Ag)	5mCi / 0.037GBq	R & D
12	Antimony-125	Antimony chloride (^{125}Sb)	1mCi / 0.037GBq	Educational sealed source
13	Cesium-134	Cesium chloride (^{134}Cs)	100mCi / 37GBq	R&D
14	Cesium-137	Cesium Chloride (^{137}Cs)	2mCi / 0.074GBq	Educational sealed source
15	Barium-133	Barium chloride (^{133}Ba)	In μCi / KBq	Educational sealed source
16	Lanthanum-140	Lanthanum chloride (^{140}La)	~ 1Ci / 37GBq	Hydrology
17	Samarium-153	^{153}Sm-EDTMP	~ 1Ci / 37GBq	Therapy
18	Europium-152/ 154	Metal	~10mCi / 0.37GBq	Calibration source
19	Holmium-166m	Holmium oxide (^{166m}Ho)	-μCi/KBq	Calibration source
20	Holmium-166	Particles	>100 mCi / 3.7 GBq	Therapy
21	Rhenium-186/188	^{186,188}Re-EHDP	>100 mCi / 3.7 GBq	Therapy
22	Tungsten-188	Generator of ^{188}Re(^{188}W - ^{188}Re)	5mCi	R&D
23	Gold-198	Colloidal (^{198}Au)	~ 1 Ci	Therapy
24	Gold-199	Gold chloride(^{199}Au)	~ 10mCi	R&D
25	Mercury-197	Neohydrin- ^{197}Hg	100 mCi	Diagnosis
26	Mercury-203	Neohydrin- ^{203}Hg	10 mCi	Diagnosis

Table - 3: In-vivo Kits for 99mTc-radiopharmaceuticals

Sr. #	Freeze-dried kits	Uses
1.	PINSCAN DTPA	Kidney Imaging
2.	PINSCAN MDP	Bone Imaging
3.	PINSCAN MIBI	Heart Imaging
4.	PINSCAN Ca Hepta Gluconate	Kidney Scanning
5.	PINSCAN Phytate	Liver / Spleen Imaging
6.	PINSCAN DMSA III	Renal Studies
7.	PINSCAN DMSA V	Head/ Neck Carcinoma
8.	PINSCAN DISIDA	Hepatobiliary Studies
9.	PINSCAN EHIDA	Hepatobiliany Studies
10.	PINSCAN PIPIDA	Hepatobiliany Studies
11.	PINSCAN BRIDA	Hepatobiliary Studies
12.	PINSCAN MAG-3	Kidney Scanning
13.	PINSCAN Pyrophosphate	RBC/ MUGA Studies
14.	PINSCAN ECD	Brain Scanning
15.	PINSCAN Sucralfate / Ulsanic	Stomach Scanning
16.	PINSCAN Dextran	Lymphoscintigraphy
17.	PINSCAN HMPAO	Brain Studies
18.	PINSCAN Ciprofloxacin	Infection imaging
19	PINSCAN Ubiquicidin	Infection imaging
20	PINSCAN EHDP	Bone, Transchelating agent

nearly twenty five hospitals including PAEC nuclear medical centres and private/ government hospitals in Pakistan for diagnosis and treatment of different abnormalities in the body.

Sterile PAKGEN 99mTc generators are also being fabricated in a 99Mo loading clean room facility created under an International Atomic Energy Agency Technical Cooperation Project (Figure-8). PINSTECH started regular production of Pakgen 99mTc generators to various hospitals in Pakistan on fortnightly basis from August 2003 and then on weekly basis from November 2004. Initially, 10 Pakgen 99mTc generators per week were produced and our weekly production is 25 generators of activity ranges from 200 to 600 mCi per generator.

Today, IPD has facilitated Pakistan Atomic Energy Commission (PAEC) to help government in the health sector by operating 13 nuclear medical centers in Pakistan, while a few more are expected to function shortly in the country. Various medical centers in the private sector are also using IPD manufactured radiopharmaceuticals. In these medical centres more than 350,000 patients are treated every year. For many years, Isotope Production laboratories are meeting almost all the demands of Sodium Iodide (131I) and cold kits for 99mTc radiopharmaceuticals for these centres.

13C Urea Breath Tests (UBTs): Helicobacter pylori (H. pylori) is a bacterium that resides beneath the gastric mucus layer of the stomach. This infection may remain asymptomatic, but can also cause consequences like type B antral chronic atrophied gastritis, duodenal ulcer, gastric ulcers and if untreated, may lead to severe consequences like gastric carcinoma (MALToma).

The Life Sciences Group (LSG) of the Isotope Applications Division, PINSTECH is involved in research pertaining to stable isotope applications in Nutrition and Health. The 13C Urea Breath Test (UBT) being one of the stable isotope breath test, was validated and successfully applied for clinical studies, with funding support of PAEC and Pakistan Science Foundation (PSF) during 1994-2000. Later, PAEC established a state-of-the-art laboratory, equipped with the breath-mat-mass spectrometer, to facilitate both research and diagnosis in the country. The project is sponsored by PAEC with a total funding of Rs. 8.3607 million. Figure 9 shows the management structure for the UBTs.

(ii) National Institute for Agriculture & Biology (NIAB)

NIAB at Faisalabad has goal-oriented research programs for solving the agriculture and biological problems of the country. The R & D activities are meant for utilizing nuclear techniques for optimum utilization of available resources to increase production through improved crop varieties, developing better methods of conservation of inputs and produce, and maximize use of innovative technologies developed through basic and applied research.

Over the years, the plant-breeding efforts have resulted in the development of 24 improved varieties of different crops which include 6 varieties of cotton, 2 of rice, 4 of chickpea, 10 of mungbean and 2 of lentil. In addition, many mutants of these crops are at the advanced stages of testing. The cumulative income to the farming community from these varieties has been estimated to the tune of 64.6 billion Rupees.

Through the use of γ-radiation, a sparse-seeded Kinnow mutant has been developed that bears fruits having 5 ± 2 seeds as compared to the parent with 20 ± 5 seeds per fruit. The mutant is under extensive evaluation in the field.

More than 6 million hectares of land is affected by salinity that causes huge loss to the agricultural production in the country. The biological approach developed at NIAB has proven effective for sustainable and economic utilization of saline wastelands and brackish ground water for plant production. This technology has been successfully demonstrated on Bio-saline Research Stations near Lahore and Faisalabad, and has also been adopted by several countries in Asia and Africa through an IAEA Project INT/5144 led by NIAB. A country wide program `Farmers Participatory Saline Agriculture Development Project' worth Rs. 176 Million funded by the Government of Pakistan is being executed at 5 sites in all four provinces covering 25,000 acres of saline land. As a result of this project, hundreds of acres of wastelands have been rehabilitated.

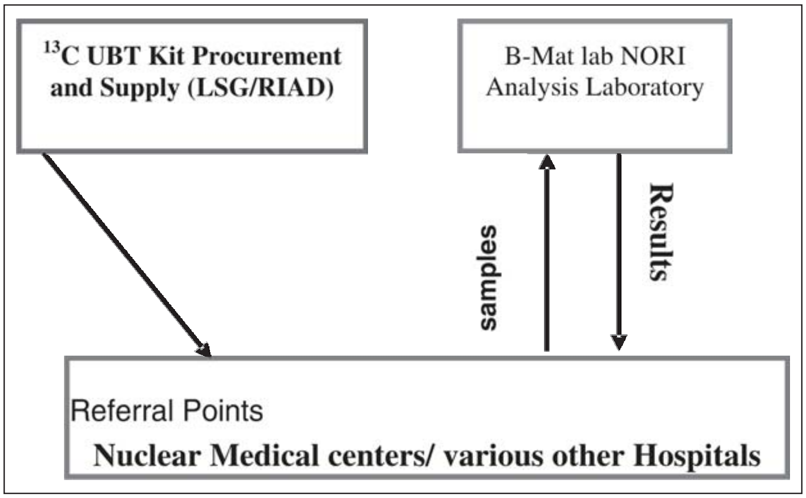

Figure - 9: Management Structure for the Urea Breath Tests (UBTs)

It has been estimated that presently there is a gap of 40 % between average and attainable yields of various crops in Pakistan. This gap could be effectively reduced to 20 % with balanced fertilization. In this regard, micronutrients have a special role to play. Based on research at NIAB on micronutrients, firm recommendations have been made to farmers to overcome Zn and B deficiencies in soils. Application of Zn and B to rice and cotton, in particular, and other crops in general have significantly enhanced crop yields in the country.

Fertigation technique has proven very useful to increase P use efficiency and thereby can save 10-50 % of phosphatic fertilizer in case of maize, wheat, potato and berseem crops.

Livestock is an important component of agricultural economy. Haemorrhaegic septicemia (HS) is an acute infectious disease of cattle and buffalo. This disease is prevalent in all the wet tropical countries particularly in Asia. Economic losses due to this disease in Pakistan are estimated to the tune of Rs. 1.9 billion. The only practical method of control and prevention of this infectious disease is timely vaccination of all the animals with suitable vaccine. NIAB has developed a new oil adjuvant vaccine which has been commercialized under the brand name `NIAB-HS-VACCINE'. This vaccine is very effective for the control of Haemorrhaegic septicemia infectious disease of cattle and buffalo.

Multi-nutrient feed blocks have also been commercialized that are effective for improving general health, reproductive cycle and milk production of animals.

The institute is also active in dissemination of knowledge and human resource development. NIAB conducts two specialized training courses annually, the one on `use of nuclear and other advance techniques in agricultural and biological research' and the other on `Radiation safety'. So far, 34 and 13 courses have been conducted, respectively. National & international training courses, workshops, exhibitions and conferences are also organized as knowledge sharing activity. NIAB also supports academic programs of educational institutions. So far, 58 Ph.D., 47 M.Phil. and over 300 M.Sc. scholars have completed their theses research at NIAB.

iii. Energy-Sector Applications (Nuclear-Power Generation)

Nuclear power plants are operating in 30 countries around the globe. Sixteen percent of the world's electricity is now being generated through nuclear reactors. There are 438 operating nuclear-plants running, safely in the world. The nuclear power programme of Pakistan Atomic Energy Commission (PAEC) has also expanded a lot in recent years for the purpose of research, radioisotope production and power generation. PAEC has already installed 2 research reactors (PARR-I and PARR-II) in Islamabad and 2 power reactors, one each in Karachi (KANUPP, 137 MW) and in Chashma, District Mianwali (C-1, 300 MW). All these plants are operating safely and making significant contributions in the clean energy sector in Pakistan. A 3rd nuclear power plant (C-2, 300 MW) is also under construction/ installation at Chashma, District Mianwali. The energy security plan of the Government of Pakistan envisages some 8800 MWe installed nuclear power generation capacity by the year 2030. In order to transform this vision of nuclear power generation programme into reality, the Pakistan Atomic Energy Commission has initiated establishment of an Engineering Design Organization (EDO) and is making significant efforts to achieve self reliance in nuclear power plant technology through comprehensive and systematic development of nuclear design and architect engineering capabilities. Indigenization in project management, design and engineering, civil construction, manufacturing of major equipment, installation and commissioning will be achieved gradually by the EDO. The development work has been initiated on reactor core design, including nuclear, thermal-hydraulics, shielding design, fuel management, flow-induced vibration analysis, core operational testing and NSSS integrity monitoring systems. The work on design of structure systems and components of 300 MW nuclear power plant has been initiated and the indigenous capability will be achieved through execution of next 4 x 300 MWe nuclear power plants (NPPs). From design up to the final decommissioning and waste disposal, the total life cycle of an operating NPP is about 100 years. During this entire period, a large number of design modifications and additional analysis are required to improve plant performance and enhance operational safety. Technical support to the operating nuclear power plants in the areas of stress and vibration analysis, fuel management, nuclear design reports, refueling support and design modifications will remain an important activity of the Engineering Design Organization. All this encompasses generation of a lot of innovation and requirements of manpower and human resource development with the ultimate objective of bringing socioeconomic uplift in the country.

CONCLUSIONS AND SUMMARY

The developing countries need to put concrete efforts in deciding about the optimal use of funds for basic and applied research with the objective of socio-economic development in the country. This calls for creative thinking about the type of research activity to be followed in view of the research grants at hand, the national needs, the regional needs and the national capacity to deliver for a specific S&T work. The strategic way forward for developing countries is to make quest for a knowledge-based economy which relates to strengthening knowledge for innovation. Accordingly, the developing countries need to strengthen scientific knowledge both in the basic sciences as well as applied technical sciences. This attitude will not only bring innovation but it will inherently support efforts for socio-economic uplift and growth.

Before making huge investments to build up status of S&T and R&D, the developing countries must assess the status of national wealth for investment in innovation. This needs assessment of (i) gross expenditure on R&D (GERD); (ii) GERD as % GDP; (iii) number of scientists per million of population; and (iv) Status of Internet connectivity/ Electronic Networking and Outreach. All these are crucial parameters for a start-up towards socio-economic development.

Research, technological progress and the economic growth are closely linked. A proper mix of basic and applied research in developing countries can result in significant enhancement of local economies, specifically, through creation of high-quality jobs and revenues for R&D institutions, universities and the society. Thus, there is a need for the developing countries to identify and recognize science and technology-based industry as a major source of economic growth and a means of addressing important social problems as well.

In conclusion, developing countries need some fundamental changes in the outlook, both in areas of science and in economic planning, for ensuring sustained development. The policy-makers in the developing countries must realize that for a viable socio-economic development, the national economic plans must be knotted with the corresponding science and technology plans. The laboratory scientists, as well as technologist have to learn business management skills, while the economists have to be aware of the realistic potential of various new S&T applications. Thus, for socioeconomic growth, the developing countries need to opt the coupling model of innovation. Further, the link between academia and industry must be strengthened by the third party i.e. the government.

The 21st century has witnessed great advancements in the field of science and technology (S&T). Of course, these advancements are mainly due to collective efforts and contributions of a large number of scientists and researchers around the globe, but the credit goes to advanced countries in the North; EU countries in the West (Germany, France, Russia), and some countries in the South-East (China, Japan), who have made tremendous financial contributions in translating innovative research ideas into reality, for socio-economic development through commercial-scale applications in domestic, agricultural, industrial, health and the defense sector. In contrast, the developing nations in South Asia; South America; Middle East; and Africa, lag far behind the developed countries in scientific investments and innovations. The shortcomings of developing countries in making significant S&T achievements of socio-economic concerns are quite varied in nature. In these countries, the problems of development extend far beyond the issues of economic strategy alone. Market forces that particularly promote science and technology, do not exist in many developing and poor countries. There is, in general, a lack of informed and sound decision-making, as well as a weak science-policy. Accordingly, top management in developing countries must take into account the urgent need for investment in appropriate areas of S&T. Further, the choice for opting for “Basic or Applied Research” in S&T has become a dilemma of some developing countries.

This Chapter presents some thematic guidelines for the scientific-management community and policy-makers in developing countries to formulate adequate strategies in S&T and follow models for investment in specific disciplines of basic and applied research for socio-economic uplift of the common man and the nation as a whole. Accordingly, this chapter addresses three main areas of concern: (a) trends in basic and applied research, (b) strategic way forward for developing countries to adopt appropriate basic and applied research programs in the quest for knowledge economy for socio-economic uplift, and (c) selected contributions of the Pakistan Atomic Energy Commission (PAEC) in basic and applied research carried out for socioeconomic uplift of the country.

Policy-makers in developing countries may opt the following strategic way forward to overcome the issues in establishing a viable S&T infrastructure and reduce the economy-gaps between developed and developing nations: (i) develop a quest for knowledge-economy; (ii) assess national wealth and investment in innovation; (iii) focus on multi-disciplinary problem-oriented research and investing wealth in selected appropriate technologies; (v) identify lead research institutions, (vi) adopt a suitable approach for transfer of knowledge. It is suggested that the decision for appropriate investment in a mix of basic and applied research is of utmost interest and bears great importance to all policy-makers in developing countries. As scientific research is the major driving force behind a knowledge-based economy, developing countries should opt model(s) of innovation that strengthen the linkage between academia and industry. Such a linkage must be further strengthened by the government. The coupling model of innovation seems to be a viable option for developing countries, as the organizational level in coupling model bears a promise of fruitful common environment for both the basic and applied research groups for scientific and technological innovations.

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LINKING INDUSTRY AND RESEARCH

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INTRODUCTION

The Pakistan of 1947 was full of enthusiasm and brimming with confidence, and looking forward to a great future, but there was very little scientific tradition. Considerable efforts were made, and resources allocated, for the next sixty years in establishing a growing number of research councils, Research and Development (R&D) institutes and science universities. In the first decade after the establishment of Pakistan, there was considerable discussion regarding the establishment of R&D within the universities or outside. The view that prevailed was based on the argument that Pakistan, with its limited resources, should concentrate on adaptive research and do only a limited amount of fundamental research. The adaptive research to benefit the industry should be done in specialized R&D institutions *set up outside the universities*, whereas, the basic research should be done in the universities. But when the R&D organizations were set up, their heads and other senior personnel had to be inducted from the universities. They did lose the link with teaching but could not establish the link with industry. The entrepreneurial approach could not be achieved. This resulted in research projects being selected according to the personal aptitude of the scientists, in most cases without any relationship with the needs of industry or product-improvement. The budgeting and funding of these organisations also did not give any incentive for taking up research projects based on marketing and survey of the industrial need for technology. Any research that was done, was to be produced as papers in journals. There were some attempts at import-substitution but only a few had any impact on industry. The delinking from the market-demand for technology is illustrated by the approach of Agricultural College & University, Faisalabad, along with many other R&D organizations. Before 1947, the Agricultural College at Faisalabad did considerable research, which resulted in improved agricultural practices and improved seeds. In those days the professors at the college were directly involved in extension work. They were active in keeping contacts with farmers and taking the results of their research directly to the farmers through many devices including demonstration plots. After 1947 the agricultural college evolved into a university, but the Government created a separate department for extension work, some say, only to ensure the promotion of a good scientist! The link with the farmers was considerably weakened in this manner.

PCSIR also expanded considerably and it was able to establish a large number of laboratories. In spite of that, it remained mostly unknown and unused by industry, in general. In order to create this link, a new organization called STEDEC or Science and

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Based in Part on a Paper “Development of Science and Technology in Pakistan” published in STD, 2001

Technology Development Corporation, was created. This organization was to market the technology and services available with PCSIR. This experiment was somewhat successful, but STEDEC fell into the trap of producing goods based on PCSIR research and marketing the products from the pilot plants of PCSIR. STEDEC can boast of a commercial approach, but it can hardly claim significant technology sales to industry, the main purpose for which it was created. The higher objective of promoting technology-sales to private industry and bringing projects from private industry to PCSIR, for research and development, could not be achieved.

THE BANYAN TREE

Some R&D organizations were attached with powerful departments like WAPDA, hoping that the basic financial strength of the parent-body and its own technological needs will create a symbiotic relationship. In most cases, this could not be achieved, as the personnel policies of the parent-body were not adapted for the attached research organisation. This resulted in some pernicious practices: the unwanted from the parent-organization were posted in the research organization. This created a serious morale problem with the research organization. The Rawat laboratory among many others visibly suffered from this approach. The grass could not grow under the proverbial Banyan tree!

ADMINISTRATIVE FACTORS

A study of research-organizations reveals an unimaginative approach toward their managerial issues. A report by the Committee on Public-Sector Corporations, Autonomous and Semi-autonomous Bodies, headed by the undersigned in 1996, collected a considerable amount of statistical data based on a questionnaire. The data-analysis brings out some very interesting points applicable to the Research organizations and their effectiveness. The relevant findings are discussed below:

a. *Selection of Heads*. Selection of heads was found to be highly discretionary. In 69% of cases the selection of heads was made without any standard formal procedure. In a large number of cases the chief executive was also the head of the governing body thus weakening even further any accountability or performance evaluation. In the case of research organizations, there was no tradition of “search-committees”. In the case of research organizations, it will be very desirable to institute the search-committee system by amending the charter or the statute. There was a unanimous view that the chief executive should not be the chairman of the governing body. The chairman could be a senior person, but, part-time, with a clear responsibility to evaluate the performance and achievement of goals.

b. *Tenure of Head of Organization*. In 77% of the cases, the heads spent less than four years in research organizations. It would be desirable to introduce a fixed tenure system in the research organizations for their heads, so that security of tenure and a suitable length is guaranteed under law. Without a suitably long tenure, say, five years, the head of a research organization cannot be expected to deliver.

c. *Governing Boards*. The data also revealed that the governing boards (GB) of most autonomous and semi-autonomous bodies are very weak. They met infrequently and irregularly; there was no incentive for the G.B. members to attend the meetings. In the case of commercial concerns, the governing board consists of directors who represent the owner. They can hold the company CEO responsible and accountable. Although the idea within the government was based on the same format but it was not implemented properly, with the result that in most cases there was not even the beginning of the corporate culture, which the designers had hoped for. In a scientific organization the corporate culture and accountability is even more difficult to achieve. However, strengthening the governing boards promises an effective method of achieving the twin objectives of accountability and a corporate culture, which is so sadly lacking in R&D organizations. In line with the recommendations of the Committee referred to above, it would be highly appropriate if: -

   i. The members of the Governing Boards (GB) have experience and qualifications, having a clear relationship with the goals of the organization and its specialities.
   ii. The members of the G.B. are of similar rank as the head and some are in higher grade than the head. This could be achieved by obtaining the services of even retired officers and scientists who have entrepreneurial approach and vision.
   iii. The administrative ministry should exercise extreme caution when selecting the members of the G.B. but must support its decisions and ensure that its decisions are implemented by the CEO or head of the organization.

d. *Performance-Evaluation*. The fact of inadequate performance evaluation by the governing boards or the administrative ministry was clearly brought out by the aforesaid study. Only 36% of the organisations surveyed had conducted any study for improving efficiency. There were also serious audit objections in the scientific organizations that had not been properly addressed or rectified. Numerous disciplinary inquiries were pending in 31 % of the organizations. On the basis of this data one can recommend that:

   i. Performance standards should be worked out by various research organizations and duly approved by the governing boards.
   ii. A system of cash incentives be worked out on the basis of quantifiable targets in addition to other methods of recognition.
   iii. Governing Boards must regularly monitor the pendancy of disciplinary cases.

e. *Merit-Orientation & Outside-Interference*. The study found that outside factors are adversely influencing the functioning of organisations. 74% of the organizations reported external factors hampering their performance. It was also apparent that ‘merit’ was being ignored because of the traditional ‘sifarish’ system, which had attained the proportions of an epidemic. This problem has to be faced and the evil practice rooted out.

RESEARCH GAP

There is a widening gap between industry and Research. This is an observable phenomenon in most developing countries. There are a number of symptoms of this malaise that are observable such as: (i) Researchers and industrialists are not in close contact and there is no tradition of regular one world. Very few industrial organizations employ engineers and scientists to improve their products and there are only a few research laboratories in the private sector. (ii) Large scale industry depends mostly on research done abroad. (iii) Small scale industry depends on, “mistri innovation” for their products. This is clearly visible in Gujranwala and Gujrat. The locally made washing machines were developed by technicians and 'mistris' and not highly qualified engineers or research scientists.

VICIOUS CIRCLE

The lesser the pace of development, the greater is the industry-research gap. This leads to the vicious cycle of (i) Decreasing quality of exportable products, (ii) Lower exports, (iii) Adverse terms of trade, as local products are not upgraded, (iv) Low G.D.P. growth, (v) Lower investment in research and widening gap between industry and research. Contribution by indigenous researchers has not been given the importance it deserves. Research has to be recognized as a factor of growth. Local industry especially small and medium scale could benefit significantly if the research gap is narrowed. Innovation and research are critical for maintaining an edge in the international market. Even low level innovation and research can be of importance in this regard. For example Pakistan lost considerable share in export of Basmati because of lack of minor innovations to meet changing demands of the international market. Pakistan continued to export in bulk whereas the market demand had shifted to different types of packaging.

LINKING INDUSTRY AND RESEARCH

The gap can be narrowed and the vicious circle of under-development, decreasing exports, adverse terms of trade, low GDP and inadequate investment in research, can be broken successfully in most developing countries, especially Pakistan. Pakistan is blessed with a large number of medium and highly educated engineers and scientists that are under-utilized. A number of steps will be required. The obvious ones can be listed as: (i) Linking industry with research as one of the goals in National Industrial Policy. This is not being emphasized in our development plans. No clear budgetary support is visible to achieve this goal. (ii) Teaching research methods at graduate level. Teaching of research methods is still not an important subject even after secondary school. This should be compulsory after secondary school and during graduation. (iii) Suitable research projects should be introduced even at intermediate level. They can be easily tailored to meet the knowledge and skill level of students. This is already being done all over Europe successfully. (iv) It should be compulsory for all Universities to introduce M.Phil and Ph.D.; otherwise such an institution should be considered unfit to be called a "University".

CONTRACTUAL RESEARCH

Giving out research contracts can be a very powerful tool to bring industry and science together. This method is eminently suited to adaptive and industrial research but not to fundamental research. Effectiveness of contractual research was demonstrated by the Ministry of Science & Technology in the late nineties. A research contract was given for developing shuttle-less air jet loom in the country. There were clear stages in the contract to ensure that the money was well spent. An engineering firm in Faisalabad took the challenge and was able to produce air jet looms for evaluation. The looms were then given to the Faisalabad Textile College for evaluation. Well designed contractual research projects can proceed from the very simple to highly complex research projects with a reasonable degree of success. This technique is not being fully utilized by the developing world. In order to support contractual research, contractual research funds have to be created. A system to use the research fund will also have to be evolved. The experiment already made by the Ministry of Science & Technology in 1993 and onwards could be of help.

RESEARCH BY PRIVATE-SECTOR

Creating research-companies that can survive on selling their research-efforts seems to be a pipe dream, but this is possible and should be adopted as a long-term goal. Initially, such companies will have to be given considerable monetary and tax incentives to be successful. This will still be less costly than spending on a large number of non-productive research organizations in the public sector, which is the current situation.

RESEARCH AS THE KEY FACTOR

The whole spectrum of innovation and research, starting from the most elementary and going right up to fundamental research, is the key element in any nation's growth. The Holy Quran after every few pages points towards various natural phenomena and exhorts all to think and do research. When will we take heed and listen to this injunction? We have suffered for centuries by neglecting research. Do we want to suffer for another millennium?

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RESEARCH AND SOCIO-ECONOMIC DEVELOPMENT: A COMPARATIVE ANALYSIS OF PAKISTAN, MALAYSIA AND INDIA

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1. SCIENCE-LED SOCIO-ECONOMIC DEVELOPMENT

Globalization is playing an influential role in socio-economic development, especially in advanced countries, while sometimes imposing new rules in socio-economic spheres worldwide. This implies that the objectives and rules guiding developments in science and technology, especially innovation-based technologies, are strongly conditioned by globalization. This process highlights the importance of national competitiveness in science and technology for success in global markets. At the international level, the scope for acting and working in science and innovation is more and more conditioned by the possibility of applying the research and development (R&D) results to product-development and commercialization in the global market. The developing countries, representing the majority of the world's population, have only a marginal percentage of the world's R&D capacity. Therefore, the issue of establishing global equity and equality, with science and technology (S&T) as the dominant determinant, has to be given serious consideration.

The rapid growth of scientific knowledge and continuing developments in technology are transforming society. The advances in the field of S&T have been driven by an ever-growing volume of exciting discoveries, largely evolving from the science laboratories in the advanced countries. These new products & processes have flooded world-markets, showering vast economic rewards on nations that have had the courage and vision to make science and technology the corner-stone of their developmental programmes. The days, when one could depend on agricultural produce or low-value textiles, leather, etc.,, for economic growth, are long gone. Now building an S&T capacity is one of the essential components for sustainable development of a country, and R&D is required to build it.

It is believed by many OIC member countries, that they should focus their efforts purely on applied research and give a much lower priority to basic research. This is dreadfully wrong! Basic and applied research, have to go together. This is true not only

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Based in part on material from the Book "50 years of Research & Development in Pakistan (1997/98) and "Science and Technology Indicators of Pakistan" by PCST (2005) for OIC member countries, but all the developing countries should opt for a high quality and integration of basic and applied research. It is because of this blend, that advanced European countries, such as France and Germany, with populations less than Pakistan are wealthier than the entire Muslim world, comprising about a quarter of the world's population.

The present study is a comparative analysis of Pakistan, Malaysia and India on the basis of six basic components, necessary for an effective R&D system, which comprise Policy, Infrastructure, Enterprise, Human Capacity, Content and Applications and Strategic Integration. The study will specifically focus on Pakistan, by analyzing the history, as well as current situation of R&D in Pakistan, to identify where Pakistan is lagging behind in efficient utilization of R&D.

2. R&D IN PAKISTAN

The national commitment to use Science and Technology as the road to development plus the political will at the highest possible level to implement the S&T policy in a country is required for economic growth.

Pakistan has a GDP of about Rs. 8,716 billion (2006-07), with about a quarter (25%) of it being contributed by the agriculture sector. The growth is due to increases in the agriculture and services sectors; despite a low per- capita income and manufacturing output. Pakistan ranked well in most innovation-related categories. The highest ranking in this group was for the capacity for innovation, in which Pakistan stood 38th among 125 countries. The innovation indicators measure whether companies produce mostly through licensing or imitation, or whether they are undertaking formal research and developing new products (1) .Knowledge- based growth must become the driving force of Pakistan's development: science and technology must be allowed to come to its rescue.

The development of new technologies based on scientific knowledge have played an important role in the transformation of human and animal labor based medieval-looking Pakistan; rural society into a progressive and technology-based culture during the last half century. In Pakistan, most of the R&D takes place in the public sector whereas the share of private sector in R&D is insignificant. The Federal Government of Pakistan and respective provincial governments have been according highest priority to R&D in the areas of Food and Agriculture, Livestock, Fisheries and Forestry. The efforts made in this R&D have resulted in significant achievements, such as developing new varieties, introduction of new crops, techniques, process etc.

Limited R&D efforts have been made towards solving energy related problems. However many R&D organizations and universities are engaged in R&D on conventional and non-conventional energy sources. The Pakistan Institute of Nuclear Science and Technology (PINSTECH), Nilore, which has been able to earn an international reputation for high-quality research, is engaged in R&D on nuclear minerals, materials, analytical chemistry and computers. To help Defense R&D, various organizations and universities have been conducting research and production of materials and chemicals on contract-basis. Despite the constraints faced by Pakistan in terms of R&D, a great deal has been accomplished.

History of R&D in Pakistan: 1947-59: At the time of independence in 1947, Pakistan received a meager proportion of scientific and technological research institutes, including four small laboratories, one agriculture college (research institute) and two universities (fully functioning). Pakistan has progressed in building up the S&T capability to the extent that R&D organizations have increased from 4 to around 2,000 and the number of universities from 2 to 109.

In order to develop industries in Pakistan, the Government initiated a vast programme through P.I.D.C (Pakistan Industrial Development Cooperation) in the fifties. Industries for the manufacture of cotton, chemicals, dyes, sugar, fertilizers, matches, soap, cement ,paper etc were established by 1960. A number of schools, colleges, universities and hospitals started functioning. Programmes to help agriculture, animal husbandry, forestry and fisheries were developed. Non-Governmental organizations such as Pakistan Association for the Advancement of Science (1947), Pakistan Academy of Sciences (1953), Scientific Society of Pakistan (1955) and Pakistan Association of Scientists and Scientific Professions (1958) started working for S&T promotion. Central Cotton Committee was established in 1948, followed by creation of Food & Agriculture Council (1949), Central Jute Committee (1950) and the Council of Scientific and Industrial Research (1949). The Pakistan Medical Research Council was established in 1953. The Atomic Energy Research Council was established in 1965 and it established a laboratory at Karachi. Despite all these research institutes, it appeared that scientific research had contributed little during the first decade to the economic development of Pakistan. Therefore a Scientific Commission was established in 1960.

1960-69: In order to advice Government on S&T matters and to coordinate the work of the research councils, the National Science Council was established in 1962 as an independent organization. A Defense Science and Technology Organization (DESTO), was established in 1963, to carry out R&D for the armed forces. The Scientific and Technological research Division was created in 1964 and research councils for works and housing, Irrigation, drainage, flood control, etc, were also established in 1964.Agriculture University, Faisalabad, and the Engineering & Technology University, Lahore, were established for the promotion of higher education and research in agriculture and engineering. A two member Mission reviewed the management of research and development in Pakistan in 1966. For the promotion of advanced studies and research in the agriculture and engineering universities, the Education Commission and the Scientific Commission were set up during the period of 1960-69. In-spite of the various R&D organizations established the full implementation of their functions could not take place due to lack of necessary funds.

1970-76: The R&D activities reduced during 1969-72 due to the political instability in the country. After the political change in the country, the scientists were encouraged to work on national problems. Ministry of Science and Technology (MoST) was established in 1972. Karachi Nuclear Power Plant with a net electrical capacity of 125 MW was also commissioned in 1972.In order to provide financial support for research on socio-economic issues Pakistan Science Foundation was established in 1973 as a lead agency. A Science Policy Cell was established in 1975 in the Ministry of Science and Technology, whereas a draft S&T policy was prepared and submitted to the Cabinet in 1976.the Minister for Science and Technology was included as a member of the Executive Committee of National Economic Council (ECNEC) and the Chairman, National Science Council as a member of the Central Development Working Party, so as to create a linkage of S&T activities with the country's economic Planning and development process.

1977-1984: The period of 1977-1984 deemed as the most progressive time period for S&T. UN activities for S&T development during this period increased considerably. Various international conferences were arranged, regional centers were established, few experts were invited and collaborative research programmes were initiated. One of the important events was the organization of UN Conference on Science and Technology for Development in 1979. Between 1980 to 1984 MoST established five R&D institutes including National Institute if Electronics, Islamabad, National Institute of Power, Lahore, National Institute of Silicon Technology, Islamabad, National Institute of Oceanography, Karachi and National Centre for Technology Transfer, Islamabad. 1985-89: Measures were taken to implement the Action plan for the proposed National Science and Technology Policy. An S&T component was incorporated in the five-year development plans. National Commission for Science and Technology was constituted as the decision making and coordinating agency for S&T. High level S&T Manpower Training Programmes were launched, leading to Ph.D. degree in new and emerging technologies.

1990-97: The period during 1990-97 had to face quick changes in the governance, interference of the international financial institutions in the formulation and implementation of economic and trade policies, introduction to WTO and scarcity of public funds to carry out R&D. Some programmes and institutions including scholarships, National Centre for Technology Transfer, Pakistan Medical Research Council had to be either closed or transferred. National University of Science and Technology was established in 1994 to improve the quality of Higher Education.

1998-2006: Pakistan achieved its indigenous missile capability through test fire of Hatf-V (Ghauri) Missile on April 6, 1998. Pakistan enjoyed a significant rise in the number of awards, particularly since 1999, but still lags behind major competitors. So far Ministry of Science and Technology has launched 270 developmental projects with a total cost of about Rs.21, 742.00 million, focusing on Human Resource Development, strengthening of R&D infrastructure, and R&D-industry linkages. To encourage public-private partnership in the field of collaborative research, the Federal

Government launched the Science & Technology for Economic Development (STED) programme in 2005. Programmes for export enhancement, import substitution, clean & safe drinking water provision, WTO requirements, intellectual property right, ISO certifications etc. were initiated during 2004-2005.

2.1 Science and Technology Policy

The prosperity of a country is not judged by its physical assets only but the technological gaps between the haves and the have-nots. No leap-frogging of the type witnessed in developing countries is possible without increasing the technological infrastructure being built into the production sector. Information Technology today drives the technological and economic advancement of the developed as well as emerging economies. The Government is fully aware of IT being the driving force in the new millennium. A number of initiatives have accordingly been taken in the recent past, to provide a sharper and clearer focus to the IT sector.

One of the prerequisites for ensuring sustained growth of the industry, in the economy, is the provision of a definite framework consisting of policy, legislative, financial, and operational guidelines, which can provide a stable umbrella for growth. Thus, the government, as the main facilitator, enabler, and promoter of the IT sector, has evolved an effective national IT Policy and Action Plan that clearly caters to the needs of nurturing the industry and is responsive to the dynamic forces of change that can affect its future growth. The Private sector is being brought into the mainstream as the main driver for growth.

The guiding theme for the Policy is that the Government shall be the facilitator and enabler to encourage the Private sector to drive the development in IT and Telecommunications. This one single element has galvanized the entire Pakistani IT community to participate wholeheartedly in the process and over 200 professionals mainly from the private sector participated in various dialogues and eleven Working Groups meetings to devise a comprehensive Policy and Action Plan document.

The IT Action-Plan is an integral part of the IT Policy. The Action Plan provides a framework for implementation of the IT Policy which includes priority areas, specific projects that can be conceptualized, formulated, assessed, prioritized and implemented. The implementation of Action Plan is very much dependent on the funding provision for the IT & Telecommunications Division and the mechanism from project approval to funds release so that projects could be implemented in a timely fashion to achieve the desirable results in shortest span of time. A separate mechanism for expeditious project appraisal by Experts Committees, approval and funding under National Scientific and Technological Research and Development Management Fund has been developed.

The Policy & Coordination Wing is responsible for dealing with matters related to National S&T Policy, and to identify areas for S&T Research to cater for requirements viz emerging technologies. According to a WTO report, Pakistan's long-term economic growth depends importantly on the continued implementation of the Pakistan's Comprehensive Economic Revival Programme. This programme was launched to address Pakistan's economic and other impediments to sustained, strong growth. Pakistan's main trade policy instrument is the custom tariffs. Pakistan has been able to achieve a lot through its Trade policy.

The Government of Pakistan is introducing such industrial policy that it would reduce unemployment. The Computer Software and IT industry is enjoying relaxations such as Zero percent customs duty on import of IT related machinery and equipment, tax relief, reduced depreciation rates etc for the growth of Computer Software and IT industry.

Infrastructure: National Commission for Science and Technology (NCST) in Pakistan works on projects for strengthening of R&D infrastructure in the country. The Asia-Pacific Development Information Programme of UNDP states that in Pakistan computer ownership per 100 inhabitants is 0.41 (2006) (2). The number of Internet hosts per 10,000 inhabitants is 0.78 whereas the number of Internet-cafes per 10,000 inhabitants is 5. The number of Internet users in Pakistan is 10,500,000 while Cell phone subscribers per 100 inhabitants are 0.56. National bandwidth within Pakistan is about 240 Mbps however current IP bandwidth available to and from the country is 600 Mbps. The Ratio of incoming to outgoing Internet traffic volume is 1:2.25. Tele-density has risen to 42 showing visible expansion in the telecommunication service while mobile phone density has reached at 32.66 in January 2007. The number of cities with Internet access has increased from 1700 to 1900 whereas efforts are being made to expand Internet services. PTCL is the major Internet backbone provider in the country. It runs the major IP backbone through which access facilities are provided to majority of Internet users in Pakistan. In addition to public sector operators, there are 80 private sector Internet service providers and nationwide data communication network operators who provide Internet accession all major cities of Pakistan. According to the Economic Survey published by Government of Pakistan, there are currently about 1.7 million active Internet users in the country thereby enabling access for about 1.16% of the population. The basic access to telecom is also facilitated through payphones, which are deployed all over the country and whose number has reached to more than 100,000. In terms of Internet access, the IP bandwidth prices have been brought down from over US$60,000 to US$1600 per 2Mbps per month (3). This drastic reduction in backbone prices has had a very positive impact on end user pricing, which have become affordable, averaging at US 25 cents per hour (peak time) in major cities of the country.

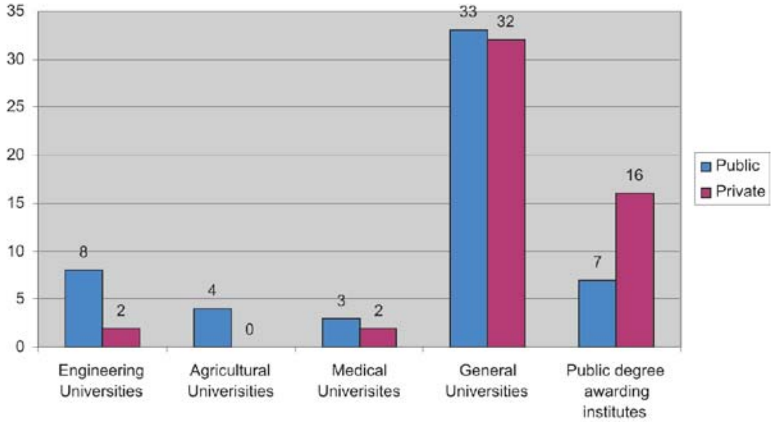
The e-Government Program was launched in 2001 with three fold objectives i.e. to encourage ICT's for enabling information and services delivery to the citizens in a cost effective manner, initiate measures for reengineering of work flow in government departments to enable electronic services delivery to citizens to bring efficiency in operation and also to bring transparency in government functions and access to information.

According to a report by UNESCO the Pakistani IT industry requires a world class-enabling infrastructure. A series of IT Parks and Incubators will be set up across the country, equipped with modern facilities and matchless incentives, to provide a one-stop shop for prospective investors in the IT industry. Telecom infrastructure will be modernized to carry broadband access in the backbone and local loops. IT Boards will be established in provinces (except in the Punjab where it exists already), tele-density increased and new technologies introduced, such as wireless local loop for data and cable Internet.

The indicators of 2005-06 show that Pakistan has 49 chartered universities and degree awarding institutes in public sector whereas 36 such institutes in private sector making a total of 85 universities. (Higher Education Commission: www.hec.gov.pk) (4). It is interesting to note that Pakistan's National University for Science and Technology figured in the top 20 Asian universities in 2000. More then 60 organizations are involved in Science and Technology activities and support (Figure-1).

2.2 Enterprise

Pakistan was able to attract $ 4.6 billion of Foreign Direct Investment in 2007 as compared to $1.9 B last year. This growth was tied largely to the privatization of select industries (led by telecom), which drew large investments from the UAE and elsewhere. In fiscal year 2006-2007 Pakistan’s inward FDI flows were estimated at $2.6 billion by EIU while current estimates put the number at close to $7 billion. The 2006-2007 estimates are likely to increase as FDI flows into Pakistan from Qatar and Kuwait will reach $4 billion in the power, hotel, insurance and oil refinery sectors.



Source: *Higher Education Commission 2004 (www.hec.gov/htmls/hei/collunilist.htm)*

Figure - 1: Universities and Degree-Awarding Institutes in Pakistan, 2004

Table - 1: Comparative Analysis

Inward Direct Investment (US $ bill)					
Country	**2005a**	**2006b**	**2007b**	**2008b**	**2009b**
Egypt	5.4	6.8	7.8	6.5	5.5
Kazakhstan	1.7	4.8	6.0	8.1	6.1
Malaysia	4.0	4.0	4.1	4	4.2
Jordan	1.5	2.8	2.1	1.8	1.9
Pakistan	2.2	2.6	1.2	1.2	1.3
Nigeria	2.0	2.45	1.98	2.1	2.1

Source: (a) Economist Intelligence Unit Estimates
(B) Forecasts

Science and Technology in Pakistan has witnessed exceptional support from government in the form of growing budgets since 2000. The increase in S&T expenditure after the years 2000-01 was due to two main factors including (1) National Commission for Science and Technology which in its second meeting held in 2000 approved a number of recommendations to initiate various S&T programmes for which the government increased S&T budget (2) increased heavy funding by the government for IT activities. S&T expenditure climbed from 0.28 % to 0.51% of GDP, Gross Domestic Expenditure on. Research and Development (GERD) more then doubled, from 0.11% to 0.24% of GDP. Pakistan witnessed a marginal decrease in spending on education from 2% to 1.8% during 2000-2004 (UNESCO Science Report 2005).

The number of patents granted by Pakistan Patent office till 2003 is very low as compared to other countries. The total number of patents granted to residents of Pakistan is 180 only during the previous years; while in India during the year 2001 only 387 residents were granted patents (Table-2).

2.3 Human-Capacity

Building S&T capacity is very important as it not only enables a country to better absorb and adapt foreign technologies but also develop solutions to problems. Pakistan with a ranking of 144 on the UNDP's Human Development Index

Table - 2: Number of Patents Granted in 2001

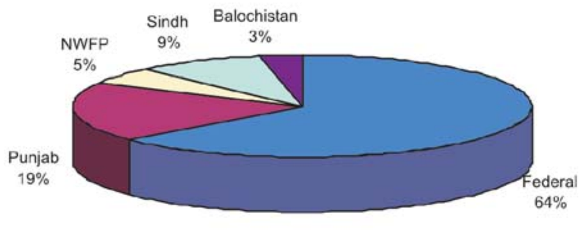
Country	Local	Foreign	Total
Pakistan	12	338	350
Korea	21833	12842	34675
Japan	109375	12367	121742
China	5395	10901	16296
India	387	-	-
USA	87606	78432	166038

Source: *World Intellectual Property Organization (WIPO)* (http://www.nchd.org.pk, 2006), out of a total of 178 countries is striving hard to work towards the challenge of capacity building. Factors such as poverty, illiteracy, lack of healthcare facilities and increasing population have for long held back the scope of generating improved social sector outcomes for the millions of Pakistanis living at the grassroots. Various steps have been taken in the past to address these issues but have often been marred by the lack of political will, economic & political instability and inadequate capacity of the implementing agencies which further reduced the possibility of human development in the country. S&T manpower is the most important component of scientific and technological development as without people such as scientists and engineers it is not possible to get good production capabilities, to take advantages of scientific and technological transfers from developed countries, to carry out effective R&D and have a productive system for training personnel. Pakistan has made great strides in improving adult literacy over the past despite of the constraints faced; total literacy rate is 41.5% while female literacy rate is 28.5% (5).

The number of scientists per million involved in R&D has increased from 72 to 95 during the last 7 years. While the number of PhD Scientists in Pakistan has increased from 1336 to 2860 during last 10 years, this number is still far less than many developing countries such as India and Egypt. (5) (Figure-3 and 4).

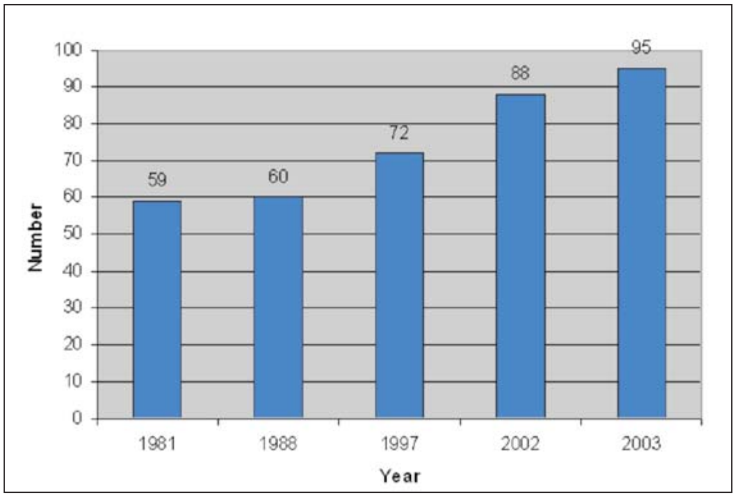
Unsatisfactory level R&D in health can be seen from the fact that there are only 64 MBBS degree holder involved in R&D. Since the independence of Pakistan the number of universities and degree awarding institutions has increased up to more then 100. The universities and chartered degree awarding institutions in public and private sectors collectively employ 10894 teachers in various fields of study. The strength of teachers in the science and technology field (68.5%) is more than twice of the non S&T area (32.8%).

The Computer Hardware sector employed 3600 personnel, including 300



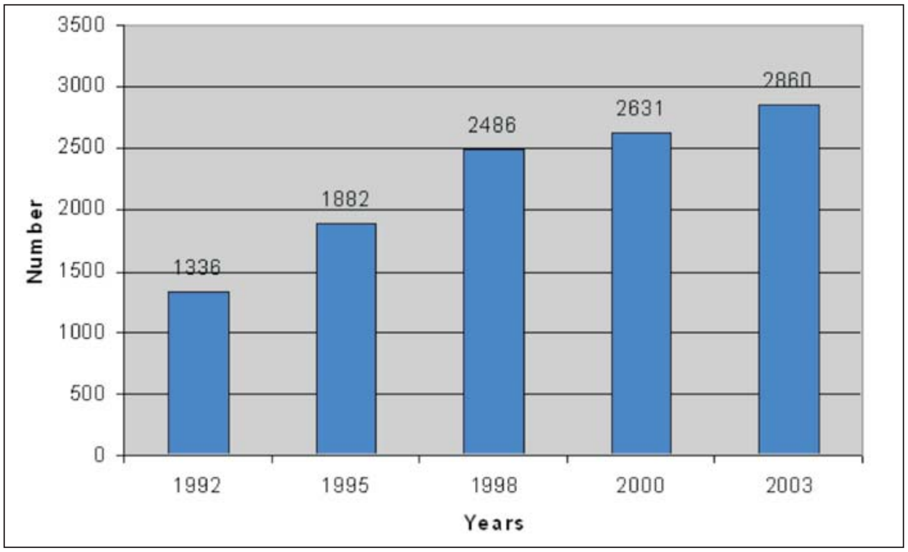
Source: *Science & Technology Indicators of Pakistan, PCST*

Figure - 2: Percentage of Scientists working in R&D Organizations under Federal and Provincial Government - 2003



Source: *UNESCO Website (www.uis.unesco.org) and 50 years of R&D in Pakistan by PCST*

Figure - 3: Increase in Number of Scientists (per Million Population in Pakistan) involved in R&D



Source: *UNESCO Website (www.uis.unesco.org) and 50 years of R&D in Pakistan by PCST*

Figure - 4: Increase in Number of Ph.D. Scientists involved in S&T Activities

professionals and over 30 fully functional manufacturing facilities across the country during 2006 (2).

The Higher Education Commission has been set up by the Government of Pakistan to facilitate the development of indigenous universities to be world-class centers of education, research and development. Through facilitating this process, the HEC intends to play its part in spearheading the building of a knowledge-based economy in Pakistan. Constant efforts are being undertaken at various quarters in the country today to devise and implement methods of developing human resources. Higher Education Commission has thus embarked upon a program to develop the human resources in the country through launching new scholarship programs for students, teachers, scientists or technologists. Following are some of the main programs being offered by HEC:

- Scholarships
- Foreign Fellowships
- Faculty Hiring Programs
- Expert Exchange program
- Research Grants
- Scientific Equipment & Library Grants

2.4 Content and Applications

There is a growing realization among policy-makers that ICTs hold great socioeconomic potential, to the extent that the government is encouraging the use of ICTs at all levels, with planned investment in both infrastructure and technological application. This has resulted in Pakistan having the most extensive Internet penetration among the countries of South Asia, with probably the cheapest Internet rates. Similar progress has been seen in the development of telecommunications infrastructure, particularly regarding mobile telephony.

The poor state of governance and weak protection of rights in Pakistan can largely be attributed to a lack of access to information on public affairs, which restricts the ability of citizens, civil society groups and public representatives to effectively monitor the performance of public institutions. (Global Information Society Watch) Information could also be made accessible through websites, but most government websites offer little useful content. Similarly, the archives are not properly maintained and updated and it is difficult to access old records. All of this is, partly or wholly, because of the absence of a comprehensive policy that recognizes the right to information as a fundamental human right and provides an efficient legislative and institutional framework for its implementation.

Virtual University has been established in Pakistan providing access to students all over Pakistan .It used Internet and video facilities, to provide distance learning to a large number of individuals. Projects such as Tele-health and distant learning programmes are being established in northern areas.

By November 2006, licenses for over 100 commercial FM radio stations, two dozen satellite TV channels, an IPTV and two DTH channels have been issued, transforming the country's media scene dramatically. An official study by PEMRA declares that Pakistan has the potential for over 850 viable FM radio stations, enabling even far-flung communities in information-dark areas to benefit from locally relevant coverage.

In 2003, the MIT set up a Task Force for Linux and as a result the Open Source Resource Centre (OSRC) was established by the Pakistan Software Export Board (PSEB) in January 2004 in Islamabad. The centre promotes FOSS in the local IT industry, and also conducts training. Pakistanis speak over 70 different regional languages, with the English-speaking community making up less than 10% of the total population. In order to take ICTs to all corners of the country, localized Urdu language content needs to be developed. This includes the translation of software for desktop and server sides. Such efforts are already being made by FOSSFP and Ubuntu-Linux. National Institute of Biotechnology and Genetic Engineering (NIBGE) has been able to accomplish the major achievement of finding a solution via biotechnology for eliminating cotton leaf-curl virus, which plagued the cotton industry.

2.5 Strategic Integration

The Public Private Partnerships sees a new era in uplifting national education, the coming together of the State, the National Program Office (NPO) and the philanthropist to work out a powerful solution. The Government with its large infrastructure and social sector assets, the NPOs lend their management expertise and the philanthropists contribute financial support. This arrangement lays out the basic resources of import and has the potential of substantially increasing the quantum of investment. Government of Pakistan (GoP) recognizes that the public sector on its own lacks the necessary resources and expertise to effectively address and rectify low education indicators, It has now taken the bold step to involve the private sector and civil society organizations in the financing, management and delivery of education services in Pakistan encouraging public-private partnerships. However the actual processes and methodologies of these partnerships (PCP) are neither well established nor well promoted. The public private partnerships arrangements have the potential of making a huge impact, if organized appropriately. The PCP aims to add value to the practice by advocating best practices and encouraging corporate social investment.

3. R&D IN MALAYSIA

Science and technology play an increasingly important role in sustaining and improving the competitiveness of Malaysia. The World Competitiveness Year Book placed Malaysia in the 16th position for 2004, ahead of some more developed nations such as Germany (21), United Kingdom (22), Japan (23), South Korea (35), and New

Zealand (18) (IMD, 2004). This enviable position can be attributed to, among others, impressive economic performance and business efficiency. The weakness of Malaysia lies in its scientific infrastructure and innovation system that still lacks innovative capability. Therefore, addressing weaknesses in the area of S&T and building scientific capabilities are the strategic directions that Malaysia must seriously consider whilst continuing to exploit their strengths and capabilities that are already embedded in their competitive structure.

Malaysia's economy continued its recovery path from the Asian financial crisis that took place in 1998. Domestic output, as measured by the real GDP figures, grew from RM209.9 billion in 2000 to RM219.3 billion in 2002, representing a growth of 4.4% over the period of two years. On an annual basis, the real GDP registered a slower growth of 4.1% in 2002 as compared to 8.5% in 2000 due to a combination of weak demand in the electronics sector and the adverse knock-on the effects on the tourism-related industry as a result of the threat of international terrorism. In terms of individual's wealth, Malaysia's income per capita improved slightly from RM13,333 in 2000 to RM13,683 in 2002 due to an almost stagnant real GNP growth of 0.3% in 2001. When adjusted for purchasing power, the income per capita for Malaysia stood at US$9,300, which was more than double the income per capita for China (US$4,400) and half of that for Taiwan (US$18,000), in line with our nation's middle - income status relative to other countries. Since 1988, The Government has implemented a centralized grant system of financing science and technology (S&T) research in public institutions and research agencies. The Ministry of Science, Technology and Innovation (MOSTI) is charged with the responsibility of managing the fund and the implementation of S&T research and development (R&D) programmes in the country. Other private agencies such as MDC, MSC, and MTDC, also participate in providing assistance.

In an environment characterized by rapid advance in ICT, globalization, liberalization, and greater reliance on knowledge for value-creation, Malaysia plans to leapfrog into the post-industrial age, by leveraging ICT as a strategic lever for national development and global positioning. In 1996, Malaysia launched a program called "Vision 2020," which laid out a plan to build a fully developed, knowledge-rich Malaysian society by the year 2020, through the development of the ICT sector and the use of ICT to increase global competitiveness. The intent behind Malaysia's Multimedia Super-Corridor (MSC) has been to create a high-tech environment and infrastructure that can attract national and international investors and create spillover effects in the rest of the Malaysian economy. Specific sectors of focus include education, healthcare, governance, commerce and manufacturing.

Awards won by Malaysian inventors have been increasing over the years, reflecting a positive growth in the capacity for inventiveness. In 2001-2002, a total of 72 awards were won compared to 35 in 1999-2000. Especially in Gold Awards, Malaysians won 16 Gold in 2002, representing an improvement of more than 100% over 2001; 20 Silvers and 9 Bronze were won in 2002.

3.1 Science and Technology Policy

The highest national policy-making body for Science and Technology in Malaysia lies with the Federal Government of Malaysia. Policy formulation on S&T and public sector R&D as a portfolio, however, is mandated to the Ministry of Science, Technology and the Environment (MOSTE). Apart from MOSTE and NCSRD, the Academy of Sciences of Malaysia (ASM), the Malaysian Industry & Government Group for High Technology (MIGHT), the Malaysian Technology Development Corporation (MTDC), as well as S&T Non-Governmental Organizations interact frequently, to contribute towards the development of S&T in Malaysia. (9)

Comprehensive policies are being developed to encourage ICT use in various sectors of the economy, as well as to accelerate the growth of R&D. Trade and investment policies, such as financial and non-financial incentives, a fair trade system, and import and export duties, promote local and foreign investment. The Malaysian government has also defined attractive policies for foreign investment, such as streamlining the investment approval process, unrestricted employment of foreign knowledge workers, and freedom to obtain capital globally.

With the inception of the New Economic Plan in the 1970s, the government made a concerted effort to deregulate the telecommunications industry. With the privatization of the government telecommunications department in 1987, and the formation of the National Telecommunications Policy (NTP) in 1994, the market has now been fully liberalized. The Malaysian Government's Master Plan for the telecommunications industry provides guidelines for competition, interconnection charges, tariff rates and network development. At the end of 1995, all operators signed interconnection agreements with Telekom Malaysia to provide seamless communication regardless of carrier, though most carriers have not signed agreements among themselves.

The computer and software markets have also been fully deregulated, though restrictions exist on participation in government bids, and there are equity requirements for setting up manufacturing facilities. These barriers do not pose an insurmountable barrier to competition, but encourage the establishment of joint ventures and local distributorships with Malaysian companies.

Infrastructure: Malaysia’s R&D expenditure as percentage of GDP is 0.7%. The R&D expenditure increased steadily from RM1,671.5 million in 2000 to RM2,500.6 million (an increase of 49.6%) in 2002. This indicates the commitment of various sectors, i.e. the government and the private sectors, to R&D.

The Malaysian Government has invested heavily in world-class infrastructure. Malaysia's Multimedia Super Corridor (MSC) is designed to create an ideal environment for ICT-related production as well as provide the backbone for an information superhighway. The network contains a high-speed link (10Gb/s network) that connects the MSC to Japan, ASEAN, the US and Europe, and is capable of supporting extensive public administration, education and business applications. The intent of the superhighway is to provide quality access to global information as quickly and easily as possible. Simultaneously, the Demonstrator Application Grand Scheme (DAGS) is intended to facilitate social and economic progress through the innovative use of ICT. It provides funds for citizens to access the opportunities associated with the MSC and to be involved in multimedia development.

The telephone penetration rate—as a measurement of the ICT readiness of the country—rose from 16.6 percent to 23.2 percent between 1995 and 1999, while fixed lines in the rural areas rose from 5.2 percent in 1994 to 11 percent in 1999 (6). Malaysia is aiming to continue the establishment of basic telecommunications infrastructure, with plans for 250 Internet access points, 250 mobile phones and 500 fixed lines for every 1,000 people within the next 5 years. This is in addition to the development of other primary physical infrastructure, such as power supply, transportation, airports, office buildings and extended business areas. Malaysia, with 137 computers per 1000 inhabitants ranks among the European countries in this regard. The number of internet users per 1000 inhabitants are 269 which is considers low among other industrialized Asian countries. Malaysia compares to developed countries in internet usage(UNESCO Science Report 2007).

3.2 Enterprise

Over the years, the Malaysian government through various ministries and agencies, has helped the Small and Medium Industries (SMI) succeed from start-up through the many stages of growth. Financial assistance is offered to help start or expand these businesses and achieve success through business loans to entrepreneurs and business owners of specialized industries. These loans are made available through financial institutions such as Credit Guarantee Corporation Malaysia Berhad, Bank Pembangunan dan Infrastruktur Malaysia Berhad and Bank Industri dan Teknologi Malaysia Berhad to enable these entrepreneurs to obtain up to 100% loan and credit facilities to support their business aspirations. Venture Capital is an alternative form of financing. The Government has proven itself in the past to be very supportive of the VC industry and has continued to do so, providing adequate liquidity to meet the industry's needs.

As a result of fair trade and investment policies, foreign direct investment in Malaysia reached US$6 billion in 1997, but then dropped to US$3.8 billion in 1998 due to the Asian economic crisis. In 1999, flows of foreign direct investment again increased by 31 percent and GNP rose 5.4 percent—much faster than initially forecasted. This increase was led by manufacturing, particularly in ICT-related electronics (for export), and this sector is now the key driver of growth in the economy. In 1999, the contribution of the ICT sector to GNP was approximately 36.5 percent. (6)

A number of incentives and projects are underway to foster entrepreneurship and business efficiency. The government provides both financial and non-financial incentives to Malaysian businesses. Financial incentives include zero income tax for a period of 10 years, R&D grants, and a 100 percent investment tax allowance on new investment in the MSC. Non-financial incentives include unrestricted employment of foreign knowledge workers, no restrictions on global capital, and limited restrictions on ownership. In terms of R&D output, the total number of patent applications has declined over the years. The total number of patents applied for the period 2001-2002 has dropped compared to the number of applications for the period 1999-2000. A total of 10,871 applications were received for the period 2001-2002 compared to 12,036 and 12,416 for 1999-2000 and 1997-1998, respectively. This decline is largely due to the decrease in the number of applications by non-residents. The number of applications by residents has increased while that of non-residents has decreased by about 15%.

3.3 Human-Capacity

The growing economy has created a demand for skilled knowledge workers and professionals. According to Malaysian Science and Technology Indicators 2004 Report researchers per 10,000 labor force during 2000 and 2002 increased from 6.4 to 7.3. The private sector of Malaysia observed a significant increase in researchers in term of headcount (45.4%) during the period of 2000-2002. the field of research that received tremendous attention in 2002 in terms of the number of researchers was engineering sciences, followed by information, computer and communication technologies.

Skilled labor is still in short supply, especially in the ICT sector and manufacturing industries. To address this issue, the Malaysian government is investing in a high-quality, comprehensive education system designed to meet the demands of the evolving workplace. At the Multimedia University, for example, new skills such as information and knowledge management, as well as programming applications, will be incorporated into the education and training curriculum. Several additional efforts have been made to increase ICT literacy. The Computer In Education (CIE) Program has provided computer laboratories to 90 secondary schools and 20 primary schools. Between 1996 and 1998, about 1,230 teachers were trained to conduct the CIE course. Computer Aided Design and Computer Aided Manufacturing (CAD and CAM) courses were also taught in secondary technical schools. (6)

The Human Capital Development Fund Programme in S&T is an effort by the Government to strengthen the human capacity and capability for the enhancement of S&T in Malaysia. Among the objectives of this programme is to increase the critical mass of scientist and researchers of the country. It also aims at further strengthening the R&D functions in institutions of higher learning and public research institutions; and to enhance the country's competitiveness through the development of trained, innovative and creative human resource.

3.4 Content and Applications

Malaysia has made a concerted effort to provide relevant content to technology users through a number of specific initiatives: for example, Agritani is developing a portal that serves agriculture communities, including farmers, agriculture agencies, consultants, and agriculture service providers; and Cybercare enables orphanage communities in Malaysia to share news, barter goods, train volunteers and increase administrative efficiency. (6)

E-commerce initiatives are helping to provide Malaysian businesses with more efficient access to input and product markets, both locally and globally. For example, MyBiz, an e-commerce platform designed for small and medium enterprises helps facilitate collaborative marketing by linking 300 companies including 26,000 employees in a business community network. The same platform can be used to make procurement processes more efficient and effective. (6)

3.5 Strategic Integration

Malaysia's leadership recognized the need for a cooperative partnership to achieve its development objectives and its ambitious vision. To leverage and coordinate public, private and community sectors, the National Information Technology Agenda (NITA) was developed as a major strategy for national development. The National IT Agenda (NITA), launched in December 1996 by the National IT Council (NITC), provides the foundation and framework for the utilization of ICT to transform Malaysia into a developed nation. The NITA vision is to use ICT to transform Malaysia, across all sectors, into an information society, then a knowledge society, and finally a "values-based" knowledge society. Malaysia has had notable success with public–private sector consultative institutional mechanisms.

The involvement of private companies in Research and Development (R&D) activities is crucial to the nation's industrialization drive. To further encourage the involvement of the private sector in carrying out R&D, the government of Malaysia has made available various types of incentives for R&D activities. Most of the R&D deductions and allowances are provided for under the Income Tax Act, 1967. The category of incentives by way of Pioneer Status and Investment Tax Allowance are provided under the Promotion of Investments Act 1986.

4. R&D IN INDIA

India stands out among its South Asian neighbors, in terms of national investment in R&D and endowment of S&T human resources; it also maintains the lead in S&T publications. The S&T policies of Indian have always stressed on the importance of Human capacity building. A spate of reforms—post-1991 economic crisis—have given impetus to the Indian economy, particularly to the ICT sector. As part of the reform agenda, the Indian Government has taken major steps to promote ICT, including the creation in 1988 of a World Market Policy, with a focus on software- development for export; telecommunications policy reform; privatization of the national long-distance and mobile phone markets; and development of a more comprehensive approach to ICT. Although India's success is commanding increasing attention and investment, it has yet to result in the distribution of social and economic benefits across a broader base of the population. Challenges—including the perception of an unfavorable regulatory climate, an overloaded judicial system, poor infrastructure and costly access, and limited use of ICT—remain. The emerging shift in governmental strategy, toward knowledge-intensive services, has created a climate more conducive to addressing enterprise, domestic infrastructure, education and the use of ICT to meet development needs.

The tradition of science and technology (S&T) in India is many centuries old. A renaissance was witnessed in the first half of the 20th century. The S&T infrastructure has grown up from about Rs. 10 million, at the time of independence in 1947, to Rs. 30 billion. Significant achievements have been made in the areas of nuclear and space sciences, electronics and defence. The government is firmly committed to making S&T an integral part of the socio-economic development of the country. (7)

4.1 Science and Technology Policy

India’s S&T Policy reiterates India's commitment to participate as an equal and vigorous global player in generating and harnessing advances in science and technology for the benefit of all humankind. India's focus on self-reliant industrialization in the 1970s and 1980s has been replaced with reforms aimed at positioning India in the world economy: the foreign direct-investment process has been streamlined, new sectors have been opened up to foreign direct investment and ownership, and the government has exempted the ICT industry from corporate income tax for five years. These reforms have helped India to become increasingly integrated into the global economy, through growth in the export of software and skill-intensive software services, such as call-centers. In 1986, the Indian government announced a new software policy designed to serve as a catalyst for the software industry. This was followed in 1988 with the World Market Policy and the establishment of the Software Technology Parks of India (STP) scheme. As a result, the Indian software industry grew from a mere US$150 million in 1991-1992 to a staggering US$5.7 billion (including over US$4 billion worth of software exports) in 1999-2000—representing an annual growth rate of over 50 percent.

The establishment of the Telecommunications Regulatory Authority of India (TRAI) was a key step towards effective implementation of telecommunications reforms. In 1992, the mobile phone market was opened up to private operators, in 1994 the fixed services market followed, and finally in 1999, national long distance operations were opened to private competition. Prior to these reforms, the Department of Telecommunications had been the sole provider of telecommunications services. In addition, to attract foreign direct investment, the government permitted foreign equity of up to 100 percent and duty free import on all inputs. Government-created technology parks also offered professional labor services to clients, a cost-effective program for India since ICT labour is so inexpensive by global standards.

Infrastructure: India's resources are used to derive the maximum output for the benefit of society and improvement in the quality of life. About 85 per cent of the funds for S&T come directly or indirectly from the Government (7). The S&T infrastructure in the country accounts for more than one per cent of the GNP.

Tele-density in India has reached 3.5 percent of the population. Approximately 1 percent of households have fixed line connections, compared to 10 percent in China. The mobile sector has approximately 3 million users, growing at 100 percent per annum, and is expected to outstrip the fixed line market in the near future. The number of Internet accounts is around 1.5 million, growing at 50 percent per annum. India also has very high penetration rates of terrestrial TV, cable and radio. Voice and data wireless solutions, for both domestic and export markets, are increasingly produced and used locally.

Access to telephones in Indian villages has improved in the last five to six years through the introduction of the Public Call Office (PCO) run by local shopkeepers. More than 60 percent of the villages in India have at least one phone. This also includes over 800,000 Village Public Telephones (VPTs). Worldtel is undertaking a pilot in four states to secure financing to upgrade the Village Public Telephones so they will soon be Internet-accessible.

In some urban locations, India's Software Technology Parks (STPs) provide infrastructure, buildings, electricity, telecommunications facilities and high-speed satellite links to facilitate export processing of software. India also has a number of progressive computerized networks in place, including a stock exchange, the Indian Railways Passenger Reservation System, and the National Informatics Centre Network (NICNET), which connects government agencies at the central, state and district levels.

A network of 50 laboratories, work under the Defense Research and Development Organization. The Department of Defense Research and Development is being developed to match and even surpass international standards in critical technologies. The number of universities has grown substantially from 209 in 1990 to more than 300 in 2005, says the UNESCO Science Report. This was possible due to the decision of the University Grants Commission to authorize several private universities. Moreover, seven Indian universities figure prominently in the list of Asia's top 20 universities in 2000.

Fund for improvement of S&T infrastructures in universities and higher educational institutions scheme was started way back in the 2000 for augmenting PG teaching and research activities in all science departments of Universities, Colleges and other academic Institutions in the country. (8)

4.2 Enterprise

Science and technology, however, is used as an effective instrument for growth and change. It is being brought into the mainstream of economic planning in the sectors of agriculture, industry and services. The country's resources are used to derive the maximum output for the benefit of society and improvement in the quality of life. About 85 per cent of the funds for S&T come directly or indirectly from the Government. The S&T infrastructure in the country accounts for more than one per cent of the GNP. S&T in India is entering a new frontier. India's well-established framework for protecting intellectual property rights has been an important inducement to business investment: well-known international trademarks have been protected by Indian laws, even when they were not registered in India. In 1999, major legislation was passed to protect intellectual property rights in harmony with international practices and in compliance with India's obligations under TRIPS.

Much of the initial domestic demand stimulus for ICT and ICT services industries in India has come from government: 28 percent of total IT spending to date can be attributed to government and public sector expenditure. Major areas of government expenditure include: financial services, taxation, customs, telecommunications, education, defense and public infrastructure. As a result of the growth in ICT use in India, the ICT industry itself has also increased its domestic economic activity, for example, a number of ICT companies have developed accounting and word processing packages in Indian languages. The potential impact of this growth on the domestic economy is much broader than developing software for export only.

From a nation dependent on food imports to feed its population, India today is not only self-sufficient in grain production but also has a substantial reserve. The progress made by agriculture in the last four decades has been one of the biggest success stories of free India. Agriculture and allied activities constitute the single largest contributor to the Gross Domestic Product, almost 33 percent of it. Agriculture is the means of livelihood of about two-thirds of the workforce in the country.

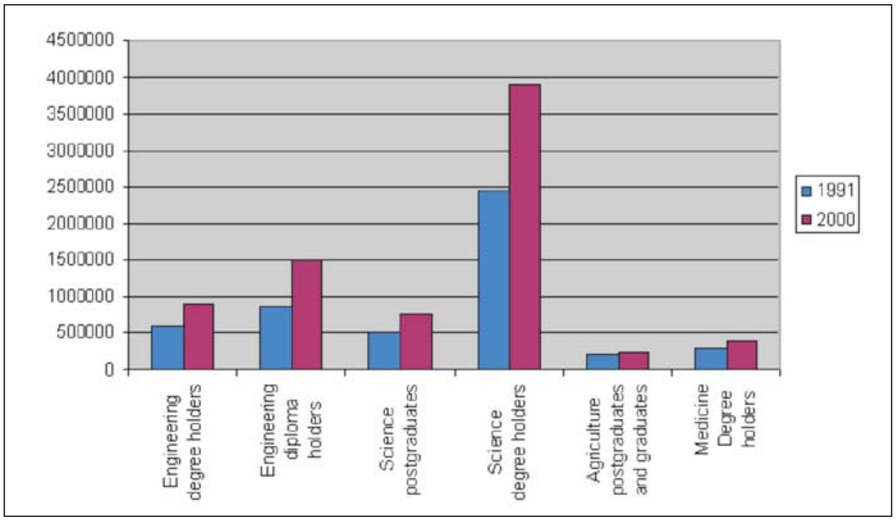
4.3 Human-Capacity

In spite of relatively low literacy rates among the general population, India has several key advantages in human capital: a large English-speaking population and world-class education, research and management institutions—a direct result of investment in self-reliance in science and technology. In addition to establishing Indian Institutes of Technology in various cities around India to create a large pool of technical skills, the government has a computer policy to encourage R&D in personal computers. The IT training sector continues to grow at a rapid rate: total training revenues in 1998 were estimated at US$225 million, 30 percent up on the previous year. However, one of the biggest challenges to the Indian software industry remains the difficulty in attracting and retaining talented professionals. India has the third largest scientific and technical manpower in the world; 162 universities award 4,000 doctorates and 35,000 postgraduate degrees and the Council of Scientific and Industrial Research runs 40 research laboratories that have made some significant achievements. In the field of Missile Launch Technology, India is among the top five nations of the world.

Utilization of Scientific Expertise of Retired Scientists (USERS) scheme aims to utilize the expertise and potential of large number of Eminent Scientists in the country who remain active and deeply motivated to participate in S&T development even after their retirement (Figure-5).

4.4 Content and Applications

India has a large population with great linguistic diversity. Creating and maintaining locally relevant content for a country with 418 languages is a challenge. Nevertheless, local language content is slowly making ICT more relevant and accessible to a broader cross-section of the population. For example, India's Center for Development of Advanced Computing has recently launched a scheme called iLEAP-ISP to create a free multilingual word processor to be made available to all Internet subscribers. On other fronts, some states such as Tamil Nadu have launched their own initiatives to support the standardization of local language software through interface programs that can be adapted to word processors, dictionaries, and commercial keyboards for use in schools, colleges, government offices and homes.



Source: *UNESCO Science Report 2005*

Figure - 5: Human Resources in S&T in India, 1991 and 2000

An emphasis has also been placed on the development of relevant e-government applications in India. Some states such as Madhya Pradesh and Andhra Pradesh have started to introduce applications which allow citizens to have faster and more transparent access to government services—for example, the provision of information on laws and regulations, and the procuring of licenses and official documents online.

4.5 Strategic Integration

Public-private partnerships, catalyzed by the IT Ministry, have played a key role in India's Science and Technology related development. One of the efforts in the way of IT development has been the IT Act of 2000, which was based on the recommendation of the National IT Task Force, and aims to set the overall strategy for the IT sector. In addition, the government and the private sector are starting to come together to foster ICT development. For example, a joint effort by the Computer Science Automation Department at the Indian Institute of Science and a Bangalore-based private company have developed Simputer—a cheap micro-computer that enables illiterate users to browse the Internet.

India had always given high priority to S&T and fostering public–private partnerships. New International S&T cooperation agreements have been signed with Canada, Colombia, Iceland, Ireland, Republic of Korea, Sweden and USA. India collaborates in selected areas of mutual interest with different countries through various modes of cooperation like:

- Exploratory missions of scientific delegations;
- Exchange visits of scientists for collaborative work and information exchange;
- Joint workshops;
- Fellowships / training / study visits for Indian scientists abroad and foreign scientists in India;
- Development and implementation of joint R&D programmes, Joint projects and collaborative R&D programmes;
- Support to Indian scientists to access major international research facilities abroad; and
- Establishment of Joint Centers of Excellence.

5. COMPARATIVE ANALYSIS AND CONCLUSIONS

One of the world’s largest economies and a developing country, India has made remarkable strides in its economic and social development in the past two decades, and is now poised to realize even faster growth in the years to come, with the help of intensive investment in R&D. In Malaysia too the Government has provided various types of fiscal and non-fiscal incentives in order to promote R&D and innovative activities for socio-economic development. Government allocations in Malaysia and India have increased substantially for Research and Development, especially in

Science and Technology, as well as for the development of intellectual human capital.

How does Pakistan compare in the R&D effort? According to ADB Institute, Pakistan currently spends around 0.3 per cent of its GDP on research and development, which is slightly more than Sri Lanka, Indonesia, Philippines, Thailand and Hong Kong. Most R&D in Pakistan is financed by the government. Enterprise-financed R&D is negligible and the lowest if the three countries studied. On a per-capita basis also, R&D spending in Pakistan is the lowest. Not only are total R&D expenditures low in Pakistan, but the share of the total science budget directed to industry is low and declining. Pakistan has a weak base for building competitive capabilities, and it does not appear to be improving over time in response to growing international challenges.

Comparison of some of the indicators is shown below for the three countries:

Table - 3: Comparative Analysis of R&D in Pakistan, Malaysia & India

Scientific Indicators	Pakistan	Malaysia	India
R&D Expenditure as percentage of GDP	0.24%	0.7%	0.80%
Number of Scientists per Million Population involved in R&D	88	299	119
Researchers per million inhabitants	80	509	115
No. of universities per million pop.	0.7	1.4	7.9
No. of patents granted	350	1492	387
Foreign Direct Investment	$4.6billion	$4.0billion	$12billion

Reference: (2), (3), (4), (12), (13), (14), (15), (16),(17),(18)

While the above comparisons bring out several weaknesses of R&D in Pakistan there are, nevertheless, a large number of institutions engaged in R&D in Pakistan. Efforts should be made to introduce flexibility in the S&T systems in order to retain the talented manpower. The R&D institutions should be assigned goal-oriented research, in accordance with the national objectives and approved R&D priorities, and should be provided with adequate financial and material resources to ensure effective implementations of their programmes. In Pakistan, the R&D expenditure ran between 0.25 and 0.5 per cent over the last decade, whereas UNESCO has recommended at least one percent of GNP for the developing countries on research and development. Almost the entire funding for R&D comes from one source, that is the government; the private-sector contribution to R&D being nominal, perhaps a couple of per cent of the total. Some of the recommendations to improve the R&D situation of Pakistan are:

- Restructuring of R&D infrastructure in the country;
- R&D, be considered as an essential tool in the development process;
- Continual Government and political will and support at the highest level for R&D;

- More money for higher education research and development at all levels;
- Radical change and drastically reduce bureaucracy in R&D organizations;

    - Embark on goal oriented R&D;
    - Launch alliance between universities, R&D organizations, government and industry;
    - Establishment of research units in large industrial organizations;
    - Promotion of industrial research in the national R&D institutions;
    - R&D labs should be part of universities;
    - Linkages/support from the industries must be established for need and demand oriented research and development;
    - Indigenous research and R&D studies should be carried out in the institutions;
    - S&T policy framework with national goals should be developed, followed up and monitored for its implementation.

6. SUMMARY

An effort has first been made to assess the S&T research and development activities in Pakistan during more than 50 years, and their relationship with the national economy. This chapter includes impact on national S&T policies, plans, infrastructure, institutional arrangements, human capital, R&D output, R&D applications in various fields, commercialization of R&D outputs, and overall impact on Industry. This historical assessment leads us to the weaknesses and strengths of the present R&D systems in S&T area and the lessons that can be learned from the experience. An attempt has also been made to study the scientific and technological R&D sectors of Malaysia and India, in order to make useful comparisons and assess how far it helped their respective industries and economies. In the end, a short comparative analysis has been made to see how both these countries were relatively more successful in translating R&D results for economic growth.

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SECTION C

SOME RELEVANT CONCEPTS OF EDUCATION AND INNOVATION

HOW TO DEVELOP SCIENTISTS IN THE DEVELOPING WORLD

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When we see the many modern technical wonders, we give the credit to 'science', with its technological amplifiers. The foundations of these marvels are often the fruits of profound depths of basic science, as in the quantum physics that enable the FETs that form the nerve and brain cells of our computers and cell phones, or the gravitational blue shift crucial to the Global Positioning System, the GPS. The GPS, in particular, can trace its accuracy back to Albert Einstein himself and the General Theory of Relativity.

But we must ask, from whence will come the ideas, large and small, that will enable the next generation of advances that will serve the well-being of future generations or enhance the intellectual strength of our species? We must also insist that the full global talent-pool is enabled to work for an even wider application of technological well-being and human- understanding. Science itself is far less the goal, and the need, than is the means to develop its practioners from among our young people. What attributes and boosts will the next generation of scientists have to acquire from our present generation? We remember that the scientific method, in its familiar form, is based upon the arousal of an idea, the creation of some scheme to test it, the carrying out of some experimental, theoretical or (now) computational means to test the idea, with then a fair evaluation of the validity of the idea and its test. This verification is best carried out by other qualified individuals, who might replicate the experiment and who provide crucial critical feedback and judgment. It is, thus, impossible to consider the existence of a single scientist, since such an idea completely lacks the evaluation and judgment phases of this process. This establishes another need for a broad range of future scientists, so as to enable this crucial feedback mechanism to operate.

Fortunately, many areas of the world, even the relatively undeveloped, already have systems and networks of scientists with demonstrated achievements and records that warrant respect. These individuals, and their contexts and systems, must be the growth-medium to breed the next scientists and to provide for their nourishment, growth and future stature. Indeed, the more accomplished these scientists of today may be, the less is their need to expand their own careers and the more fitting it is for them to develop a concern for the future and to take appropriate actions to direct the future. As one of these all-too-senior scientists, I have seen these steps in my own thinking, and have given the idea its, appropriate 'scientific' tests by my own experiments and observations of the results. This chapter is a distillation of my assessments of what our responses should be to the science and scientists of the future, here written down for the first time.

Einstein seems to arise at a rate of somewhat less than once a century, but in no way is science to be achieved only by the rare genius working with the biggest ideas. Our standard should not be Einstein or the other great geniuses of the past, nor should our goals include only very large-scale projects. Modern scientific ideas and theories have been extraordinarily successful, in that they survive very severe tests, very often involving large facilities and teams of perhaps thousands of collaborators, as noted particularly in the experiments that explore the properties of elementary particles. The Large Hadron Collider in Switzerland is costing about six billion dollars, for instance, and will absorb the careers of thousands of scientists and technicians from around the world. (See http://LHC.web.cern.ch /lhc for more information). The next fundamental, universal and thought-shifting breakthroughs are going to be very very difficult, and it is wrong to hold only these huge ideas as the standard for the future. Science and its many benefits are going to be important at many many levels of ambition and accomplishment, and not all results will be seen in headlines. **We need a broad and general push, aiming for a broad range of scientific skills and ambitions, while never forgetting that we might bring to light an Einstein or a Salam.** I will break my analysis of the means to develop future scientists, and thence future science, into four phases. With my basis largely from chronological age, let us separate these phases into

1. ***Building enthusiasm***
2. ***Gaining the skills***
3. ***Amplifying the apprentices***
4. ***Ensuring a suitable level of rewards and satisfaction***

LIGHTING THE FIRE

The simple question asked by so many two-year olds is the best possible starting point, that is "why?". Perhaps all children have the first necessary requirement to develop scientific thinking, in their fundamental curiosity. All busy parents have probably answered the "why?" With "because, just because" at some time, but I suggest that the best answer is "let's find out!" Since such ideal parenthood is not to be expected, it is the first teachers, the neighbors, and the other family members who should seek to recognize and develop this common human curiosity. Items in the popular press and other media could readily encourage parents to take pride in the curiosity of their children, and to keep it active. How about a system of billboard advertisements to suggest -"let's find out"?

When school starts, the teacher, especially the first teacher, carries the awesome burden of advancing all students, and it is perhaps enough that those with curiosity and talent not be thwarted in their dreaming, ideas and experiments. A little smoke in the kitchen or something broken in the class room is a small price to pay.

Which child still asks "why?" , even after an overly quick answer? Who looks out the window, seeing the patterns in the clouds or wondering why the shadows move across the playground? Who takes apart the toys? Who pushes buttons on devices, just to see what happens? Do teacher-training programs include classes on what to do when these children are noticed? I suggest that working scientists invite themselves in to the teacher-training colleges and add their advice at that important level. Let's find out!

These same scientists, especially those with school-age children of their own, are ideal ambassadors to the first few years of school. Teachers have always seemed grateful for guests to their classes, since the break in their responsibility is welcome under almost any circumstances. In contrast to what I expected, it was the youngest students who showed the longest attention-spans and the greatest enthusiasms. They also often asked the best questions, with the fewest inhibitions.

Many agencies funding basic research have recognized the value to the future of science, in any area, not just the one being supported, of outreach programs, taking science and its attitudes to the community, often at the first levels of education. In the US for instance, the US National Science Foundation formally asks all proposals to address the 'second criterion', in addition to the 'first criterion' of scientific merit, and reviewers are asked to assess both criteria. The second question asked and reviewed in the peer review system now is 'What are the broader social impacts of the proposed activity?' Quite often, proposers suggest novel ways to teach the young about the methods and results of their sponsored basic research project. See www.nsf.gov and search on 'second criterion' for a wealth of discussion on this standard and its impacts. It seems remarkably difficult for accomplished scientists to write these sections of their proposal the first time, but skills and enthusiasm for outreach seem to arise quickly because the results can be so vital to a successful proposal. I know of cases of proposals with equivalent scientific merit being decided in favor of the most innovative second criteria. Senior scientific advisors to governments or to funding agencies are the ones who can redirect some small fraction of the effort towards equivalents of the NSF second criterion suited to the local cultures and systems. Those who review funding proposals should also find ways to reward innovative or effective efforts for today's science so as to enhance tomorrow's scientists.

Once a year or so, I am asked to be a judge at school-science fairs, and I find these to be enjoyable and rewarding. Some of the projects are remarkably uninhibited, and can go into many different directions. Yes, sometimes one does detect the hand of a parent, so we always do our judging partly on the basis of discussions with the students. The organizers of the science fairs will have to provide guidance to the judges, such that one finds the right balance between strict assessment and positive comments. Awards of ribbons, citations, and small amounts of cash carry great weight, and a recognition ceremony is a great event in young lives. You can see examples of procedures and rules for several levels of science fairs from my own local school district. Go to www.bvsd.org and search on 'science fair' for a wealth of information.

More ambitiously, a regional or even national system of competitive science fairs can be arranged. There needs to be some means to subsidize travel, but the collective effects of bringing together a bunch of bright kids begins an early network. A completely new idea would be an international science fair, established among a few neighboring nations. This would be likely to be even more important to the nations than to the individuals.

THE HARD PART

Curiosity, enthusiasm and bright ideas are necessary for a scientist, but so is a solid tool kit of skills. Once the beginning levels of schooling are past, the rigor of teaching and learning must increase. Mathematics is the most common stumbling point, and a fall here may end a worthwhile path. It is not just skills in mathematics that must be acquired, but most importantly, confidence in the results of mathematics. In the US, the only course of formal logic met within our educational system is Euclidean geometry, where the important analytical stage of the scientific method is encountered. If each step of a hypothesis can be proven, then the results of the hypothesis must be correct. It is to be hoped that teachers of geometry emphasize the triumph at the end of each proof. Quad erat demonstratum is worthy of being shouted! And then there is algebra, or 'the method'. Once any problem can be written as equations, the algebra machine can be relied upon to produce the correct answers. Trust that this works is fundamental, and should then lead to a desire to complete the problem by means of algebraic skills, which will always work. This belief, that care in setting up the problem will lead to confidence in the result, is now even more important when so many results are obtained from computer programs. Only with confidence in the result can the labor of algebra problems or a computer program be accepted by the students. Algebra is a great intellectual gift that teachers can give, and we should never let it be seen as a burden or chore to be gotten through. Take a look at an introductory algebra book. Does it transmit the sense of a wondrous gift?

A successful school career can also be the source of another important hallmark of scientists, one that we do not talk about enough. This is ego. If a student sees, understands, or solves something, this should become a point of pride, just as is the publication of a paper in a prestigious journal or acceptance of the Nobel Prize. Science is not competitive in its basis, but it surely is in its practice. School years should serve as the means to first foster and recognize the ego aspect of accomplishment. For some, this may happen in the teen years of schooling, while others may find this as an important part of their college or university education. Praise and rewards at the right time can build this sense of self-worth and spur the next step.

Then, at the right time and with the right students, it will become appropriate to move them from their basic education into the best institution of higher-learning. The two steps are to work with the promising science student to find the right place and to obtain suitable funding. There is a lot of money out there to support these young scientists, and we must all become skilled at finding it and obtaining it for our students.

Applications for admission and funding require a most thoughtful, insightful and carefully-worded letter from you, the recognized scientist, whether you were a direct teacher, a class visitor, or a more general contact. This is where our hard-earned reputations can count the most. Students rarely have the boldness to initiate contacts with active scientist mentors, and we must find ways to get these contacts started.

MENTORING

But someday these budding scientists will leave school, perhaps with an advanced degree, and encounter the harsh realities of the real world. Lets talk with them about this while they are still under our charge. The school years were always somewhat insulated from the realities of the world. Almost all problems had answers, probably known to the teachers and professors. Lab projects followed known paths, and many were almost guaranteed to succeed. It is only through the inefficient but vital step of one-on-one discussions, questions, criticisms and advice that a mature scientist can be formed. I have found laboratory classes to be the best times for individual discussions, since periods are longer and we can talk in the context of the actual work of the students.

I have also become aware of something important I saw in all of my doctoral students. At some stage they realized that they knew more about their project than I did. Of course, I had known this for some time. The symptom of their awareness of surpassing me was always the same-- they became extremely polite and careful in the way they explained things to me. **Then I knew I had helped to create a self-standing scientist. These are shining moments.**

Today with email, we need never be far from our students, apprentices and research colleagues. A young scientist is likely to be shy about initiating exchanges with senior researchers, and so it is our responsibility to start and maintain a healthy interchange, even if only once or twice a year. We can ask how things are going, offer help with manuscripts, research projects and proposals for funding or other support. This proof-reading of initial writings is perhaps the most important thing we can offer, since successful article or proposal-writing is an art form, going beyond just a good idea. It would even be a good idea to share our successful proposals with beginners to serve as models, since successful proposals are usually considered to be in the public domain. Could our successful proposals be posted on our institutional or personal web sites to show examples of what works? These could also serve as examples of the latest scientific thinking.

Although we rarely speak of such matters, the ethical foundations of good science are vital. The rare scandals we see in scientific work are shocking and shameful to anyone calling himself a scientist, and so we all must be alert to see that no young person gets started along the wrong paths. We must talk about the ethical standards of science, perhaps by pointing out that only the truth is consistent and any claims can and will be independently tested, and the truth will prevail We must sometimes be doubtful critics for early works. Again, laboratory classes are probably the best way to establish good habits.

We must make sure that any experiments of any size that we know about in our scientific or geographical areas are carried out with care, and that uncertainties and assumptions are always clear. I have found this to be the difficult part in teaching science, since the results are too often seen as the important answers, without acceptable understandings of the uncertainties and fair reporting of the error bars. Every reader of any scientific work deserves the right to understand the reliability of the results. Yet another of our responsibilities is to avoid overstated or unfounded conclusions by our colleagues, especially those with inflated claims of relevance or importance. National leaders cannot be expected to have the judgment to evaluate such claims, and great harm can be done if some crackpot scheme is adopted to absorb scarce resources. The failure of these schemes would surely leave a bad taste for science (and scientists) in the mouths of those whom we hope to have as our supporters.

BUILDING A TRADITION

We scientists of today are going to be replaced, and those who replace us will be standing on our shoulders to reach higher, see farther and become involved in a larger world. The past fifty years or so have seen the establishment of a global system of scientific collaborators, widely-distributed publications and a closely-connected web of electronic communication. The young people we introduce into science must become adept at using this global network. **The two mechanisms are publishing and conferences.**

That first refereed publication is a high barrier for a young person, especially if not working in a large group. You might lend your name, if your role in a project merits this, to assist in getting a paper accepted, but in such a way as to emphasize the role of the younger partner. It would be most noble to put the most junior name first in the order of authors. Another recent path is an international journal devoted to publishing work by beginners. Check the Journal of Young Investigators, www.jyi.org.

Conferences are an important part of the ecology of science, since it is in fact a social business, not merely the publishing and reading of manuscripts. Almost all major international conferences have special funds set aside to assist attendance by young scientists, and we should keep an eye on the appropriate websites to find conferences suited to those we wish to bring into the community. Those of us on conference advisory committees should always put pressure on the organizers to include this valuable increment. At conferences we should introduce our junior colleagues around and arrange opportunities for them to meet other junior researchers. The early establishment of networks, especially at an international scale, is a vital part of future science.

SUMMARY

The single theme that has been emphasized in this chapter, in its many day-to-day applications, is involvement with the next generation. There is no single step that might work, but to urge the cumulative effect of applying our experience and status towards enabling, encouraging and accelerating the dreams, skills, ambitions and success of those we hope will carry on the ideas and standards to which we have dedicated our careers.

THE MAINSPRINGS DRIVING RESEARCH, DISCOVERY AND INNOVATION

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1. INTRODUCTION

Man has always been curious by nature, wanting to find out or determine how and why things happen. In the early days of his existence on earth, whenever he looked around him, certain questions arose in his mind, such as, how did this universe come to be, who made it, what will its future be, where did I come from, where shall I go to and what will the end of all this be? These and a host of similar questions have been asked by thinking people down through the ages.

So, an attempt has been made by various religions and philosophers to provide acceptable answers to these questions, with varying degrees of success or acceptability. The revealed religions, which stem from the revealed books of Allah (S.W.T), have based the answers to these questions on certain basic assumptions that hang together in a logical fashion. We are told that the human race, as we know it today, began with the creation of Adam (A.S.) whom Allah (S.W.T.) fashioned with His own hands (or in his own image) and after He breathed life into him, made the angels prostrate themselves before Adam, this establishing Adam's superiority, particularly in respect of knowledge (e.g. see Surah Al Baqarah[1] v. v.30-34).

Firstly, Allah (S.W.T) gave Adam knowledge of various things, which the angels did not possess, and secondly Allah T'ala values the worship by human beings more than that of angels, because the humans are surrounded by things of the physical world and, yet, turn to think about their creation by the Creator and about the laws of the Universe made by Him. So, when Allah ordered Adam and Eve to go and inhabit the earth for a time, He promised to send persons (prophets) to guide them to think about their future destiny[2] (Al Baqarah, vv. 38-39), which does not simply consist in using up and living off the produce of the earth, the sea and the air.

The intelligence that a human being possesses does make him do some or all of these things; but the man who uses all his faculties is usually able to see a bit farther than others.

Study of Natural Phenomena: Looking around him, man observed numerous happenings and phenomena of nature. In some elementary manner, man in the earliest societies did attempt to observe and understand what happened, how it happened and why it happened? This, in a sense, can be called the basis or beginnings of science, whether pure (basic) or applied.

Observation is the first step; correct observation, verifiable and verified by others, constitutes the first step even today. Having repeatedly seen or observed the sequence of what happened, early man then proceeded to make plausible guesses i.e. theorize as to how it happened. The basis, of course, is that the cause should, or ought to, come before the result or effect. In this way, a broad sequence of events would have been arranged in a "cause and effect" chain, building up these chains is the basis of science, which attempts to build these chains in a systematic manner. But there is a basic problem that arises here.

2. INITIAL HUMAN RESPONSES: DIVERGENT THINKERS AND CONVERGENT THINKERS

One comes up against the problem of the diversity of human beings and their perceptions. This has been the subject of considerable study and, lately, the concepts of "convergent thinking" and "divergent thinking" have been under considerable discussion in literature on educational research. Thus, it is now being noted that humans beings have at least two types of thought-processes, namely convergent thinking and divergent thinking.

Broadly speaking, the convergent thinkers look along one line only and arrive at a single solution (to a problem), while the divergent thinkers come up with a variety of solutions and, often, a variety of ways of arriving at the solution. We may broadly, but not precisely, think of the divergent thinkers as being highly imaginative and the convergent thinker as a person with a matter-of-fact approach.

It is now being found, in many studies, conducted at secondary and higher educational levels, that these two modes or types of thinking[2] are frequently associated, to a high degree, with the choice of subjects, namely physical sciences, biological sciences, social sciences, and fine arts[2]. This, however, is only a rough way of putting it; the divergent ways of thinking tend to reflect or be linked with the capacity for innovation and invention, which is at the basis of new scientific discovery, as well as technological innovation or invention. The final test is: if it works, you are a genius. We give below two relevant extracts from a paper by Tanvir-uz-Zaman[2]:

> **Convergence/Divergence:** According to Hudson (1966), convergent thinkers are distinguished and defined by their comparatively high scores in problems requiring one conventionally accepted solution, clearly obtained from the material and the information available. They would obtain low scores in problems requiring the generation of several equally acceptable solutions. The reverse description would define the divergent thinkers.
>
> Divergent thinker showed an ability to be more creative than convergent thinkers. Creativity is an ability which most of us are concerned to develop and foster. It

becomes a very important objective for educators to see creativity being encouraged in the classroom and the laboratory. Creative thinking occurs when the boundaries of the known are first measured, through convergent processes and then extended, by the application of divergent processes.

Al-Naeme (1991), in his Ph.D thesis reported that the issue of convergent or divergent thinking plays a significant part in learning ability. Those who are convergent thinkers having thought-processes which lend themselves to a narrowing down of a problem to one idea, one given end, while those who are divergent are thinking in a way that branches out and explodes into new shapes and patterns.

It is often observed that some students tend to use long and convoluted methods to reach any solution. Those students are more capable than others of offering a variety of answers to each question that may be asked concerning their everyday life. Nevertheless, some of the learners are able to show good and efficient ways to reach answers to many problems. By contrast, some other subjects tend to use short and concise methods to reach the answer. Their ability consists of a narrowing in focus, an imaginative austerity that is quite formidable. These subjects may exhibit less ability in giving a variety of answers to question related to their life.

Convergence/Divergence and Creativity: In the 1960s, educators were alerted to the attitudes of learners towards subjects chosen during the secondary level of education. It became apparent that some learners preferred to do science subjects, whilst others are to do arts subjects. Getzels and Jackson (1962) found that learners who excelled in science tended to have an interest in technical hobbies and outdoor activities, whilst learners who were better in arts subjects had cultural interests, like music, drama and poetry.

Getzels (1962) formulated a distinction between the two categories of learners. The first category was called the “high IQ” learners who are good at intellence-test in terms of scores, but relatively weak on test of creativity. The second category was called the “high creative” who are good at the creativity tests but score relatively low in intelligence tests.

The concept of convergence/divergence, as cognitive learning style, was explored by Hudson (1966, 1968, 1970). Hudson used the phrase “convergent and divergent thinking” and also noted that convergent/divergent thinking might be thought of as polar opposites. A convergent thinker is defined by Hudson (1966) as an individual whose performance on IQ tests is better than his/her performance on open-ended or ‘creativity test” and the divergent thinker shows the reserve result. Guilford (1959, 1978) defined convergent thinking as thinking towards one right answer or towards a relatively uniquely determined answer, while divergent thinking is a way of thinking in which a number of ideas will be produced from a given set of information. In other words, variety of answers to the questions would more likely be found by divergent-thinkers. Convergent thinkers like to see information as leading to a restricted answer or solution.

Hudson (1966) rejected the belief of many psychologists that divergent people are potentially creative and convergent people are uncreative. He suggested that convergers are naturally attracted towards one end of the spectrum and divergers to the other. Based on this, he noted that convergent and divergent students use different tactics in dealing with the pressures of work and emotional experience. One tactic is not necessarily better or worse than another.

Runco (1986) suggested that a divergent learning-style is of course not completely synonymous with creative ability. It is just *one component* of creativity, despite the fact that divergent thinking tests are psychometrically reliable and widely employed as estimates of creative potential. Results of Runco's study indicated that divergent thinking and creative performance scores were moderately related in the gifted school-children samples, but unrelated in the non-gifted sample.

This imaginative streak cuts both ways e.g. it can help to produce quickly a completely rational system and, on the other hand, also come up with a system (of supernature) in which man, at one time, had assigned every major natural phenomenon to a god (e.g. thunder-god, rain-god, cereal-god ("ceres")! Seen in this perspective, ancient mythology is a manifestation of this imaginative streak in human beings, untrammeled with the processes of reasoning and further experimentation!

3. SOME TYPICAL MODERN EXAMPLES OF VARYING PERCEPTIONS

Exaggeration is one aspect of this imaginative streak in human beings That we continue to look at our own research findings in this somewhat imaginative manner is indicated by the following two extracts, **"A conference glossary"** and *"A glossary for research papers"* taken from[3] "A Random Walk in Science" by Weber & Mandoza (1989) published by Adam Hilgen for the Institute of Physics, London.

(i) A Conference Glossary

From Proceedings of the Chemical Society May 1960 p 173	(A) IN PRESENTING PAPERS	
	When they say	*They Mean*
	1. Elegant	A reference to work of an author whose work is to be attacked
	2. A surprising finding	We barely had time to revise the abstract. Of course we fired the technician

David Kritchevskv and R.J. Van Der Wal

continue...

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3. Preliminary experiments have shown that…	We did it once but couldn't repeat it
4. The methods, in our hands…	Somebody didn't publish all the directions
5. A survey of the earlier literature	I even read through some of last year's journals
6. Careful statistical analysis	After going through a dozen books, we finally found one obscure test that we could apply
7. We are excited by this finding	It looks publishable
8. We have a tentative explanation	I picked this up in a bull session last night
9. We didn't carry out the long-term study	We like to go home at 5 pm What do you think we are, slaves?
10. The mechanism is not yet clear	We plan to do the second experiment as soon as we get home
(B) IN DISCUSSION	
1. We say this with trepidation	a) They are going out on a limb when in the presence of an author whose work is to be, or has been, attacked. b) They are about to make a statement about something they know nothing about.
2. Could you discuss your findings?	Tell us now. Don't hide it in some obscure journal
3. Have you considered the possibility?	Have you read my work?
4. Have you any ideas at all…	What are you keeping from us?
5. Would you care to speculate?	I wonder if you agree with me
6. Why do you believe…?	You're out of your mind
7. I would like to make one comment on these suggestions	Awful!
8. We cannot reconcile these data	Are you telling the truth?
9. We have repeated your experiments in our lab.	Brother, were we surprised!
10. Did I read your slide correctly?	Did you write it correctly? I never make mistakes
It is evident that the fields of scientific semantics offers ground for fruitful investigation (which means 'I never expect to do it myself, but If someone does, this statement will give me a claim on priority')	

(ii) A Glossary for Research Reports

	When They Say	*They Mean*
From Metal Progress 71,75(1957)	It has long been known that…	I haven't bothered to look up the original reference
	- of great theoretical and practical importance	… interesting to me
	- While it has not been possible to provide definite answers to these questions…	The experiments didn't work out, but I figured I could at least get a publication out of it
	- The W-Pb system was chosen as especially suitable to show the predicted behaviour…	The fellow in the next lab had some already made up
	- High-purity… - Very high purity… - Extremely high purity… - Super-purity… - Spectroscopically pure…	Composition unknown except for the exaggerated claims of the supplier
	- A fiducial reference line…	A scratch
	- Three of the samples were chosen for detailed study…	The results on the others didn't make sense and were ignored
	- .. accidentally strained during mounting	… dropped on the floor
	- … handled with extreme care throughout the experiments	… not dropped on the floor
	- Typical results are shown…	The best results are shown
	- Although some detail has been lost in reproduction, it is clear from the original micrograph that…	It is impossible to tell from the micrograph
	- Presumably at longer times…	I didn't take time to find out
	- The agreement with the predicted curve is excellent	Fair
	Good	Poor
	Satisfactory	Doubtful
	Fair	Imaginary
	… as good as could be expected	Non-existent
	- These results will be reported at a later date	I might possibly get around to this sometime
	- The most reliable values are those of Jones	He was a student of mine
	- It is suggested that… - It is believed that… - It may be that…	I think
	- It is generally believed that…	A couple of other guys think so too
	- It might be argued that…	I have such a good answer to this objection that I shall now raise it

C.D. Graham, Jr.

continue...

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- It is clear that much additional work will be required before a complete understanding…	It don't understand it.
- Unfortunately, a quantitative theory to account for these effects has not been formulated	Neither does anybody else
- Correct within an order of magnitude	Wrong
- It is to be hoped that this work will stimulate further work in the field	This paper isn't very good, but neither are any of the others in this miserable subject
- Thanks are due to Joe Glotz for assistance with the experiments and to John Doe for valuable discussions	Glotz did the work, and Doe explained what it meant

So, we can see how far the spoken or written responses to one and the same thing *can and do vary in human society today*. What we have to constantly aim at is a workable synthesis of the factual with the imaginative.

4. THE NEED FOR SCIENCE

The Developing World is faced today with numerous challenges, mostly arising out of economic exploitation, illiteracy, cultural subversion and internal dissentions. This has created a wide-spread consciousness of the need for solidarity amongst the Third-World Countries and nurturing the necessary capability of self-reliant development. There is an increasing realization in the Third-World and Muslim countries that only a concerted, collective and persistent effort could free them from poverty and underdevelopment and protect them from overt aggression and domination. In fact, there is a consensus amongst the Muslim countries for initiating a joint action for rebuilding a sizeable Science and Technology capability in the Islamic World.

The current rate of scientific growth in the Third-World is, in general, at a pitifully low level. Whatever "progress" has been made, at the university or institutional level, is largely based on teaching of the borrowed knowledge from the West. Even this borrowed knowledge is frequently partially applied. AI! we have achieved so far is to produce a . number of engineers, physicians, etc., who are mere technicians of science, unless they engage in research - the "manufacturing" of knowledge. They can satisfy short-term needs of the nations, but research-oriented institutions, which lead nations to economic and socio-political independence and prosperity, are either absent or dysfunctional. Because of little indigenous research in science, our institutions are likely to remain dependent on the imported knowledge for a long time. There is a great danger in' this attitude for the Third-World and entire Muslim Ummah. For one, advanced knowledge is often kept secret by nations, especially if it has implications for technology and trade. There is no substitute to one's own reliance on advancement in knowledge in science. This brings intellectual maturity to the institutions, leading to durable national socio-economic growth; because of achievements in science, western civilization has overshadowed the entire world! These two entities, i.e., science and Western civilizaiton, have been wrongly confused and are thought to be inseparable. Muslim scholars must highlight the difference, if we wish to preserve Islamic civilization. However, we must not forget that only by reclaiming dignity and superior socio-economic well-being, would we be able to preserve and advance Islamic civilization. Sooner the Muslim nations realize this, the earlier they can acquire prestige; and Muslim scholars and scientists have a significant role to play in this regard. A major effort by them is likely to bring larger benefits for our children and subsequent generations[4(a)].

When we discuss the importance of scientific advancement in the Muslim world, this is not to say that other issues are not important, for example, religious obligations and high moral standards. However, scientific inquiry of nature is probably one of the most neglected aspects of our institutions and nations. Two major reasons why Muslim nations must engage in research and aim for superiority in science are the Quranic concept of studying science (discussed below), and the welfare and financial security and dignity of the Ummah. As stated by EI Fadl[4(b)], "check any. book of Islamic law (medieval, not contemporary please) and you will find that for a Muslim to be well fed. well clothed, well protected. well respected and dignified is a top priority". Such a science-oriented culture is necessary today.

"Only recently. most scientists and laymen believed that science was inherently good. and that the technologies, derived from it. constituted the major agents of desirable change and inevitable social progress. Unfortunately, this vision remains a forlorn dream and, instead, man is still filled with anxiety, unfulfilled dreams and disillusionment. 'So much so, he reaches outside himself for religious answers, which themselves are the causes of division and strife. He is now cornered by his own power, greed and selfishness.

"There is no doubt that man has, and can develop. incisive technologies to control and transform the environment. yet he is no nearer the beauty and tranquility he seeks. Furthermore, the knowledge and wisdom to eradicate poverty, for example does not exist anywhere, either in the industrialized or non-industrialized countries. And, although we can guide a missile thousands of miles to destroy a farm-house of an enemy. explore the outer reaches of the universe and the ultimate nature of matter, we cannot ensure that. in a world of plenty, all children are properly fed. that there is clean air and water for most of us. and cannot prevent squalor from being the immutable birthright of those born in poverty.

"Man is clearly in a precarious state. having much to live with. but little to live for. He is submerged in an abundance of trifles and meaningless riches. Progress has come to mean just moving on without care for the consequences of his materialistic technologies. The more technologically powerful he becomes, the more destructive he is, to himself and his planet. There is obviously something fundamentally wrong with our behavior, or is it simply that we have not recognized that science has reached its limits?”[5]. We may close this section with a quotation from Huxley:

Technological progress has merely provided us with more efficient means for going backwards. – Aldous Huxley

5. SUSTAINABLE DEVELOPMENT

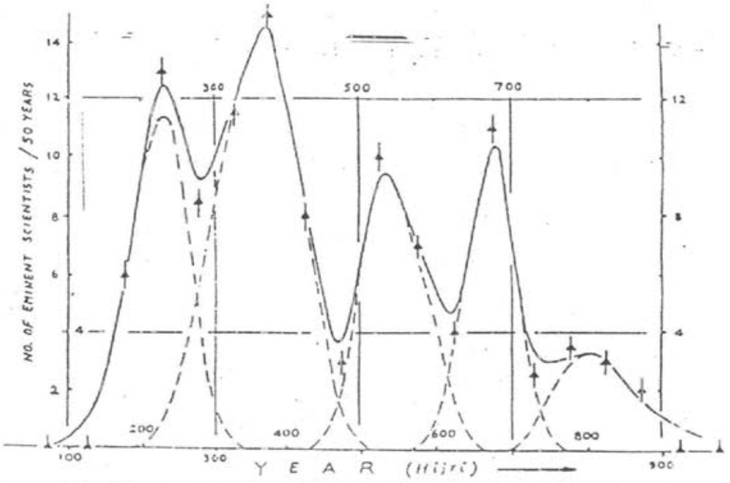
Two important studies[5], entitled “Limits to growth” and Blueprint of survival”, have pointed out the hazards of unsustainable development, leading to myriad scourges and fear of impending catastrophes, including resource-depletion, global warming, ozone-layer rupture, deluges and desertification. The twentieth century witnessed the currency and domination of secularism and anthropocentric world-view, which brought in its wake the industrial revolution. Technology became the hallmark of modern civilization and the most crucial instrument of development. After having reached the peak of technological bonanza, quite a few discerning social scientists were able to identify some deleterious impacts of unbridled 'technical development on the biotic system or ecology. With increasing awareness of the environmental degradation caused by technology, a fairly assertive ecological lobby came forth, resulting in the constitution of World Commission on Environment and Development, which submitted its first report in 1987 (Our Common Future). The recommendations of this' report were endorsed in the United Nations Conference on Environment and Development (UNCED) held at Rio-deJanero in 1992. The follow-up of this conference engendered intensive ecological studies, including a very important report entitled "Caring for the Earth". These studies introduced the concept of Sustainable Development, which was defined in the above-mentioned report as "improving the quality of human life while living within the carrying capacity of supporting ecosystems"[6].

It is, course, universally recognized that science and technology provide the most effective means for achieving progress and development, self-reliance and independence and, above all, national harmony and security. Pakistan is an ideological state, committed to the development of Islamic tradition. The Islamic World had a glorious past in terms of scientific achievements, but its present. capability in Science and Technology is far from being enviable. In fact, no single Muslim country today is self-sufficient in the context of Science and Technology excellence, nor is the cumulative capability of the entire Islamic World sufficient to create enough high-quality science and to apply it, either for the acquisition or the generation of new technologies. The Muslim world is totally dependent on the North for its technological needs as well as for the training of its high-level scientific and technological manpower; a situation which needs to be corrected as early as possible.

6. SCIENTIFIC CULTURE OF THE EARLY MUSLIM WORLD

Let us stop a moment and ponder how the scientific culture of the early Muslims was developed. A great deal has been written about science in the Muslim world especially regarding the history of the glorious days of Muslim science and the transmission into the West. A few examples of well-known medieval Muslim scientists include al-Khwarizmi, ibn-al-Haitham, al-Razi, ibn-Sina, ibn-Rushd and Abul Qasim Zahravi, all of the 3rd to the 5th century Hijra. Some authors have attempted to analyze the causes of the subsequent failure; however, there is a dearth of literature in this regard and undoubtedly more needs to be written to rectify our shortcomings. Similarly, Muslim scientists and historians could learn a great deal by analyzing the inner strength of the institutions of the scientifically' advanced nations. This requires a renewed and sustained critical effort in two more or less parallel directions viz. (i) a detailed analytical study of Muslim Sciences & Technology from 100 to 900 A.H., and (b) a corresponding study of Western Scientific & Technological Development in Europe and USA over the last three centuries. This comparative study would reveal several features to guide us at the present juncture.

Let us take a critical look at the past history through two self-explanatory diagrams[7]. (Figure-1 and Figure-2) based on data taken from Gillispie's Dictionary of Scientific Biography and the Siyyarah Digest, 14th century Hijra Number. The parallelism between the scientific and cultural development is obvious, with a lag of about two centuries (actually 200 ± 10 years) between them (See Table-1).



Plot of Scientific activity, showing the number of Scientists of note in the Muslim World.

Figure – 1: PESOLUTION OF EARLY MUSLIM SCIENTISTS OF WORLD RENOWN PER HALF-CENTURY INTO PEAKS: The broken-line curves show this resolution into symmetrical peaks of approximately Gaussian (error-function) shape

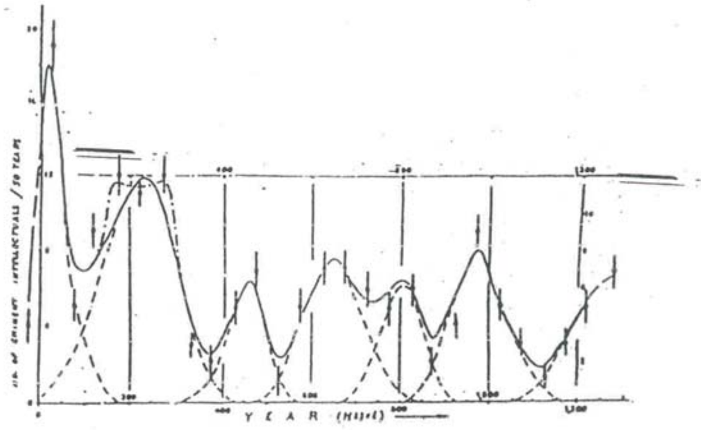


Figure – 2: Plots of Socio-Cultural Activity in the Muslim World during the first 12 centuries Hijra based on the data published in the Siyyarah Digest, 14th century Hijra Number

Table – 1: Comparison of Peaks of Intellectual Activity and Scientific Activity

Ordinal No. of Peak in Scientific Activity	1	2	3	4	5	6
Year	230 A.H.	370 A.H.	535 A.H.	680 A.H.	815 A.H.	--
Ordinal No. of Peak in Intellectual Activity	1	2	3	4	5	6
Year	10 A.H.	-150 A.H.	-275 A.H.	460 A.H.	620 A.H	805 A.H
Lag = Scientific Peak – Intellect. Peak	220 Yrs.	220 Yrs.	260 Yrs.	220 Yrs.	195 Yrs.	--

It can be reasonably concluded from this Table-1 that scientific activity is most probably a direct or indirect result of well directed cultural activity in a nation. So we see that Science & Technology follows *after* socio-cultural development.

7. SOME THOUGHTS ON THE MAINSPRINGS OF SCIENTIFIC DISCOVERY AND INNOVATION

a. The Interaction between Science and Spiritualism

One step in the process of discovery is probably well-known and often observed. A person accumulates a large amount of factual information and data on 2 or 3 apparently related phenomena or processes, and then looks at them from time to time. But at first they fail to fit. So, one puts these data aside and starts active work on something else. And then, one day all of a sudden (may be after a long restful sleep), all the bits and pieces fall into a pattern, and we have the answer to the problem! It seems that the material has been worked upon in the sub-conscious parts of the brain, or may be the super-concious (or whatever else). Then we have the "Inspired Guess", which is also a manifestation of the sudden emergence of one idea or way of action that produces the full solution of the puzzle. The fact remains that somehow, at sometime, things happen as though on an inspiration from somewhere outside.

So, this scientific quest for the solution to a problem and the spiritual quest for a direct connection between man and his creator have a great deal in common.

Galileo saw no conflict between his religious convictions and his scientific ideas, because God is the author of both the 'book of nature' and the 'book of Scripture'. But, the holy book's (basic) role is to lead to the spiritual and moral development of humans. It does not provide us with scientific facts. In Galileo's words:

> *God has endowed us with senses, reason and intellect… would not require us to deny senses and reason in physical mattes which are set before out eyes and minds by direct experiences or necessary demonstrations.*

As against this view, the *doctrine of empiricism* claims that the senses are the only sources of knowledge; thus, metaphysical concepts should be eliminated from any physical theory, because they are not rooted in sense experience. This doctrine is an old one, but it got prominence with the works of the British empiricists of the seventeenth and eighteenth century and was fortified by the positivism of August Comte and the logical positivism of the "Vienna Circle" of the 1920s and 30s. A common feature of all schools of empiricism is that they give primacy to sense-experience and reject metaphysics. It was claimed by empiricists that the methods of experimental knowledge are universal and that they should be used in all fields of knowledge, including humanities.

In the last few decades, however, *science has lost part of its sovereignty* and one notices a revival of interest in religion. Today scientists are much less arrogant and they are more cautious about the limits of science than they were, say, forty years ago. There are several reasons for this change of attitude. We just mention here the most important factors.

It has been noticed that contemporary science is based on some controversial generalizations. For example, our knowledge about the early universe is so little that we should be careful in answering questions concerning the origin, just on the basis of some transient theories. The American astrophysicist J. Bahcal has beautifully expressed[8] the matter:

> *It has become more and more clear that science cannot work without some meta-scientific assumptions: the assumption of reliability of senses-data, the assumption of comprehensibility of nature by human intellect, etc. Science cannot explain its own success, and it cannot rule out meta-scientific dimensions of the universe.*

Some religious scholars have tried to become experts in various areas of modern science and have tried to explore the common grounds of science and religions. On the other hand, some scientists have willingly exposed themselves to theological ideas, and, frequently, scientists, philosophers and theologians have become engaged in serious dialogue. In short, human experience has more dimensions than what science can accommodate. One needs a much larger framework to integrate all aspects of human experience. Dr. R.L. Thompson has put the matter[9] nicely.

In the last three decades, especially during 1990s, we are seeing a noticeable movement towards religion and spirituality. As a witness to this movement, we just mention a few observations:

1. *Popular books of eminent scientists, which bear the name of God (e.g. God and the New Physics, The God Particle, The Mind of God, etc.) have sold out, and their number is increasing. The main reason for popularity of these books is that people really want to remove any discrepancy between their faith and science.*
2. *During the last two decades, there has been an increasing number of conferences about the subjects of mutual interest between science and religion. An important and unprecedented aspect of these conferences is that they were interdisciplinary, i.e. they involved scientists, philosophers and theologians. Thus, they were very fruitful and enriching.*

In the light of the above, we now try to look a little more at the sources of innovation and invention. First we note how sometimes an expert's "foresight" can be totally wrong.

b. Some Typical Predictions and Comments

It is interesting to see how often the person steeped in a given kind of work comes up with predictions about the future of an innovation or invention that turn out to be entirely wrong. This is a result of the "convergent thinking" attitude mentioned earlier. Some well-known examples are given below, taken from pp 67 – 68 of "A Random Walk in Science"[10] by Weber and Mendoza, published by the Institute of Physics, London.

Predictions and Comments

Smithsonian Institution: I am tired of all this thing called science here… We have spent millions in that sort of thing for the last few years, and it is time it should be stopped.
Senator Simon Cameron (1901)

Aircraft: We hope that Professor Langley will not put his substantial greatness as a scientist in further peril by continuing to waste his time, and the money involved, in further airship experiments. Life is too short, and he is capable or services to humanity incomparably greater than can be expected to result from trying to fly… For students and investigators of the Langley type there are more useful employments.
New York Times, December 10, 1993, editorial page

The demonstration that no possible combination of known substances, in own forms of machinery and known forms of force, can be united in a practical machine by which man shall fly long distances through the air, seems to the writer as complete as it is possible for the demonstration of any physical fact to be.
Simon Newcomb (1835 – 1909)

Robert Goddard's Rocket Research: That Professor Goddard with his 'chair' in Clark College and the countenancing of the Smithsonian Institution does not know the relation of action to reaction, and of the need to have something better than a vacuum against which to react – to say that would be absurd. Of course he only seems to lack the knowledge ladled out daily in high school…
New York Times editorial 1921

I would much prefer to have Goddard interested in real scientific development than to have him primarily interested in more spectacular achievements which are of less real value.
Charles A. Lindbergh to the Guggenheim Foundation 1936

Bombing from Airplanes: As far as sinking a ship with a bomb is concerned, you just can't do it.
US Real-Admiral Clark Woodward (1939)

Possibility of Intercontinental Missiles: There has been a great deal said about a 3000 miles high-angle rocket. In my opinion such a thing is impossible for many years. The people who have been writing these things that annoy me have been talking about a 3000 mile high-angle rocket short from one continent to another, carrying an atomic bomb and so directed as to be a precise weapon which would land exactly on a certain target, such as a city.

I say, technically, I don't think anyone in the world knows how to do such a thing, and I feel confident that it will not be done for a very long period of time to come… I think we can leave that out of our thinking. I wish the American public would leave that out of their thinking.

Dr. Vannevar Bush (1945)

The Atomic Bomb: That is the biggest fool thing we have ever done. The bomb will never go off, and I speak as an expert in explosives.

Adm William Leahy to President Truman 1945)

Proposal to Drive a Steamboat by Screw-Propeller: Even if the propeller had the power of propelling the boat, it would be found altogether useless in practice, because the power being applied in the stern it would be absolutely impossible to make the vessel steer.

Sir William Symonds, Surveyor of the Royal Navy (1837)

Radio: In 1913 Lee de Forest, inventor of the audion tube, was brought to trial on charges of fraudulently using the US mails to sell the public stock in the Radio Telephone Company. The District Attorney charged that
'De Forest has said in many newspapers and over his signature that it would be possible to transmit the human voice across the Atlantic before many years. Based on these absurd and deliberately misleading statements, the misguided public… has been persuaded to purchase stock in his company.

C. Some Conclusions

All these examples show the effect of so-called "convergent thinking" and the inability to visualize the significance of other viable alternatives. That this failing can occasionally even afflict otherwise brilliant inventors is shown by the following example from Thomas Edison, giving his views about the future of alternating current:

Alternating Current: There is no plea which will justify the use of high-tension and alternating currents, either in a scientific or a commercial sense. They are employed solely to reduce investment in copper wire and real estate.

My personal desire would be to prohibit entirely the use of alternating currents. They are unnecessary as they are dangerous… I can therefore see no justification for the introduction of a system which has no element of permanency and every element of danger toile and property. I have always consistently opposed high-tension and alternating systems of electric lighting, not only on account of danger, but because of their general unreliability and unsuitability for any general system of distribution.

Inspite of what Edison then said, the situation today is that alternating current is every where, on band, at sea and in the air, while direct current is used now only in a few very special applications.

Thus, we can see that what is at the heart of innovation and discovery in Science & Technology is the ability to think about different ways of doing things or of events phenomena happening, which is manifested in the phenomenon of nature i.e. develop so-called "Divergent Thinking". How can we develop this in our young people?

We give below some suggestions and recommendations kindly provided by three school teachers, one of whom has taught in Pakistan, as well as Canada. **The process has actually to begin in childhood.**

8. SOME PROPOSALS AND RECOMMENDATIONS

For obtaining more innovations and inventions by the young generation, the development of "the divergent way of thinking" among the students is important at the secondary, as well as primary school levels. It is also one of the ways of making young people more capable of tackling the new problems of the future world.

To implement this concept, appropriate modification in the curricula, as well as in teachers' training is required, viz:

a. ***Curriculum Improvement:*** The Curriculum should be shifted from instrumental to rational understanding.

The curriculum should be designed to provide hypothesis-diversification, divergent and analytic thinking. Thus, the students could be asked to choose hypothesis, collect data and for example plot a graph between 'u' and 'v' and then make their own deduction, instead of just proving "The lens formula".

Assessment should be object-oriented and the objectives should be process-based. Concepts should be assessed, rather than merely the contents. "Scaffolding" should be done at the primary level and junior secondary level, so that the students become more independent thinkers as they reach their teenage.

b. ***Teacher's Training:*** In order to implement the process-based curriculum, teacher's training is of utmost importance. It is actually a matter of "mindset" of the teachers as well as the students. Teachers, while teaching the core curriculum at primary level, should encourage critical thinking.

They should give more emphasis on divergent thinking even in grades 1-3, with some parallel convergent thinking. Learning by rote should be avoided at all costs. Teachers should be trained in such a way that they themselves become more of a problem-solver. Teaching should become more open-ended and flexible, with more stress on divergent thinking from grades 4 to 7.

Vocational guidance should be provided from grades 8 to 10, according to individual interest. Career-orientation should be started in grade 8.

c. ***Home Environment:*** This should be conducive for learning. Reading material should be readily available. Logical thinking, instead of learning by rote, should be encouraged. Every child requires individual attention, and *the parents must* make sure that they *allocate some time for each child*.

Time-management is of utmost importance during all stages of life, especially childhood. Rewards and incentives should be used to encourage children, and a system of "consequences" should be in place. "Learning by doing" nearly always leads towards improved divergent thinking.

If the process outlined above can be started at the various educational stages in schools, then we can hope to get a large intake at high school, college and university levels that will further benefit from *close interaction with the best teachers and researchers* in the country. This interaction could then lead to the growth of many highly innovative and productive groups of scientists and technologists.

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SEARCH FOR A NEW KIND OF NUCLEAR ENERGY: SUGGESTION FOR A BROAD INTERNATIONAL COLLABORATION IN BASIC AND APPLIED RESEARCH

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1. INTRODUCTION

Mankind is facing, on earth, at present several severe challenges; among these are:

- The warming-up of the earth, which is becoming a reality, has been confirmed by serious scientific investigations. The way to reduce, or at least to ameliorate this impact is the reduction of the carbon-dioxide emission, together with the emission of several other climate-influencing gases. This means, practically, a massive reduction of man-caused emission of these gases into the atmosphere.
- The population is increasing continuously on earth. About 50 years ago, only 2.5 billion people lived on earth; today this number has increased to about 6 billion. All of them are striving for a better life. This means, practically, they all want to have access to more and more energy.
- Alternative energies, such as solar- or bio-energies, have their specific problems when it comes to increasing their contribution to the global energy-supply by considerable margins. The same holds for nuclear-energy supplies, based on fission and fusion technologies. Therefore, it appears useful to consider questions such as: Can one think about structurally new energy-resources, which may contribute on a large scale to the energy-needs for mankind?

Admittedly, this is a bold and simultaneously a highly-speculative question. On the other hand, the demand for energy is so massive and some major energy reservoirs are definitely limited, that it should be allowable to look seriously for new kinds of hypothetical energy-reservoirs. In this paper, I will concentrate on one special aspect of this problem: Is a new kind of nuclear Energy Generator possible? The only way for mankind to tackle this problem is research. As the problem is a universal one, all interested countries should participate in international collaborations to study such projects. Countries with an advanced technological base can contribute with their sophisticated technologies. Developing countries can contribute in those fields, where they have acquired a special ability in relatively simple technologies. The Western countries have no longer a leading position in some of these scientific areas. A typical case of such well-suited technology for less wealthy countries is the broad field of

SSNTD or the field of “Solid-State Nuclear Track Detectors”. This technique has many applications in applied research, as well as in the most advanced basic research. This has been demonstrated most convincingly in recent international conferences of the International Nuclear Track Society, the last one being the 23rd International Conference on Nuclear Tracks in Solids, in Beijing (China) from 11th – 15th September, 2006. The proceedings of this conference have shown that developing countries are, in this field, definitely at par with most advanced countries. This is due to the fact, that there are a number of sufficiently large teams, well - supported for a long time and with a stable internal organisation. This has been achieved most effectively by combining applied with basic research, within one team, and in the researchers themselves. It will be shown, that a collaboration of different teams with a broad variety of special abilities could be the most effective way to investigate the above - stated problem: Is a new kind of nuclear Energy Generator possible?

2. POSSIBLE FIRST INDICATIONS FOR NEW NUCLEAR ENERGIES AT TOTAL ENERGIES E_T<100 GEV.

Recently, there have been some indications—however, still not generally accepted—of a possibly new form of nuclear energy, observed in the study of effects induced by relativistic ions interacting in THICK targets, say with a thickness of about 2 cm or more. These phenomena are associated with short-range problems [dimension: 0.1 cm d 30 cm] observed in interactions of secondary fragments produced in high - energy reactions at very high total-energies, $E_T > 5$ GeV. The interpretation of these interactions in THICK targets [d > 2 cm] was impossible within established model calculations and these phenomena are considered, in a review, as unresolved problems$^{(1, 2)}$. The two different sides of such unresolved problems can be described as follows:

1. One aspect is the - still controversial – observation in nuclear emulsions of a reduced mean-free-path of the secondary fragment itself, as reviewed by Ganssauge in 1988$^{(3)}$. Later on, further evidences of this phenomenon were published only occasionally. Two such observations have been presented recently during the International Baldin Seminar on High-Energy Physics Problems, Relativistic Nuclear Physics and Quantum Chromo-dynamics, at the JINR in Dubna (Ru), in 2004 and in 2006.

    - Orlova, observed a single event in nuclear emulsions irradiated with 27 GeV ^{14}N at the JINR. During this interaction of one primary ion with an emulsion nucleus, four relativistic secondary fragments were observed; all of them had a consecutive nuclear interaction within a strongly reduced flight path, as expected for these secondary fragments under normal conditions$^{(4)}$.
    - Levitskaya, studied interactions in nuclear emulsions irradiated with 158 A GeV ^{208}Pb at CERN in Geneva. She observed under well-defined experimental conditions, i.e. in certain experimental jets, very strong evidence for a

drastically reduced mean-free-path of relativistic secondary fragments (5).

2. Another aspect of these unresolved problems is the details in nuclear interaction of secondary fragments with nuclei of the THICK target. These facts were studied within rather extended international teams, using radiochemical methods, SSNTD`s, and various neutron - measuring techniques in THICK Cu- and Pb-targets, and reviewed in detail (1, 2). The essential experimental facts are: [quote from Ref. 2]:

    - Spallation products produced by relativistic secondary fragments in interactions of {[44 GeV ^{12}C or 72 GeV ^{40}Ar] + Cu} within thick copper yield less products close to the target and much more products far away from the target as compared to primary beam interactions.
    - The neutron production of 44 GeV ^{12}C within thick Cu- and Pb-targets is beyond the estimated yield as based on experiments with 12 GeV ^{12}C."

These experimental results cannot be understood with well-accepted nuclear-reaction models. Nevertheless, it is of interest to speculate about several practical and socio-economical applications [quote from Ref. 1]

- Enhanced transmutation capacity for the destruction of plutonium [Pu fission fragments] with high - energy relativistic ions [as well as for the reversed process of breeding Pu].
- The observation of excess neutron production in 44 GeV ^{12}C irradiations may give us access to hitherto unknown energy reservoirs.

These results have been evaluated externally by Professor P.B. Price, from the Physics Department of the University of California in Berkeley (USA), during his closing talk. Overview of the 23rd International Conference on Nuclear Tracks in Solids, recently held in Beijing (China)(6), several scientists have summarised their research, using (quote from Ref. 6) nuclear-track recording solids, as well as production of radio-nuclides in thick targets to compare products on interaction by primary heavy-ion beam and by secondary particles. They have found that secondary particles behave differently from primaries. Their methods examine only a small fraction of all outgoing particles. (End-of-quote). This holds for studies on interactions with relativistic ions having a total energy $E_T > 5$ GeV. But it must be mentioned: Price was strongly against accepting some suggestions to understand these phenomena on the hypothetical basis, questioning the universal validity of fundamental Thermodynamic Laws.

As this paper is concerned with practical questions, we shall ignore all controversial discussions about theoretical models for the interpretation of these experimentally observed facts. We shall concentrate on practical experimental approaches. At first, it appears to be useful to present some of the key experimental observations that secondary fragments can destroy target nuclei stronger than the primary-ion, provided the proper conditions are given. The results are shown in Tableau-1, further details can be found in Refs. 1 and 2. The top-part of this Tableau-1, presents the well-known results for radiochemical mass-yield distributions in the interaction of relativistic ions in THIN Cu-targets (<1 mm): One observes many product-nuclei close to the mass of the stable $Cu^{63,65}$-target nucleus, and less and less the product-nuclei, the larger the mass-difference between target and product is. In summary one observes:

- The shape of all three mass-yield curves is the same and independent of the energy or mass of the primary - ion, provided (E_T > 5 GeV). This observation is called limiting fragmentation, well understood with established model calculations.
- The absolute values for yields of specific product nuclei increase with the mass of the primary-ion and is called factorisation, again well-understood.

The bottom-part of Tableau 1, presents results for similar radiochemical studies on THICK Cu-targets (2 cm) at the JINR, Dubna, Ru:

- the shape of the mass-yield curve is enhanced for product - nuclei with masses around A 43 and depressed for masses close to the Cu-target around mass A=59.
- This effect increases with the total energy, E_T , of the primary - ion.

These results cannot be understood by any established model calculation, and show:

The nuclear destruction of secondary fragments goes beyond limiting fragmentation and is, therefore, stronger than observed for primary ions. This effect increases with the total energy, E_T , of the primary ion.

Further experiments carried out, the LBNL (Berkeley), CERN (Geneva), SATURNE (Orsay) and PSI (Villigen) have given rather similar and consistent results, as reported in Refs. 1, 2.

This enhanced nuclear destruction ability of secondary fragments leads immediately to the next question: Can there be observed some enhanced neutron production in THICK targets during the irradiation with the same ions as employed in the bottom-part of Tableau 1? The most significant experiments in this respect have been carried out by Vassilkov, et al., at the JINR, in Dubna, Ru. This experiment has also been described in detail in Ref. 1. Vassilkov used a lead target of 20 cm diameter and a length of 60 cm, placed inside a large 1 m^3 paraffin bloc, to allow for neutron moderation. The essential results are shown in Tableau-2. To a first approximation, the number of neutrons released in nuclear interactions increases linearly with the total energy E_T. More detailed investigations show (for the technically available range of specific energies of protons, deuterons, alphas and carbon - ions at the Synchrophasotron (JINR. Dubna) with 1GeV/A E[total]/A 3.7 GeV/A) the following results:

- One observes for protons, behaviour compatible with well-accepted model calculations: the relative neutron yield decreases with increasing proton-energies.
- One observes for ^{12}C quite an opposite behaviour: a drastic increase in the relative number of neutrons by a factor of (5.0 0.3) for an increase in the primary ^{12}C ion-energy by a factor of 3.7. This effect is completely outside any known model-calculation.
- The behaviour of deuterons and alpha-ions is in-between the behaviour of protons and carbon.
- Again, this effect scales with the total energy of the primary ion, E[total], similar to the effect of enhanced nuclear destruction shown in Tableau-1.

Further and extended experiments demonstrated, with SSNTD techniques and radiochemical product yield measurements in THICK Cu-targets and in THICK Pb-targets of the same dimensions, that structurally the same results for neutron production and nuclear destruction could be observed in Cu- and Pb-targets [Refs. 1, 2]. Now the next question is: As an enhanced neutron production coupled with an enhanced nuclear target destruction could be observed in THICK targets below 100 GeV for the total ion energy, what will be the experimental situation for larger total energies with E_T > 100 GeV? As there appears to be no theoretical model around to understand these effects below 100 GeV, one can expect no such theoretical predictions for energies above 100 GeV.

The only way to find out is to do the experiments with the same technical set-up using THICK target at the largest total energies available.

3. POSSIBLE, HOWEVER FEEBLE, EXPERIMENTAL EVIDENCES FOR NEW NUCLEAR ENERGIES AT E_T > 100 GeV

During the past century, quite often the first indications of new nuclear phenomena have been observed with nuclear emulsions, a simple experimental tool closely, related to the SSNTD technique: One can study, with both detectors, individual nuclear events with an optical microscope coupled to a patient human researcher. One notable observation of this kind has been the occasional observation of the complete disintegration of heavy - emulsion target nuclei Br or Ag into all their individual nucleons after an irradiation with ions of energy in the GeV-range. (Of course, only charged particles, like protons, can be observed directly under the microscope). However, only one, such complete disintegration has been recorded by Frielander, et al. for this type of complete disintegration by for 220 GeV ^{238}U in nuclear emulsion and documented by Ganssauge [3].

Khan, et al. observed quite abundant evidences for the complete destruction of 220 GeV ^{238}U into individual nucleons at the end of their range within a THICK stack of SSNTD composed of thin CR-39 plates. This exiting - however, not yet reproduced - evidence for a possibly new nuclear energy (being able to induce considerably enhanced nuclear destruction) has been observed only at this high-energy interaction of 220 GeV ^{238}U-ions. The results of this experiment are summarized in Tableau-3. On the left side are shown two microscopic pictures: The round, fat and black circles are just etch-pits of primary ^{238}U-ions or due to uranium fission fragments in this thin CR-39 plate. They are of no special interest for us here. Interesting are the TINY elliptical spots. The multitude of these elliptical spots appears to be formed by one (or several) anisotropic{not identified} sources below the surface plane of the observation and producing many light, charged particles. The exact nature of these light, charged particles has not yet been identified. This includes also their „effective charge“. Such events could only be observed at the end-of-tracks due to 220 GeV ^{238}U, however, such events could not have been observed with 110 GeV ^{238}U (top right). Thus, it appears to be connected with a threshold effect. The number of these TINY elliptical spots increases up to about 90 (the nuclear charge of an uranium nucleus) during the long etching time of 17 hours (bottom right).

A preliminary suggestion is that one is starting to observe a complete destruction of large projectiles, at the highest available lab energies, into their individual nucleons with a quite abundant rate. At present, it is unclear if this destruction is occurring in the first nuclear interaction, or if it is induced by secondary fragments or even by primary, as well as by secondary interactions. Historically, a first indication of this increasing enhancement of nuclear destruction in THICK targets, induced by secondary particles produced by increasing Ar-ion energies in the range from 36 to 72 GeV, has already been reported in the first publication concerning these “new effects due to relativistic secondary fragments“ in 1985. [Ref.7 and reviewed in Ref. 1 {Figure-7b}]. Two further samples of nuclear interactions in THICK targets irradiated at the largest energies are shown in Tableau-4:

- A THICK target stack of Lexan SSNTDs was exposed to Ultra Heavy Cosmic Rays onboard a Space Vehicle in order to search for Superheavy Elements in cosmic rays. A small part of the sample was also investigated for effects due to reduced mean free paths of secondary fragments in this mass and energy regime. Some preliminary positive evidences for such types of Friedlander´s anomalies (see Ref. 3) have been observed [Ref. 8]. However, one must wait for hard-working young scientists with patience and a good microscope, in order to complete this study and settle this open scientific problem. This is a good chance for scientists in developing countries to do front-line basic research without demanding too much material and logistic infrastructure. Of course, such research can only be carried out in laboratories having an inspiring intellectual atmosphere. This does not need too many financial resources; however, some money is also needed for this research.
- A THICK target of the type discussed in this paper has been irradiated at the largest available energies of 158 A GeV ^{208}Pb-ions at CERN several years ago. Very beautiful calibration results have been published [9]. Even more exciting results for the first nuclear interactions in the THIN front target have been presented by

Sher at the recent 23rd International Conference on Nuclear Tracks in Solids, in Beijing during September 2006. One should be able to read soon about this work [10] in the forthcoming Proceedings of this Conference in "Radiation Measurements". However, we are even more eager to learn, what happened further downstream in this THICK target irradiated at the largest available heavy ion beam at CERN. The open question is: does one see more and more of the complete nuclear destruction of relativistic ions and fragments, as has been reported by Khan, et al. (Tableau-3)? What happens in nuclear interactions of secondary fragments in the downstream foils? Does one see a general destruction in all kinds of nuclear interactions? All these investigations on SSNTD do not need too much technical support, only dedicated researchers, who publish their results. Furthermore, there is this opens questions about the neutron production in such THICK targets irradiated at the largest available energies E_T.

4. SUGGESTION FOR INTERNATIONAL EXPERIMENTS TO SEARCH FOR NEW NUCLEAR ENERGIES AT E_T > 100 GeV

It is obvious; one needs further experiments on THICK Cu- and Pb-targets in the direct beams at those accelerators supplying the largest heavy ion beams: the AGS at BNL in the USA with their 16 A GeV ^{197}Au-beams, or the SPS at CERN, with their 158 A GeV ^{208}Pb-ions. As we have no theoretical models available to understand the new effects, even at the lower energies up to 100 GeV, it is impossible to make any reasonable prediction on what one can expect at the higher total energies. We only know that the effects shown in Tableau-1 and 2 increase with E_T up to 44 GeV. Nevertheless, one can try to make a bold extrapolation, based on the observed neutron yields in Table-1 of Tableau-2.

- We assume that we understand the neutron data in Table 1 perfectly well for proton, ^{1}H, irradiations, as we observe: 3.7: 1 (3.0 0.2). Obviously, some part of the energy during the 3.7 GeV proton irradiation is not used for neutron production, as there is a more abundant production of ^{0}, etc, at the larger energy as compared with the lower energy of 1 GeV.
- We assume that ^{2}D, ^{4}He, and ^{12}C are only a sum (or assembly) of resp. 2, 4 or 12 nucleons. These individual baryons are interacting independently within the nucleus and one should look always for irradiations with ^{2}D, ^{4}He, and ^{12}C ions: 3.7: 1 (3.0 0.2).
- Obviously, the experimental results in the last column of Table-1 do not agree with this low value 3.7: 1 (3.0 0.2) for ^{2}D, ^{4}He, and ^{12}C irradiations. Their ratios are above (3.0 0.2) and have been considered as unresolved problems in [1, 2]. We define this phenomenon as being due to „excess neutrons" and, in a correlated fashion "excess energy":

We define "excess neutrons" n (exc) at
E/A=3.7 GeV/A: n(exc) = n(3.7 GeV/A) – 3 • n(1.0 GeV/A) **(Equation-1)**

(Normalized to neutron measurements for proton irradiations shown in Table-1)

Then one can calculate accordingly:

n(exc) = 0 = 0 % of all neutrons in ^{1}H-irradiations at E[total] = 3.7 GeV
n(exc) = (20 5) = 13 % of all neutrons in ^{2}D-irradiations at E[total] = 7.4 GeV
n(exc) = (63 13) = 23 % of all neutrons in ^{4}He-irradiations at E[total] = 14.8 GeV
n(exc) = (254 27) = 40 % of all neutrons in ^{12}C-irradiations at E[total] = 44 GeV

Additionally, we define „excess energy“ E(exc) as follows:

$$E(exc)_A = n(exc)_A \bullet 10\ \mathrm{MeV} \qquad \textbf{(Equation-2)}$$

The most interesting results of Table-2 are the values for E(exc) and the ratio Y=E (exc)/E (total). The values for E(exc) have been clearly defined in equation-2. However, the physical significance or the basic meaning of this term is completely unclear. Nevertheless, it has been shown that within the limited range of experiments considered, the value for Y increases with E(total). The value of Y = (5.8 0.5)% has been determined for 44 GeV ions. Now we may assume that Y will increase linearly with E(total) up to the largest energies available. We have no theoretical basis for this form of a dependence - or any other form of dependence. We just use it ad hoc. As one has at the AGS@BNL (USA) ion beams with 16 A GeV ^{197}Au and at the SPS@CERN (Geneva) 158 A GeV ^{208}Pb, the respective maximum total energies are E(total)$_{BNL}$ = 3,1 TeV (or 3.100 GeV) and E(total)$_{CERN}$ = 32.9 TeV. Working with the above assumption of a linear increase in Y with E(total), one obtains Y(BNL) = 4.15 and Y(CERN) = 43.4. Provided the input assumptions turn out to agree with future experimental results, then the output-energy during this interaction in a THICK target is larger than the input-energy due to the primary heavy ion. Of course, this does not mean, one has some sort of perpetuum mobile. The experimentalists have drastically destroyed nuclear matter during the irradiation. This result is due to interactions of primary and secondary particles within the THICK target irradiated with an external beam. One must expect substantial amounts of radioactive debris in this THICK target after the irradiation. The composition of this radioactive debris is at present also completely unknown. Only experiments can reveal their composition. On the other hand, we may have obtained in this way a new form of nuclear energy, even, when we have at present

Table - 2: Experimentally measured values for E(exc) and n(exc), as based on Vassilkov´s neutron measurements in Dubna

Primary energy E[total]	excess neutrons n(exc)	n(exc) /n(total) %	excess energy E(exc) / GeV	Y=E(exc)/E[total] %
3.7 GeV	0	0	0	0
7.4 GeV	20 ± 4	13 ± 2	0.200 ± 0.032	2.7 ± 0.4
14.8 GeV	63 ± 9	23 ± 3	0.630 ± 0.090	4.3 ± 0.6
44 GeV	254 ±23	40 ± 4	2.54 ± 0.23	5.8 ± 0.5

no idea, where this energy comes from. Of course, the basic assumptions of these speculations are not based in accepted model calculations; they are ad hoc, as has been stated earlier. Only experiments can find out, what actual facts will be observed in proper future experiments.

These experiments to find out about the measurable reality are comparably simple and not too expensive. It may appear to be worthwhile to carry out such experiments in international teams, as the questions at stake may appear to attract a broad international interest. One cannot exclude some socio-economical consequences, in case one observes certain surprisingly massive experimental results. Of course, it is very uncertain that such results may be observed.

The experimental apparatus to be used can be simple and rather similar to the set-ups in earlier experiments, as shown in Ref. 1 and 2. The results of the experiments at the JINR in Dubna, Ru, have been summarized in Tableau-1 (bottom). The essential experimental set-ups in those earlier experiments can be considered as „calibration experiments". They can be the basis for corresponding experimental set-ups using the highest energy heavy ion beams at BNL and/or CERN. Some examples of such earlier experimental set-ups used at the JINR are shown in Tableau-5: A metallic target core of 8 cm diameter and a length of 20 cm consists of 20 Cu- or Pb-disks, each one being 1 cm thick. The metallic core is surrounded by 6 cm thick paraffin in order to moderate partially the fast neutrons emitted from the target during the irradiation with the relativistic heavy ion beams. A large variety SSNTDs can be positioned around or even inside the target assembly during the irradiation, which can last from several beam burst within a short time for certain sensitive SSNTD exposures and it may last up to several hours in order to accumulate sufficient radioactivity inside the metallic target core. After the end-of-irradiation the analysis of the different target components begins:

- The metallic disks get studied with gamma-counting electronic devices, in order to determine the identity and amount of produced radioactive spallation nuclei. This is a standard analytical procedure for nuclear chemists and physicists, who need modern and not very complicated or expensive electronic systems. The deduction of neutron fluencies from these activity measurements is state-of-the-art.
- All the various SSNTD-teams can take their specific systems home into their laboratories. It is sufficient when they have access to simple chemical etching devices for their SSNTDs. In addition, they need some good optical microscopes coupled to dedicated researchers. It has been shown that this is a fine chance for laboratories in developing countries to participate in advanced international research projects. One example for this has been demonstrated earlier during the above-mentioned "calibration experiments" at the JINR in Dubna (Ru). Several different SSNTDs have been used. Each team has supplied their own specific materials and detectors, among then CR-39, Makrofol, Lavsan, mica, etc. All these samples had been prepared in their own specific manner, in order to investigate one specific aspect of interactions of relativistic secondary particles. All teams

have published their results in detail in their own and independent way and simultaneously, together in larger review articles and also reported their results during national and international conferences.

Furthermore, new experimental tools can simultaneously be tested during such irradiations. This can give some international team a chance to participate and contribute to such an international experiment at an advanced research accelerator. One such new detection-system has been presented by E.U. Khan, et al. at the 23rd ICNTS in Beijing recently: "Can spectrometry method resolve nuclear energy? " [11]. In the spirit of broad international collaborations this new technique and others could very well be incorporated in such an advanced project.

These results could become the basis to prepare for possible future technological developments and answer the question:

Is a new kind of nuclear Energy Generator possible?

5. CONCLUDING REMARKS

In such an anticipated joint and international scientific research project, the question. Basic or applied research? , loses its dilemma. Both aspects are necessary ingredients, and only the concentration towards the research-goal becomes important. This is just in continuation of the modern research impetus, which inspires society and leads to technological progress. It started in ancient times, with great men like the Greek scientist-constructor Archimedes, was continued by such leading scientists as Galilee, some centuries ago and Faraday not too long ago. As a more recent example of this truly scientific approach, we note the discovery of nuclear fission by Hahn, Strassmann and Meitner around December 1938 - this discovery was certainly fundamental and it has found many practical applications for the life of human beings on earth. All of these great leaders in science did research, without asking the question: Basic or applied?

SUMMARY

In this chapter the following thesis has been presented: All societies, who want to develop, need research and the researchers. It does not matter too much, whether it is basic or applied, as both the research approaches are necessary. This thesis will be demonstrated by describing a present research goal.

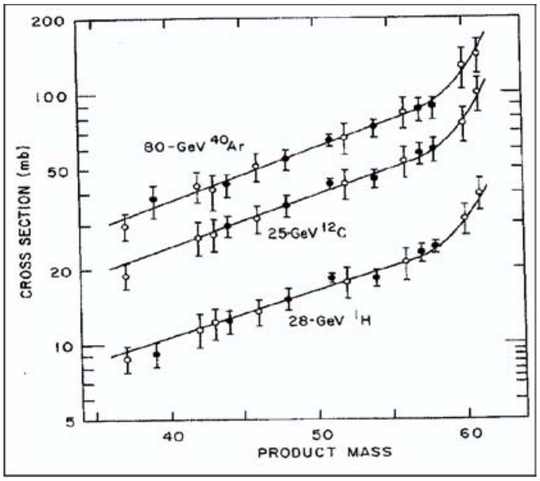
The world needs new energy resources. There may be a new form of nuclear energy around the corner; the only way to find out about it is to do research. In our global world, such a project should be carried out on at open and international level. Developing countries have an excellent chance to participate, when they are fresh and open-minded, and they can bring their special expertise in manpower-intensive technologies, such as the SSNTD (Solid State Nuclear Track Detector) technique into

such an international team. It has become evident, that developing countries have become at par with the advanced countries in such fields, as in SSNTD studies.

Tableau-1) What are the effects of high-energy secondaries in THICK targets ? (A short summary)

TOP FIGURE: The "Standard Model of Physics" explains the experimental product-yield distribution [$(cm)^2$] in thin Cu-targets (< 0.1 cm) irradiated with ions of energy E_{total} 1 GeV. This leads to the concept of "Limiting Fragmentation". BOTTOM FIGURE: Experimental product-yield distribution [B(^{A}Z)] in a thick Cu-Target (20 cm Cu) irradiated with relativistic heavy ions within the energy range 3 GeV < E_{total} < 44 GeV shows for E_{total} > 10 GeV: Secondary fragments produce less M=59 products and more M=43 products compared to primaries. This nuclear destruction goes beyond the concept of "Limiting Fragmentation", due to THICK targets used.

Visual demonstration for the concepts of „Limiting Fragmentation" and "Factorisation" as observed in mass yield curves for thin Cu-targets irradiated with 80 GeV ^{40}Ar, 25 GeV ^{12}C or 28 GeV 1H.



Production rates B(^{A}Z) of four nuclei (^{24}Na, ^{43}K, ^{52}Mn, ^{59}Fe) in 7 Cu-disks from a thick Cu- target consisting of 20 Cu-disks (dimensions: 8 cm , 1 cm thickness each) in the irradiation with relativistic Deuterium- and ^{12}C-ions at different energies. The ordinate axis gives the ratio of the "Sum of B(^{A}Z) in 7 Cu-disks" divided by "B(^{A}Z) in the first Cu disk". Each B(^{A}Z) is measured with an uncertainty of ±15%.

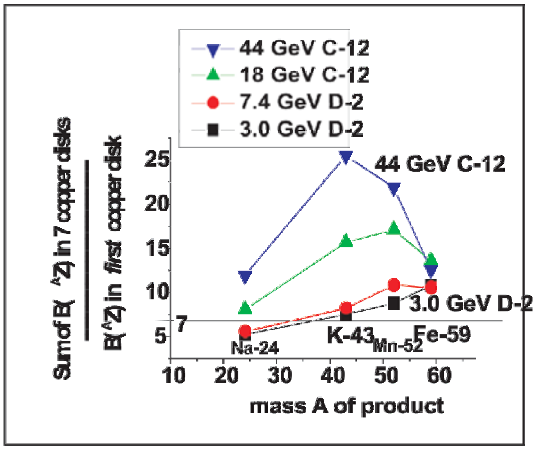
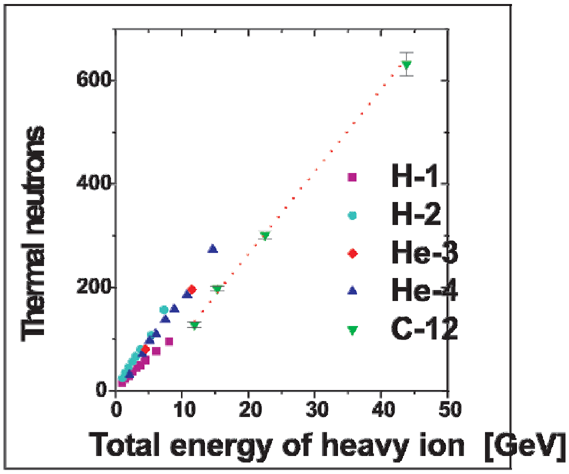


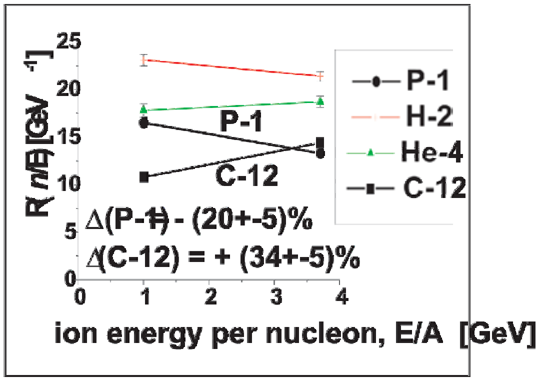
Tableau-2: Basic phenomenon: the more-than-linear neutron breeding

Table-1: The total number of thermal neutrons n, generated by one primary ion(^{1}H, ^{2}H, ^{4}He, or ^{12}C) in a THICK lead target.

Ion	Mass A	Thermal neutrons at E/A=1 GeV/A	Thermal neutrons at E/A=3.7 GeV/A	n at (E/A=3.7 GeV/A) / n at (E/A=1.0 GeV/A)
P	1	16.5 ± 0.5	49.4 ± 1.9	**3.0 ± 0.2**
H	2	45.8 ± 1.2	157 ± 3	3.4 ± 0.2
α	4	71.2 ± 2.8	277 ± 9	3.9 ± 0.2
C	12	129 ± 5	641 ± 22	**5.0 ± 0.3**



The number of thermal neutrons n per primary ion in a Pb target placed inside a 1 m^3 paraffin moderator was measured by Vassilkov et al. The irradiations were carried out at the Synchrophasotron in Dubna. Only the experimental points for the ^{12}C irradiation are connected by a line in order to guide the eye.



The relative production rates [R(n/E)/ GeV^{-1}] of measured thermal neutrons per ^{1}H, ^{2}H, ^{4}He, or ^{12}C ion between two specific energies E/A= 1.0 GeV/A and E/A=3.7 GeV/A - using the results shown above. The values (p-1) and (C-12) are the change in R(n/E), when E/A increases from 1.0 GeV/A to 3.7 GeV/A for ^{1}H and ^{12}C, respectively

Tableau-3: The possible (?) complete destruction of 220 GeV 238-U
"Interactions of relativistic 238-U and light targets". H.A. Khan, et al. ,
NIM (1991), B61, 497. Details are given in the text.

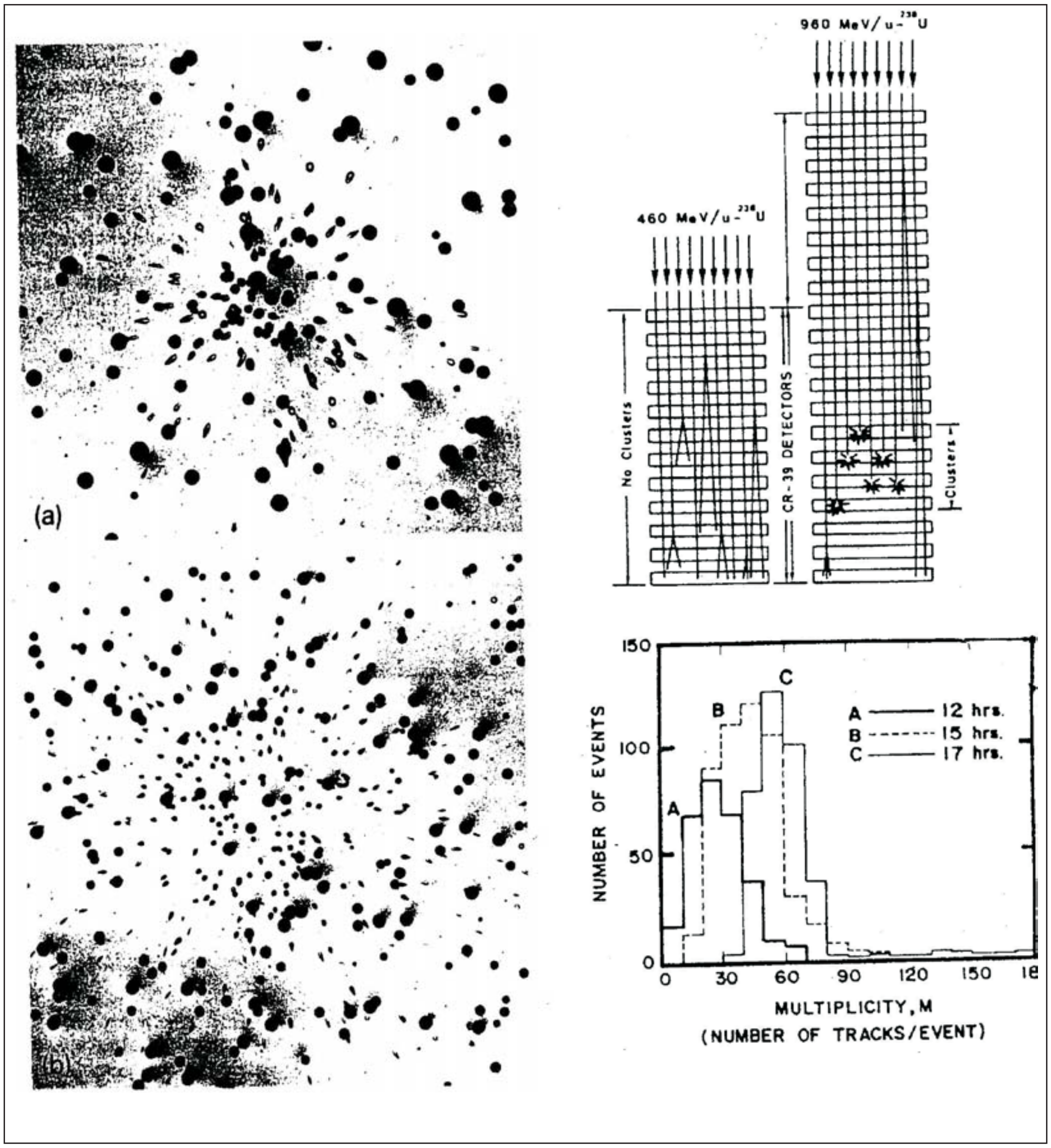
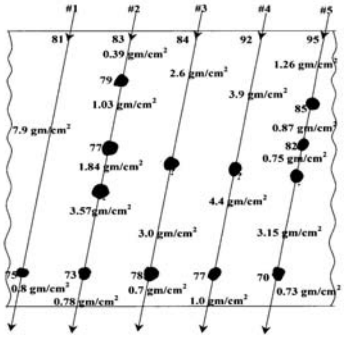


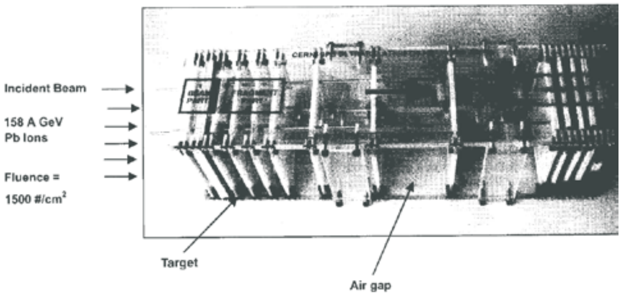
Tableau-4: Experiments at the largest TOTAL energies in

(a) Cosmic Rays



A stack of Lexan polycarbonate sheets was exposed in the Ultra Heavy Cosmic Ray Experiment from 1984 to 1990 to cosmic rays , measuring heavy relativistic ions with Z>65 and E/A > 1.5 GeV/A onboard NASA´s Long Duration Exposure Facility onto a Space Vehicle send into an orbit circling the Earth. After retrieval, a small part (approxm. 1%) of the entire stack was investigated IN DEPTH, showing some evidences for a "reduced mean free path of secondary fragments (Ref. 8). Further study will reveal, if this "effect", similar to Friedlander, et al. anomalons, can be confirmed.

(b) from accelerator in CERN: exposure with 158 A GeV 208-Pb

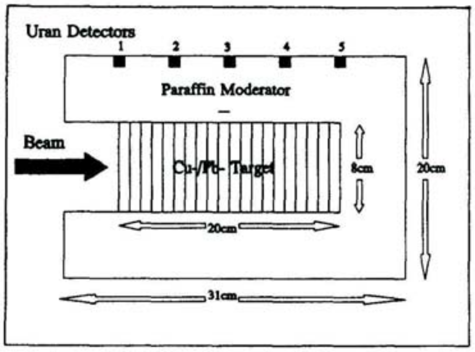


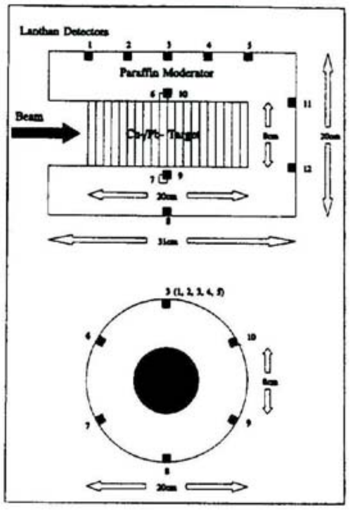
Photograph of a stack of target detector combination used as a 2π - detection arrangement

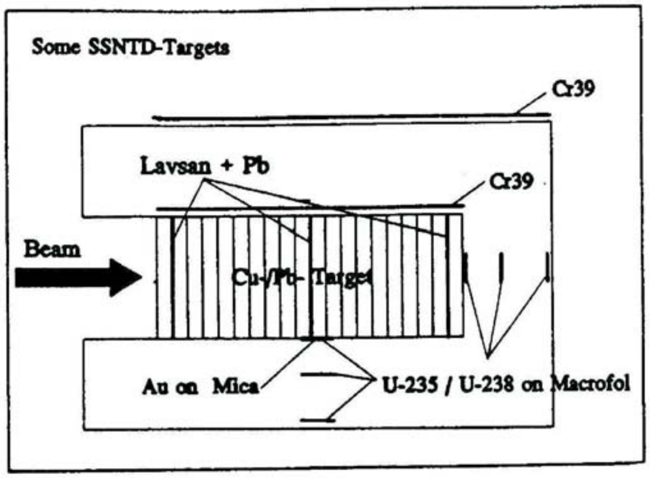
So far, calibrations have been published for the first foils (Ref. 9, 10). Will the possible "self destruction" of heavy ions inside this THICK SSNTD-target (CR-39) destroy these heavy secondary fragments to such an extent, that only much less than expected etch able tracks due to massive heavy ions can be observed further downstream as compared to standard model estimations? Further results will reveal the facts.

Tableau 5. Experimental THICK Target setups for the search of a possible new Nuclear Energy in the external beams at the largest ion energies

All figures show the central target core (Cu-/Pb-target) being either 20 Cu disks or 20 Pb disks, each 1 cm thick. The TOP figures show the position of the radiochemical La- and U-sensors, the BOTTOM figure shows positions for placing various SSNTD sensors.







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ROLE OF SCIENCE AND EDUCATION IN NATIONAL DEVELOPMENT: BASIC OR APPLIED RESEARCH - DILEMMA OF DEVELOPING COUNTRIES

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INTRODUCTION

History can be viewed in terms of human curiosity and ingenuity-driven quest to:

i. Understand natural phenomena and processes,
ii. Study various aspects of different forms of life and devise ways and means to appropriate their surplus and, thus, using the knowledge so gained in these two endeavors to enhance the chances of their survival, and
iii. Appreciate possible negative consequences of the above-mentioned two steps, and working out remedial strategies for minimizing their adverse effects.

In the distant past, curious individuals and keen observers used to engage in research in order to understand natural phenomena, while those fond of tinkering, invented gadgets for fun and play, some of which would also facilitate daily chores of life. Occasionally, a researcher would invent a useful gadget and a technologist's insight would lead to better understanding of some aspect of natural phenomena. Rarely an individual, such as Galileo Galilei, would combine both these geniuses in one single person. However, the close interplay of science and technology is a much more recent phenomena, dating back to the beginning of the last century.

The unprecedented growth of science and technology and the ubiquitous presence of its products in all walks of life have opened a debate on the relative importance of resource-allocation to science and technology or basic and applied research. Some of the following questions are being increasingly debated.

- Who should be paying for basic research?
- Should the government spend less of the taxpayer's money on basic research, in order to concentrate more funding on research-projects that have potential economic value?
- Should public funds be used to subsidize applied research being carried out by private industrial companies?

This chapter is partly based on a similar paper written for the Vision 2030 Document of the Planning Commission of Pakistan

DEFINING BASIC AND APPLIED RESEARCH

Before we address such questions, we need to define and clarify the terms “basic” and “applied” research (RAND Europe, 2001).

Basic Research: Usually curiosity-driven research is termed as “Basic”, “Pure” or “Bottom-up” Research. The main motivation is to expand man's knowledge, not to create or invent something specific. There is often no obvious commercial value to the discoveries that result from basic research. For example, basic-science investigations might seek answers to questions, such as:

- The origins of the universe,
- The fundamental constituents of matter, or
- The genetic code of an organism.

Basic research lays down the foundation for applied science that follows. Applied spin-offs often eventually result from this research. Our understanding of genetics and heredity is largely due to the studies of Mendel, who studied pea-plants in the 1860s, and the experiments with fruit-flies by T.H. Morgan in the early 20th century, which led to the discovery of DNA in the early 1950’s by Watson and Crick. DNA is rightly called the ladder of Life. Similarly, many of today's electrical devices (e.g., radios, generators and alternators) can trace their roots to the basic research conducted by Michael Faraday in 1831, leading to his discovery of the principle of electromagnetic induction. *As Dr. George Smoot says*, "*People cannot foresee the future well enough to predict what's going to develop from basic research. If we only did applied research, we would still be making better spears*."

Applied Research: Demand or need-driven research is referred to as “Applied”, “Commercial” or “Top-down” Research. It is motivated by finding solutions to practical problems, rather than to acquiring knowledge for the sake of knowledge. The goal of the applied scientist is to improve the human condition. For example, applied researchers may investigate ways to:

- Improve or enhance agricultural production
- Understand and find cure of a specific disease such as cancer
- Study and improve the energy efficiency of homes, offices, or modes of transportation

There have been many historical examples, in which applied research has had a major impact on our daily lives. In many cases, such as those mentioned above, the application was derived long before scientists had a good, basic understanding of their underlying science. Vaccinations against various diseases save countless lives each year. The first use of a vaccine occurred in the late 1790's, when Jenner developed a technique for vaccinating people against smallpox, a disease that once killed millions of people. Pasteur in 1885 successfully innoculated a patient with a rabies vaccine.

More recently, Jonas Salk developed a vaccine for polio in 1953; an oral form of the vaccine was produced by Sabin in 1961.

A classic case of serendipity (chance discovery) took place in 1928, while Sir Alexander Fleming was trying to find chemicals that behaved as antibiotics, substances that kill bacteria. A Penicillium mold accidentally contaminated one of his bacterial cultures, and he observed that the bacteria could not grow near the mold, suggesting that the mold was producing a natural anti-bacterial agent. After years of research to isolate and purify the substance, our first true antibiotic, penicillin reached the marketplace. Fleming stated that "nature created penicillin. I only found it."

BASIC OR APPLIED RESEARCH?

Research, whether basic or applied, is still not getting its due importance in most of the developing countries, where less than a fraction of a per cent of GNP is allocated to it, as against more than 2% of GNP in some industrialized countries (sify.com). Universities in industrialized countries get much of their funds from the national agencies, such as science foundations, for doing basic research, while government-departments dealing with energy, food, health and transportation, tend to support applied research, either at universities or in governmental research-laboratories.

Due to the highly competitive nature of the business-world these days, commercial research tends to emphasize those projects require less than 10 years to develop a new product or process. Businesses simply cannot afford to engage in long-term research projects. As a result, universities and governmental laboratories are left with the responsibility to carry out basic research and long-term applied research. Since research is getting very expensive, some costing billions of dollars, many countries are pooling their resources to build major facilities, such as the European Organization for Nuclear Research (CERN). Politicians are greatly influencing decisions regarding research funding, leading to a shift in national priorities in favor of applied research. In 1996, a group of 60 American Nobel-prize winning researchers co-signed a letter that was sent to President Clinton and every member of the US Congress saying:

> *" … America's investment in research over the last fifty years has been a vital source of our economic and political strength around the world, as well as the quality of life Americans enjoy at home. The polio vaccine, computers, jet propulsion, and disease resistant grains and vegetables are some of the thousands of advances pioneered at our universities that have had dramatic benefits for our health, economy, security and quality of life.*
>
> *New and equally breathtaking advances may be just around the corner. Genetic research, for example, gives promise of better treatments for Alzheimer's disease, cancer and other diseases. Lighter and stronger composite materials may be developed with important applications in transportation, medicine and the military. Continuing support for university-based research will not only pave the way for these*

> *important breakthroughs, but will also train the next generation of pioneers and nobelists.*
>
> *The engine of scientific innovation and discovery cannot fuel itself. Our own achievements and the benefits they have brought would not have been possible without the government's 'patient' capital. Discoveries are rarely made instantaneously, but result from years of painstaking work by scientists in a variety of fields. With competition forcing industry to focus research investments on returns over the shorter term, the government is left with the crucial role of making the longer term investment in discovery.*
>
> *America's future prosperity will depend on a continued commitment to producing new ideas and knowledge, and the people educated to apply them successfully. They will be central to our economic opportunity in the face of intense global competition, to our protection against renewed threats to our security and environment, and to ensuring the health of Americans. Federal funding for university-based research is an investment in our future that should be maintained."*

SCIENCE AND DEVELOPING COUNTRIES

Skills and knowledge have been essential elements of the human survival kit since antiquity. In most societies, including most developing countries, however, these have mostly remained undocumented and have been passed on from generation to generation, through apprenticeship and social and cultural rites. Such societies lack innovative spirit and often find it difficult to cope with rapidly changing situations. However, communities and societies that document and regularly assess and evaluate their skills and knowledge, and pass these on to their future generations through formal education, have been more innovative and successful in this regard. Such societies constantly keep updating their knowledge and skills in the form of science and technology, through the scientific method, and are much better prepared for coping with the ever accelerating changes taking place around us.

Most of the developing nations have the necessary resources to become prosperous, progressive and tolerant societies For this purpose they have to carefully chart out a strategy that would help it tap into their key assets and overcome their main hurdles that are mentioned below.

The key potential assets of developing countries are their;

i. Population of more than one billion, mostly under 20 years of age, who are keen to learn and eager to work, and have ancient, rich and diverse cultural heritage;
ii. Vast territory, with climate ranging from hot and humid along the equator to hot and dry weather in the deserts and to cool and dry in the highlands with their breath-taking landscape, densest forests and high mountains;
iii. Rich resource-base that includes ample quantities of fresh water, flowing down

from the mountains to the sea with mostly untapped hydroelectric potential, fertile land, natural gas and petroleum, vast coal reserves and a variety of minerals and gem-stones.

The main hurdles that are to be overcome are;

a. Long periods of political instability, marked by personalized autocratic rule and weak institutional framework and consequent lack of continuity of government policy;
b. A society fragmented along ethnic and communal lines and burdened by poverty, high illiteracy rate, lack of culture of innovation and entrepreneurial spirit;
c. Nominal participation of general public in policy and decision-making process.

In order to convert their large and diverse population from its current status of a liability that has to be fed, housed, provided healthcare, etc; into an asset, the developing countries have to invest heavily in relevant and quality education and scientific research to support broad national goals. As mentioned earlier, knowledge and skills have been essential elements of the human survival-kit since antiquity and innovative societies constantly update their knowledge and skills in the form of science and technology, through the scientific method.

QUALITY AND RELEVANT EDUCATION

'We recognize a wide consensus that elevates the status of education to that of national defense as a guarantee of national security. Education is also a guarantor of economic prosperity, of exemplary personal health and environmental sanity, of protection against rigid belief-systems.'1 –Leon Lederman, 1988 Physics Nobel Laureate and a pioneer of Inquiry-Based Science Education, or IBSE.

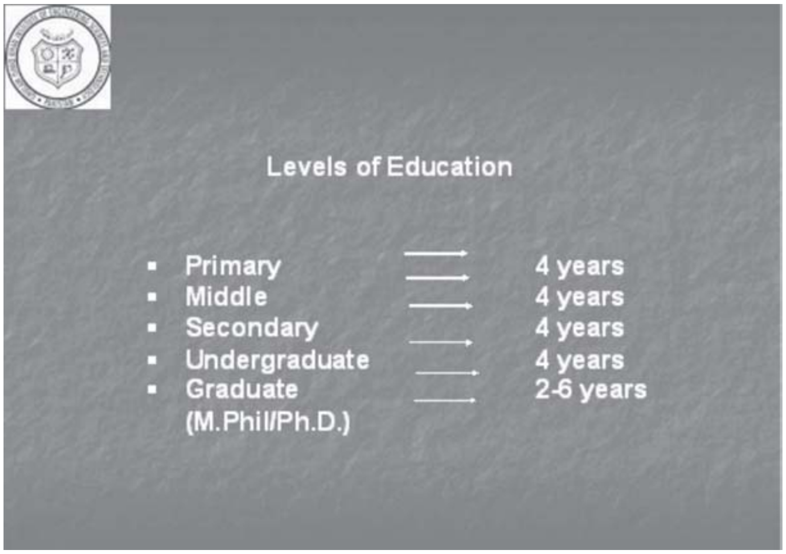
Education is a crucial ingredient of an innovative society that, until recently, has unfortunately been grossly neglected in most developing countries. For example the recent report of the Action Plan of Education Sector Reforms of Pakistan (Ministry of Education - Pakistan, 2004) gives some disturbing statistics, which might also reflect similar trends in other developing countries. Its gross literacy rate still hovers around 50%, almost sixty years after independence, and it is below 2% among some rural female population of certain parts of the country. It still has to adequately address-access related issues, while the problems of quality and relevance of education largely remain unattended. The net participation rate in 2000-2001 at primary level was 68% and the female participation rate was 53%. During 2001, only 12 million children were enrolled out of 18 million children of primary level age-group while 6 million, or about one-third, were out of the school system.

'Educational institutions lack (proper) physical facilities (and infrastructure). The target of minimum essential requirement of competencies for quality education has not yet been achieved. Educational institutions face shortage of qualified and motivated teachers, especially female teachers (Ministry of Education - Pakistan, 2004). According to the former Federal Minister of Education '…education remains a central and sobering challenge for Pakistan, on account of short falls in access, quality and transition. The demand for quality education continues to outpace supply, not just at the primary level but also at the middle, secondary and higher secondary levels. For every 10 primary schools, there is only 1 middle school in the public sector. These gaps lead to low possibilities for completion and transition. There is not sufficient cushion in the non-salary component of the recurrent budget; so repairs and maintenance, facility up-gradation remains unattended (Ministry of Education - Pakistan, 2004).

These stark realities of the state of literacy and education in the country are reflected in the low ranking of Pakistan and most other developing countries in various Human Development Indices (HDI). For example in The Economist Survey of "Quality of Life" Index for 111 countries for 2005-6 Pakistan ranks at 93, just 18 notches above Zimbabwe, which is at the bottom. Only two Muslim countries, namely Malaysia at 36 and Turkey at 50, are ranked above the median rank of 55, and all the resource-rich countries of the Middle East, except Kuwait are ranked below this median. The ranking of a country in this survey depends on many factors with varying weights. These include, social and community activities (12.2 %), job-security (7.7 %) family relations (11.3 %), political freedom (26.2 %), health (19%) and GNP per-capita (18.8 %), which is reflected in the material well being. A broadly based science, technology and engineering education should help us preserve our relatively high ranking in terms of family-relations, while helping us improve our ranking in material well-being, job-security and the other indices.

A recent encouraging development in Pakistan, and perhaps also some other developing countries, has been the greater involvement of private sector in education. It accounts for about 35% of the student enrollment or a total of 12.121 million students out of the total of 33.479 million students from the primary to post graduate and professional level. As compared to the average of 33% of the intuitions in the private sector at all levels the private sector had 61% schools at middle and secondary level and as high as 70% of technical and vocational institutions. Quite understandably, private entrepreneurs are investing their money where the returns are higher, as these institutions teach the skills which make a person employable. They are also providing better education than the corresponding government institutions with less money, spending an average of 8,940 rupees per head per year as compared to 9,746 rupees per head expenditure in the government institutions (Ministry of Education - Pakistan, 2006). The governments of developing countries should, therefore, encourage private sector educational institutions and further strengthen public-private partnership by evolving a transparent mechanism to fund private institutions that provide quality and relevant education and meet certain minimum laid down criteria.

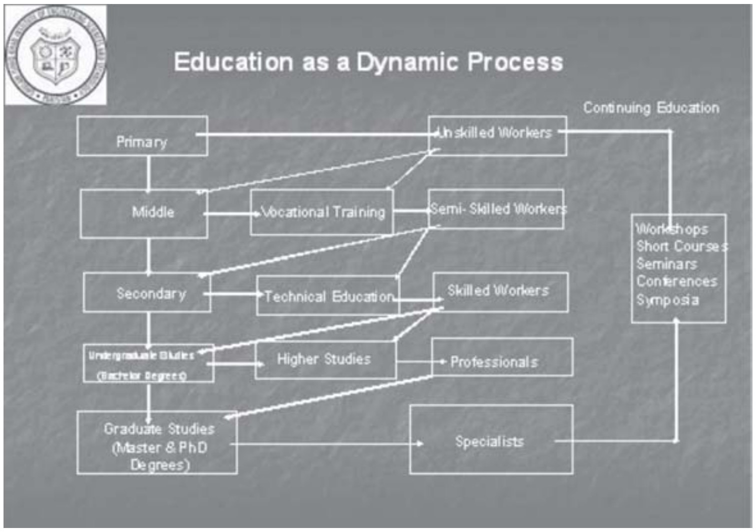
There is also need to replace the (5+3)+2+2+2+2-years education system prevailing in some developing countries by a more rationalized (4+4)+4+4-years system, with well-defined targets to be achieved at the end of each period of four years of education as suggested in the Chart-1 and II. This will help to address the issues of access, quality and relevance in a more systematic manner. Quality of education is closely linked with the satisfaction of intrinsic human curiosity, inculcating which should be given the highest priority in any system of education, as indicated in Chart-III.



Levels of Education

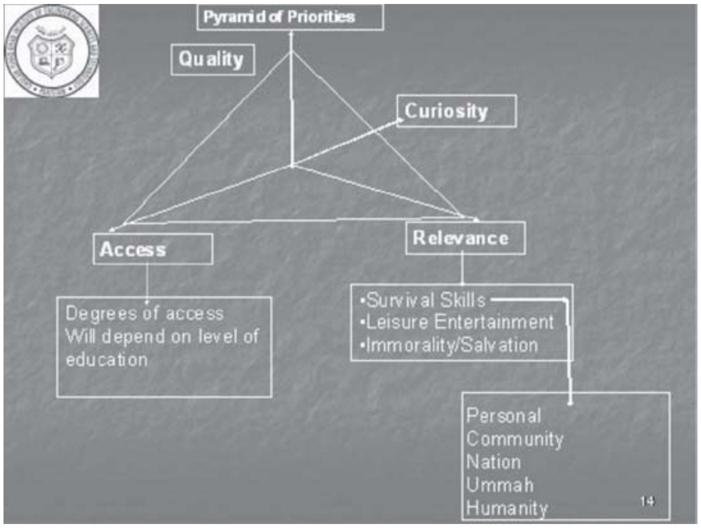
- Primary → 4 years
- Middle → 4 years
- Secondary → 4 years
- Undergraduate → 4 years
- Graduate (M.Phil/Ph.D.) → 2-6 years

Chart - I



Education as a Dynamic Process

Chart - II



Pyramid of Priorities

Quality

Curiosity

Access

Relevance

Degrees of access
Will depend on level of
education

- Survival Skills
- Leisure Entertainment
- Immorality/Salvation

Personal
Community
Nation
Ummah
Humanity

Chart - III

In Pakistan, traditionally education was bifurcated into technical and non-technical education, with higher education being primarily funded by the Federal Government through the University Grants Commission (UGC). With the recent establishment of the Higher Education Commission (HEC) in place of UGC, higher education is being further strengthened through generous funding. The Federal and Provincial ministries of education are now concentrating their efforts to strengthen elementary (K-12), vocational and technical education through the Education-Sector Reforms mentioned earlier. This approach has been very helpful in identifying and addressing the specific issues of each of these three components: elementary, higher and technical education. However there is need for a more integrated and holistic approach and much greater cooperation among various stake holders of all these three components that are closely linked together.

Even in the highly industrialized countries of the world, such as USA, educationists are advocating elevating education to the status of national defense and are beginning to realize the need for adopting new approaches using existing and potential results of education research. In particular some recent research on how children learn can be more effective is being widely adopted in many countries around the world. One such example is the Inquiry-Based Science Education (UNESCO Newsletter, 2006) (IBSE) for K-12 classes that was inspired by the work of American Nobel Laureate Leon Lederman in some schools in Chicago and later adopted by French Nobel Laureate Charpak in schools in Paris. In IBSE program a teacher is expected to take his/her pupils by the hand and lead them on a voyage of discovery, stimulating their imagination, curiosity observation and reasoning skills. This program has already been implemented in 24 different countries in North and South America, Europe and Africa, including Egypt. Encouraged by its success the European Union is launching a new initiative code named 'Pollen' (www.pollen.com) to stimulate and support science teaching and learning in primary schools. Its successful implementation will, however, depend on how effectively one can forge together a consortium of various stake holders such as the academies of sciences, the ministries of science and technology, ministries of education and the federal and provincial ministries of education and partnering them with relevant public and private sector intuitions.

SOME CHALLENGES FACED BY EDUCATION

We, however, face numerous challenges, for which generous funding alone is not the answer. In this age of globalization and knowledge economy forward looking countries are fiercely competing with each other for talent. Leading universities of the world, such as Cambridge, Caltech, Harvard, MIT, Oxford and Stanford, are offering full sponsorships to bright young high school students for their higher studies in science and engineering. For example in 2006 four of the five inter-science/A-level students, who represented Pakistan in the International Physics Olympiad that year, went to some of these universities for their fully sponsored undergraduate studies. Finding talented graduate students for enrolment in MS and PhD programs in local universities is even more difficult. For quite understandable reasons, they prefer to pursue their studies abroad either under foreign financial assistantship or the various HEC scholarships schemes.

The main reason for this state of affairs is the lack of scholarly and research environment and culture in most of our institutes of higher learning. The severe resource constraints in the past made it difficult to establish such a culture. Even when there are ample resources available it is difficult to find enough accomplished academics of developing countries, who are willing to sacrifice their active and well established research careers abroad for helping establish such an environment back home. The most sympathetic among them might not be able to spend more than 4-8 weeks a year away from their home institutions in industrialized countries and their MS and PhD students. Joint research projects between local and expatriate or foreign researchers might be a short term solution of this difficult and challenging problem.

RESEARCH IN THE SERVICE OF PUBLIC OBJECTIVES

"*Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress". — V Bush*

"Increase the federal investments in selected areas of basic scientific ignorance, where understanding may open new opportunities for society to address its most important concerns"— Gerald Holton

"The inspiration that basic research can draw from societal need strengthens its claim on public support in the policy community and from the public to which it responds." — Donald E. Stokes

While it is highly desirable to invest in research as an integral part of quality graduate-education, as well as a long-term investment for socio-economic development, it is also important to encourage research in the service of public objectives. This would entail identifying, listing and prioritizing problems of public interest in various sectors of the economy that need to be addressed. Other countries and societies might also face or have faced similar problems and found their solution. In such a case one need to adopt these solutions. For example, **Annex-I** gives a list of some such questions compiled by the Office of Science and Technology OSTC), USA under the direction of President's Science Advisor, Frank Press. Solving such problems would require expertise, resources and managerial skills. Implementation of these solutions would give rise to numerous additional questions that need to be addressed. Such questions, when shared with the teachers and students of universities and scientists working in various research-organizations, would help them design curricula and R&D programs that is relevant to national needs.

A key feature of innovative society of this century will be its capacity to cope with the ever accelerating and overwhelming pace of change. Perhaps change is the only invariant or constant of nature. However, until the advent of industrial and the more recent S&T revolution the pace of change was slow enough for humans to be able to cope with it. Those changes were mostly transient, isolated and local in nature. Some changes that are taking place today, due to the impact of science and technology on human life styles, as well as the consequent changes, such as climate change, are long term, self-reinforcing and global in nature. The pace of these changes is exceeding the capacity of humans and other organisms to cope with such changes and it is thus, beginning to pose threat to the very existence of life on plant earth.

Language, curiosity, innovative spirit, skills and knowledge are our most distinguishing features as human and have helped our ancestors to survive the harsh conditions on Earth. It has helped us thrive and populate the remote and hitherto inhospitable corners of the globe and encouraged us to colonize distant planets of the solar system. The slow but steady accumulation of knowledge and skill has been responsible for a gradual transition from gathering and hunting mode of life to pastoral and agricultural modes and the emergence of towns, crafts and guilds. Industrial revolution, the outcome of urbanization, gave rise to manufacturing, marketing and service-sectors, and paved the way for a more systematic acquisition of knowledge and skills in the form of science and technology. This in turn revolutionized manufacturing, transport and communications and health, and medicine leading to population explosion, increased urbanization, unsustainable consumption patterns and changing life styles.

As has been amply demonstrated by the industrialized societies, science and technology has the potential not only to provide clean environment, potable water, nutritious food, healthcare and shelter to all members of the human-race, but also provide them the means to enjoy their free time and leisure. In order for the rest of the people inhabiting mother Earth to be able to share these bounties of science, engineering and technology one has to work for a fair and just society, with a caring and sharing-culture, reminiscent of the ancient village culture. Information and communication technologies have shrunk the whole world into a global village. We need broad-based education to make everybody realize that our prosperity, peace and happiness is closely linked with prosperity and happiness of the rest of the mankind.

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Annex - I: List of Some More Questions Related to Basic and Applied Science (Source: OSTP, USA in ref. 4 mentioned above)

The brackets at the end of each item indicate its origin (i.e., Press: part of Frank Press's original memorandum; DA: Department of Agriculture; DoD: Department of Defense; DoE: Department of Energy; S: State Department; NASA). The four questions submitted by the Department of Transportation [DoT], but not included in the list have been added, in brackets, to the Engineering, Computer and Material. The questions were unnumbered in the original; the numbering provided here was added for convenience.
As it might be evident from the following list, somewhat arbitrarily classifies for this paper, it is not easy to classify some questions into Basic and Applied.

Questions Related to Basic Science

1. What is the nature of the universe? How did it originate? Is it expanding, contracting or in a steady state? How large and how old is it? [NASA]
2. Is there intelligent life elsewhere in the universe? [NASA (part of original item)]
3. What are the matter and energy mechanisms of stars—-quasars, pulsars, black holes? [NASA]
4. For many applications, solar energy is impractical because sunshine is intermittent, and energy storage is wasteful and expensive. Basic research is needed to develop ways in which sunlight can produce storable fuels. One possibility is to mimic but improve on photosynthetic processes, with emphasis on increased efficiency and products simpler than carbohydrates. Another approach is the use of sunlight to promote reactions which decompose water to hydrogen and oxygen. [DoE]
5. What is the chemical basis of life? Where and how did it originate? Is a carbon-based chemistry a prerequisite for life? Does gravity play a significant role in the development and maintenance of life? [NASA]
6. Can materials be found that exhibit superconductivity at room temperature? Such a discovery would be extremely important to our energy needs as well as revolutionize all technology using electrical energy. [DoD and DoE]
7. Are there fundamental building blocks in nature? Some recent advances have been made which indicate that even the subnuclear "particles" are not fundamental and further research is necessary to uncover the secrets of the nucleus. [DoD]
8. How can considerations of second law efficiencies be incorporated into energy strategies? Energy should be valued not by its amount alone, but also by its thermodynamic quality. A significant reassessment of energy economics may be in order. [DoE]

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9. How are the fundamental forces of nature related? Four types are currently known: nuclear (strong), electromagnetic, radioactive (weak) and gravitational. Only electromagnetism is well understood; the rest defy us to master them. [DoE]
10. Does an "island of stability" beyond the current periodic table or "abnormal" states of nuclear matter exist? These speculations can be tested and if found could have important consequences for nuclear energy production. [DoE]
11. What is the nature of gravity? Are there gravity waves, and if they exist, how do they propagate and at what velocity? [NASA]
12. What is the nature of matter? Why is matter and charge quantized? [NASA]
13. What are the limits for communications use of the channel capacity in the visible spectrum? Progress in this area could significantly expand the capacity of optical communication systems, and since these systems use glass fibers instead of copper, their use would result in tremendous monetary and resource savings. [Press]
14. What is the nature of intelligence [NASA (part of original item)]
15. How do we think? [NASA (part of original item)]

Questions Related to Applied Science

1. Can we discover anti-viral agents to combat viral diseases? The development of such drugs would have as large an effect on mankind as did the discovery of antibiotics. [DoD]
2. What are the mechanisms by which cells repair damage to their genetic material? This information will provide a better understanding of how the cells minimize mutations as a result of normal and imposed environmental stress. [DoE]
3. How do cells change during growth and development? Advances and understanding in this area should provide insights into the development of cell specialization and, perhaps, the aging process. [Press]
4. What are the molecular mechanisms by which genes are regulated to produce specialized products, and what new information is required to exploit the new DNA recombinant technology? This work may lead to improved knowledge of gene action. [Press]
5. Can microbiological research develop organisms which can convert crude organic materials, such as common cellulose, into livestock feed?

The ability to convert common cellulose to feedstock would significantly increase the availability of high -grade animal protein for human consumption. [S]

6. What are the mechanisms by which hormonal substances regulate growth and reproduction in plants and animals? Answers to this vital question could help solve many perplexing problems, e.g., conception and embryonic mortality in animals and control of post-harvest ripening of fruits and

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vegetables. [DA]

7. In our eco -system affecting man and animals, how do microorganisms gain resistance to antimicrobial drugs and what mechanisms affect the maintenance and transfer of such resistance? Research to provide an understanding of bacterial resistance to drugs used in their control is essential for the protection of human and animal health. [DA]
8. What are mechanisms within body cells which provide immunity to disease? Research on how cell-mediated immunity strengthens and relates to other known mechanisms is needed to more adequately protect humans and animals from disease. [DA]
9. How can utilization of the forest resource be enhanced through manipulations at the level of the plant cell, and through single-cell biodegradation? Tree cells can be stimulated to produce oleoresins, natural biocides, specific carbohydrates, and organic acids. Cell morphology such as fiber length can be altered to affect paper properties. Single-cell protein, hydrocarbons, acids, vitamins, steroids, and alcohols can be produced through biodegradation of tree components. [DA]
10. What are the quantitative differences between minimum human requirements for nutrients and those amounts needed for optimum physical, behavioral and mental functions? Research in this area will contribute to the attainment of maximum physical fitness and a longer, more vigorous, productive life. [DA]
11. Combustion is older than recorded history, yet it is poorly understood in scientific terms. It is important that better understanding be achieved for all aspects of combustion, in order that our fossil fuels can be used with maximum efficiency and minimum adverse impact on the environment. [DoE]
12. The liquefaction of coal is currently done by converting the complex coal structure to simple molecules, then re -combining these into appropriate fuels. The process is capital intensive and energy wasteful. Research is needed on means to transform the coal into useful liquid fuels by a more direct route. This will involve much greater insight into the structure of coal and its reactions during the transformation process. [DoE]
13. What mechanisms of herbicidal action, at the cellular level, are responsible for weed-killing effectiveness? Understanding these mechanisms is essential to improving technologies for reducing the billions of dollars annual crop losses caused by weeds. [DA]
14. To what degree can conventional chemical pesticides be replaced by novel chemicals such as pheromones and insect growth regulators for forest insect pest suppression? Development of such chemicals would provide means of protecting the timber resource with minimal adverse environmental effects. [DA]

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15. Can a predictive capability be developed regarding geochemical transport processes in the accessible regions of the earth's crust? Successful research directed toward this question would have major impact on expansion of the Nation's resource base, and would be of vital importance in resolving waste (nuclear and non-nuclear) problems. [DoE]
16. What is the nature of climate? What are the processes that control climate? How far into the future can you predict it? Is our climate warming or cooling? How far in advance can you predict weather, climate? Is there a relationship between climate and solar activity and, if so, what is the physical connection? [NASA]
17. What is the economic and technical potential for saving energy in the processing and marketing of agricultural commodities? [DA]
18. What are the effects on farm income and consumer prices of environmental rules that pertain to farming? What environmental benefits result from such restrictions on farmers? [DA]
19. What is the potential for microbial production of useful complex organic compounds including food products? Economic microbial processes for producing many complex organic chemicals from waste products appear feasible. [DA]
20. How and how much is the instability of food and fiber product prices accelerating wage -price inflation and so handicapping real national economic growth? What gains in real economic growth would result from alternative price stabilizing mechanisms? What are the distributional effects of alternative economic gains and losses? [DA] 21. Can man-machine interfaces be made so simple as to allow real time translation by untrained personnel? Such developments would not only provide improved communications between the nations, but also have a profound change in our daily life. [DoD]
22. How can productivity be enhanced by automation and artificial intelligence? With limited trained manpower supply in some areas and the saturation of productivity in others, it is extremely important for the nation to develop methods which will permit continual increases in productivity. [DoD]
23. Computer models o f physical and socio-economic processes are needed to guide, and often to replace, experimentation. Advances in analytical and numerical techniques and in computer hardware are required to simulate these processes more effectively. [DoE]
25.] [How can the development of improved construction materials impact the cost of construction? Examples include soil stabilization and development of improved structural concretes. In FY 1976 and the Transition Quarter, DoT grants for construction totaled $7.86 billion. A 15% reduction in construction costs could have saved over $1 billion in this time period alone. DoT]

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26. To what extent can the occurrences of natural hazards such as fire, flood, earthquake, and pestilence be foreseen sufficiently in advance to permit mitigation of their effects? The problems of prediction and of mitigation are different for each hazard, but for each, research offers promise of reducing human and physical costs. [S]
27. What are the economic, technical, and public health impacts of restricting antibiotics and other additives in animal feeds? Adverse impacts may more than offset direct benefits of feed additive bans. [DA]
28. What factors most influence the distribution of foods and so relate to human health? Research to help answer this question is needed prior to public nutrition programs. Such research could indirectly enable reduced health costs. [DA]
29. Can microwave technology or other alternative sources of energy be safely and effectively used to process and preserve food? Food processing and preservation account for nearly 5% of the nation's consumption of fossil energy. Research could provide alternative less costly energy sources and methodology. [DA]

SECTION D

CAPACITY-BUILDING AND OTHER FACTORS INFLUENCING RESEARCH AND DEVELOPMENT

CAPACITY-BUILDING AND NETWORKING FOR BASIC AND APPLIED RESEARCH: IMPORTANCE OF INTERNATIONAL COLLABORATION

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INTRODUCTION

The pursuit of prosperity, peace and security is the rightful endeavour of every nation. The inability of the world community, to check and narrow the prosperity-gaps, existing between rich and the poor countries, has created new problems of intra and international conflicts, violence, degradation of social values and catastrophic damage to the health of earth's environment. These demons do not recognize the political boundaries of the countries and wage havoc freely, wherever and whenever, deemed feasible.

The last century turned out to be a period of the world's political, social, economic and cultural instability, providing fertile ground for the emergence of various types of divides, which afflict the world today. The urgent need to address these problems was painfully felt by a large number of countries, poor and rich alike, which agreed to launch some international initiatives, such as, the UN Millennium Development Goals (2000) and the World Summit on Sustainable Development (2002), in order to try and check the further spread of the above-mentioned socio-economic miseries in the world. Every interested nation has started doing whatever it can, in order to meet its obligations to the various international agreements and treaties. The results of these efforts will appear in 2015, which is a target date for many such initiatives. Intermediary assessments show mixed outcomes, which means that the world community may need to introduce appropriate corrections in the strategies and implementation procedures. The next two or three decades are, thus, crucial for the world's future peace and prosperity, especially for the developing societies.

COMSATS' twenty one member countries, comprising approx. 2.2 billion people (35.5% of world's population) and spread over an area of approx. 23.4 million square kilometers, are predominantly poor (approx. 34% being below the poverty line) despite the fact that they have enough resources in agriculture, minerals and manpower. At one end of the spectrum there is China, which has undergone strong industrial development, and on the other end are several countries in Latin America and Africa that are either poor or making development at slow pace. Most of them have adequate skilled and semi-skilled manpower, which is responsible for the sustenance of the existing small or medium-scale industries or for running the not - so -

profitable agricultural activities. Some are well - advanced in industrial management, science and technology, economic and social infrastructure, whereas many others lack these basic requirements of development. The percentage of literacy also varies considerably among them and the standards of education are generally not very high. Socio-economic stresses on most of the societies have created a peculiar mindset, which is not very receptive to the importance of change and improvement through education and training. In this way the membership of COMSATS can be regarded as a fair representation of wider distribution of countries; least-developed, fairly - developed and highly-developed, all over the world. The socio-economic and developmental attributes applicable to COMSATS' underdeveloped and developing member countries can safely be applied to the rest of the world's countries, while discussing various parameters related to progress. The ensuing discourse will, therefore, endeavour to encapsulate, as much as possible, the above approach, and the understanding contained therein will serve as the context in which relevant parameters of capacity - building, networking and international collaboration will be discussed.

AVENUES OF HOPE

The present profile of an overwhelming majority of the poor and the developing countries of the world, inter alia, consists of one common factor – weak industrialization. Previously, those least-industrialized countries which took the path of intensive industrialization have become appreciably prosperous. Examples are China, Japan, South Korea, Malaysia, etc. Others, like India and Brazil, which have invigorated the process of industrialization, are making impressive progress in their developmental objectives. Sale of resources, like oil, minerals and agricultural products, may make the less - populated nations rich, but this richness cannot be regarded as sustainable. Even exploitation of the resources needs a sufficiently strong industrial capacity and technical competence. Industrial strength also provides military power to the rich nations, who use this power to protect their wealth and political influence. Industrialization is, therefore, a reliable avenue of hope for any poor or developing country to attain prosperity, power and security.

Education is another avenue of hope, which must be vigorously pursued by the poor and developing countries, to attain skills; mental, psychological and physical, in order to prepare them for the change, and to enable them to acquire the right vision for the change. High-quality education, in management, economy, sociology, natural and physical sciences, environment and ethics, is essential for any measure of progress. The present discussion should not digress into areas such as the importance and role of quality education in development, but it would be appropriate to point out that poor and developing societies must give highest priority to quality of education which will, in turn, provide such nations an established way out of poverty.

International collaboration, and effective interaction between the developed and developing countries, provides another reliable channel that can be helpful in making tangible differences. Several UN agencies like UNDP, UNESCO, UNDP, World Bank, etc., have adequate expertise and experience, from which the developing countries can benefit. The right approach, focused policies and genuine commitment by the stakeholders, can increase the chances of success. Although, it is a difficult task to harmonize and synchronize the mechanisms involved, on both sides, for the purposes of transfer of right type of information and financial resources to the poor and developing countries, yet, it will be wise to continue trying for the best results. The incremental effects of this exercise are often positive and substantial. Developing countries must create confidence, courage, skills and patience to interact on an international level, in an effective and efficient way, to draw maximum benefits from such interactions. Many nations have good success stories in this connection.

In order to embark upon the transition from underdevelopment to development, every country has to equip itself with high quality of competence and adequate capacity. Competence is the outcome of education, training and experience, whereas capacity results from vision, resolve and commitment of the policy - makers of a nation. In certain ways, the competence and capacity reinforce each other, after the society has spent an optimum amount of time and efforts on the course to development. Knowledge is a common denominator of both competence and capacity. The power of knowledge drives the nations towards progress, prosperity and dignity. Research creates and enhances knowledge, and also enables the societies to utilize the knowledge for their betterment and well-being. A country strong in research will be strong in the knowledge and will be more prone to development.

Creating and acquiring knowledge, conducting meaningful research and being competent, is an expensive endeavour. Poor and developing countries are often unable to afford the high costs of these essential prerequisites of development. Tailor - made knowledge to design and implement developmental programmes, specifically applicable to a particular nation, is often not available easily. Any contractual arrangements in this connection will cost the developing countries heavily, without much surety of their reliability or success. It is, therefore, desirable that the developing nations strike a balance between creating and acquiring knowledge, and then adapt this knowledge themselves to their particular needs. This also requires research and competence.

BASIC AND APPLIED RESEARCH

As mentioned earlier, achieving development by a nation entails collective efforts of scientists, engineers, economists, sociologists, environmentalists, managers and policy- makers. Here, the discussion will focus on science and technology, as these disciplines are now major drivers of economy and of social values. It may not be appropriate also to analyze here the interconnection between these disciplines and development, or to indulge in the discourse on development versus sustainable development. Science and technology, is equally important for the progress of both the types of developments.

Many expert groups, policy - makers in the governments, scientists, engineers and educationists, often raise the question of preferences of basic or applied research for creation of knowledge and for its use in national development programmes. Realistically speaking, this question should not occupy much of the time of the decision - makers. It is logical to assume that any type of research efforts should depend upon the needs and well - identified priorities of a nation. Basic scientific research, which creates new knowledge on the fundamental properties of nature, is usually carried out in the universities or in the publicly-funded research organizations. The outcome of this type of research is mostly open and is regarded as public-property. Applied research is usually required by the industry, civilian and defence, for the business and profit purposes. This type of research is generally kept in secrecy and largely protected by intellectual property rights. Sometimes, basic research is also conducted by industry and defence for special purposes, mostly to bridge the knowledge-gaps which appear in the chain of mission oriented projects. Similarly, applied research sometimes becomes the necessity as a gap-filler in the basic research programmes conducted in the universities and the research organizations.

For sustainable development, the existence of a competent and effective setup of research of various types in the country is an absolute necessity. Strategists, visionaries and policy-makers of a nation, must make an optimal use of all these types of research organizations and their knowledge-outputs to the socio-economic uplift programmes of their nations. The question or concern for the policy-makers should then not be "basic or applied research" but consideration should be based on the resolve and motto of "basic and applied research". This would be the pragmatic way to rid the developing nations of the dilemma concerning basic or applied research, causing impediments in the progress of their developmental strategies and programmes. A recent publication on the related issues by Hameed A. Khan et al (Editors), provides an excellent source for further reading and insight (COMSATS Series 6, July 2005).

CAPACITY- BUILDING IN BASIC AND APPLIED RESEARCH

It is a well - known fact that developing countries lack adequate capacities in science and technologies and also in other fields of knowledge. Consequently, the capacities in research, basic or applied, are also extremely limited. Some relevant but interesting facts and figures about the state of affairs regarding scientific and technological research in the developed and the developing countries are given in Box-1.

The figures in Box-1 give a broad picture of relevant indicators linked with development and science and technology. It is clear that the richer nations spend more than 1% of their GDP on science and technology, have 3.6 time higher number of scientists and engineers, enjoy 17 times more patent-grants to their citizens, but will have around 14 percent of the world's population in 2015 (target date for MDG's assessments). The per capita GDP of the nations giving high-priority to science and technology is nearly ten times higher than those who spend the least on these

Box - 1

1. World Population and per capita GDP (2001)

Category	Population (Billion)	GDP US $
High income nations	0.8	29000 approx.
Middle income nations	2.8	5000 “
Low income nations	2.5	3000 “

(UNDP Report 2003)

2. Typical National Research and Development

Expenditures as a percentage of GDP.

Country	% age
Sweden	3.7
Japan	3.01
U.S.A.	2.63
China	0.69
Turkey	0.49
Malaysia	0.22
Ecuador	0.08

(U.S. National Science and Engg. Indicators 2002)

3. Scientists and Engineers in Research and Development

Category	No (per million people)
High income nations	3300
Middle income nations	900

(UNDP Report 2003)

4. Patents granted to residents

Category	No (per million population, 1999)
High income nations	350
Middle income nations	20 (approx)

(UNDP Report 2003)

5. Projected World Population (2015)

Category	Population (billions)
High income nations	1
Middle income nations	3
Low income nations	3.2

(UNDP Report 2003)

Source: *Items 1-5 abridged; courtesy Inter Academy Council Report (2004)* disciplines. The developing countries must spend at least 1% of their GDP on science and technology, in order to attain just enough capacity to effectively move on the road to socio-economic development. Of course, major part of this expenditure will be on research, applied and basic together.

It has been well - established through several independent and reliable studies that:

- in a world moving fast toward the knowledge - based economies of the 21st century, capacity-building in science and technology is necessary everywhere,
- the capacity gap between the advanced countries and the poor and developing countries is widening rapidly, which calls for an urgent worldwide action to address this challenge and
- the need for capacity-building in science and technology by the developing countries, is the greatest in the contemporary world.

With this perspective, the capacity of a country in science and technology can be defined as "the personnel, infrastructure, investment and institutional and regulatory framework available to generate activities and acquire scientific knowledge and technological capabilities, for addressing with competence and creativity, local, national and international needs". (Inter Academy Council Report 2004, p. xii). In the subsequent discourse on the capacity-building in applied and basic research, we will adhere to this definition. Although, this definition is general in nature and has the scope of application to all the developing countries, it applies particularly to the developing member-states of COMSATS. It may also be remembered that capacity - building is a dynamic phenomenon, i.e., the advancement in knowledge through basic and applied research requires new capabilities to continue the process of progress. In this context, even the developed world needs enhancement of capacity, at appropriate intervals of time, in their research organizations. However, the developed nations are much more motivated to enhance their research capacities than the developing ones. This is creating an ever-increasing gap of competencies and capacities between the rich and the poor nations. This gap must not be allowed to increase to such an extent that it may become impossible for the developing countries to take advantage of the knowledge created by the advanced countries.

The aforestated definition of capacity-building comprises three components. First, the basic building blocks of personnel, infrastructure, investment, and institutional and regulatory framework. Second, generation of activities, acquire knowledge and technological capabilities. And the third involves, addressing local, national and international needs with competence and creativity. The third component is related to the objectives (end result), whereas the first and the second components are linked to facilities and action respectively. All these components are relevant to basic and applied research and are closely interlinked. The prime consideration is of the third one, which points out the desired results, consequently setting the stage of the design of policies and strategies of the first two components.

Universities and research organizations, both in private and public domain, are the main hubs of basic and applied research in civilian and military fields. They are the major entities equipped with appropriate tools to acquire, generate and disseminate knowledge, expertise and experience for the national interests.

Industry and private enterprises are the other crucial entities which can contribute significantly to the national efforts of strengthening basic and applied, predominantly the latter, research. Generally, the private industry in the developing countries does not recognize the importance of research for the better financial returns. Mistrust between the university and industry results in hampering the promotion of research. This, in turn, causes a serious blow to the capacities of both universities and the industry. A large majority of developing countries' research laboratories and knowledge-warehouses are of a substandard level.

The work culture and relationship ethics in most research organizations, universities, industry and others is such that does not promote, encourage or create the sense of collaboration and team work. Individuals try to be as autonomous as possible in their research programmes, for guaranteed and assured returns. This not only lends a serious blow to the capacity of the research organization, but also causes deterioration of the quality of research. This phenomenon also exists in the research organizations and universities of the developed nations, though to a lesser extent. It is difficult to achieve university-industry collaboration even in the advanced societies. Developing countries will, thus, have increasing need to devise their policies and strategies for capacity- building on more indigenous and autonomous basis. Each developing country will have to stand on its own feet, if meaningful progress in science and technology for sustainable socio-economic developments has to be achieved. Universities and other research organizations can establish demonstration centres to promote the outputs of their research for the acceptance of industry. The outputs and products of research may also be displayed in industrial exhibitions or in national science and technology museums. Media can also play an important role in promoting public acceptance, thus, indirectly contributing to strengthening of research capacities.

Many studies have been carried out on the subject of capacity - building in basic and applied research from a variety of perspectives on national, regional and international basis. As the subject is of much interest to the developing and developed countries alike, due to its direct linkage to the socio-economic development, many governments keep reviewing the matter through their respective ministries and planning commissions. National academies, specialist organizations, both national and international, debate and publish their recommendations for public assimilation. A recent comprehensive report by Inter Academy Council (Inventing a better future, 2004), can be consulted for detailed information on worldwide capacity-building in science and technology. This report analyses various aspects of capacity- building for all categories of the countries, and gives recommendations for further action. Another useful publication in this regard is a book by COMSATS entitled "Capacity-Building for Science and Technology" (Eds. Hameed A. Khan, et al – 2003). This book is based on COMSATS' meeting on Science and Technology Capacity-Building for Sustainable Development (Feb. 2003) and contains specific material on a large variety of allied topics. A synthesis of the above-mentioned publications and relevant considerations from other sources on the pertinent points linked to capacity- building in science and technology and hence in applied or basic research, is presented in the following paragraphs.

Every developing country is aware that capacity-building in basic and applied research, whatever the ratio of combination between the two may be, is necessary if benefits to its economy are to be derived. However, there is usually not enough political commitment to implement the measures envisaged for such purposes. Secondly, many developing countries are unable to identify their real needs both in qualitative and quantitative terms. These countries choose to depend upon foreign consultants for their advice on their economic problems and their solutions. Often, the foreign consultants' findings do not turn out to be workable. The developing countries' political leadership has to take courageous decisions, may be not entirely without risks, to start relying on their indigenous resources, i.e., manpower, universities, research organizations, technical infrastructure, repair and maintenance services, business incubators, science and technology parks, financial back-up schemes to the science and technology students, national seminars, symposia, workshops on the indigenous creation, maintenance and dissemination of knowledge, and finally elevating the social status of scholars and researchers.

Much advice on various aspects of capacity - building in planning and execution of basic and applied research for the socio-economic development, is available in the conventional and traditional sense. But, there is not much of the outcome from the efforts made by the developing countries which could become visible on ground. The poor countries are still poor and backward, and one does not expect much from them in the near future also. It is because most of them are too much dependent upon the richer countries for aids and loans. This is an easier and short-cut way to partly address the socio-economic problems on a short - term basis. But it is only an adhoc arrangement, which makes nations addicted to foreign-aid and acquires the reputation of a parasite in the world community.

Key Steps for Building Indigenous Capacities in S&T

Indigenization of activities to enhance capacities in basic and applied research in science and technology is one safe answer to the problems discussed above. Developing nations must try new initiatives to help promote indigenous science and technology capacity as suggested by the Inter Academy Report (2004). According to this report, the following recommendations which are new, or at least novel, to many science and technology policy-makers and to the public at large, can be useful in building indigenous science and technology capacity around the world:

a. **Grooming and Retention of Young Scientists and Engineers:** This effort should be made with vigor and seriousness. Attraction of young talent to research in science and technology requires imaginative and compelling curricula. The retaining of young talent depends upon first-rate research and educational environment, on programmes for cultivating opportunity and on recognition and reducing brain-drain. This could be achieved by providing adequate compensation and working conditions, motivating them to return home to their native countries and accommodating the special needs of women. Once these new scientists and engineers are developed, they require access to the best regional facilities for continued training to deepen their knowledge and develop their skills.

b. **Provision of Science and Technology Education at All Levels:** Early development of scientific and technological outlooks, sense of discovery and accomplishment and desire for research, is needed in order to build for future S&T training throughout one's school years. Simultaneously, it is desirable that special programmes be developed for ensuring quality S&T education for all students, not just for future researchers, to increase general S&T literacy and to propagate the values of open and honest science among the public at large.

c. **Building Centres of Excellence:** This measure is of extreme importance for advancement of science and technology. Local centres of excellence, no matter how small their number may be, provide the foundation for indigenous capacity for research in science and technology. Although a nations' infrastructure, links between its components and its connections to colleagues in other countries are important, it is actually a nation's centres of excellence that truly drive that nations' efforts to build capacity for scientific and technical research.

d. **Establishment of Virtual Networks of Excellence:** Another crucial requirement is the establishment of networks, each anchored in a physical centre of excellence that creates virtual science and technology complexes. Such virtual networks of excellence are fundamentally new means, made possible by new technologies, by which links and consequent synergies between talented and compatible but geographically dispersed individuals and teams can be created to upgrade priority areas of research and development in particular countries and egions and even on a global basis.

e. **Public-Private-Academia Partnership:** In many developing countries, having attained fairly advanced research and development capacities, the universities are succeeding in establishing spin-off companies that have the right to patent and license the results of their advanced research, even though much of it originated in academic settings. This interlink is not that easy to establish and maintain, and if not handled properly, can distort the traditional functions of a university. However, such partnerships can offer important advantages for promoting cutting-edge research and directing the outcomes to the public benefits.

f. Strengthening Links with Expatriate Scientists and Engineers: It is a common phenomenon that, many highly-qualified and talented scientists and engineers from developing countries work in industrially advanced nations. Although, many developing countries cannot offer them the congenial working environment for their own good, it is important that strong links are established with these expatriates. Serious efforts must be made to secure for the native developing country, some of the benefits of their education and experience, for example, through collaborative projects with local students, scientists, research organizations and policy- makers.

g. Creation and Maintenance of Digital Libraries: The developing countries desirous of capacity- building in research, must try to harness the new information and communication technologies by means of universal digital libraries that are readily accessible all over the world. Editors of science and technology journals and books also need to play their role, by facilitating online access to the literature, particularly for the developing countries' professionals and their research institutes.

h. Regional Collaborative Networks: The regional collaborative networks can play a very important role in strengthening the science and technology capacities of the participants. Although, it is a difficult job to create proficient and effective networks and then maintaining them, yet, this arrangement can be made feasible if good management practices are employed. Leading countries, i.e., those advanced in science and technology, can act as hubs of regional research activities can also help in increasing the strength of S&T projects designed to benefit the members. Sharing of manpower, equipment and information among the developing member countries of a region, can enhance the capacity and strength of science and technology manifold. Organizations like TWAS, ISESCO, UN, international banks and donor organizations, should reinvigorate their efforts and readjust their policies and strategies to make best use of regional capacity building arrangements.

i. Need for Novel Funding Mechanisms: The world science and technology consortia such as the Consultative Group on International Agricultural Research, which involve collaboration among advanced and developing nations on some particular issues, have to be more active in the area of capacity-building in applied and basic research. Novel and practicable financial mechanisms to implement sectoral funding, global funding and regional cooperation grants having capacity- building components of the projects, need to be devised.

j. Local and Regional Centres for Supply and Maintenance of Equipment: Capacity-building efforts to promote basic and applied research in the developing countries, is seriously hampered due to nonavailability of equipment, instruments and materials in a timely fashion. In many cases there are frustrating delays in the provision of technician services, spare-parts and other after-sale (back-up) services. Strong local and regional nodes are necessary alongwith efficient logistical capacities to address such serious practical issues. Industrial and technical resources must be systematically mobilized by the developing countries through business arrangements with the manufacturers and vendors.

k. Strengthening the Role of the Universities: The universities in the developing countries have a special role to play in building science and technology capacities for basic and applied research. The current structure of higher-education systems in many developing countries is inadequate to meet the challenges of the 21st century. The shrinking independence of the universities due to financial, social and political pressures, to promote world class research, is a major impediment in the efforts to build capacities. Socio-economic development through the aegis of the universities is a direct and effective way of a nation's prosperity. The universities must build capacities in areas directly affecting the development of a nation such as information and communication technologies, aeronautics and astronautics, agricultural sciences, anthropology, biology, brain and cognitive sciences, chemical engineering, chemistry, civil and environmental engineering, earth, atmosphere, planetary sciences, economics, electrical engineering, health sciences and technologies, computer sciences, systems engineering, mathematics, mechanical engineering, physics, medicinal chemistry and engineering, nuclear engineering, political science, psychology and sociology. More emphasis needs to be given on health, agriculture and engineering capacities in the developing countries. In these countries collaborative work in an interdisciplinary and in a systems-level fashion is critical, both for creating capacities and sharing these capacities in a cost effective manner.

l. National and International Investment: It is obvious, that no capacity-building in basic or applied sciences can take place without adequate and assured funding. National and foreign investment is essential in this respect. Investment in science and technology and other areas of knowledge, which have direct bearing on the socio-economic development of the countries, have to be realistically arranged and applied in a well-planned manner. Each developing country and foreign donor will decide upon the investment in the light of its political and economic policies. Prosperity of all is essential for the guarantee of the world peace. Therefore, it is a shared responsibility of all the nations of the world to assist the developing countries in pulling them out of poverty through the effective use of science and technology which has historically been the most credible way of the rich nations to achieve their present economic status. Capacity-building in science and technology has direct linkage with better outputs of basic and applied research. In this context and in short-term analysis, one comes to the conclusion that (a) national sectoral funding programmes provide support for research and development of national importance, (b) regional S&T networks should share responsibility for funding research and (c) global funding mechanisms should be strengthened for support of science and technology research in developing countries. It may, however, not be forgotten that the funding problem is one of the most serious problems attached to the progress of basic or applied research in science and technology. The present mechanisms of funding are not satisfactory; either they are too inadequate to meet even the most genuine needs of research, or they are exuberantly exhausted on aimless and ill-conceived research efforts. Although several recommendations are available around the world to create effective mechanisms of funding for the capacity-building in the developing and the least-developed countries, most of them do not possess the merit of being practicable. This is because the international mechanisms are either too ambitious in nature or too weak in their designs. It is imperative that developing countries should rely more on their indigenous resources, financial as well as others, than on global assistance. This will, no doubt, make the capacity-building in science and technology a bit slower but will ensure a steady improvement. A slow but steadier progress in the capacity building in basic and applied research in science and technology is much better than fast but frequently interrupted progress. The developing countries must attain the strength of marketing their research outputs before they could expect any meaningful foreign investments. Some specific aspects of capacity-building in science and technology have been given in COMSATS' publication series No. 1 (2003), which can serve as useful additional reading on this subject.

NORTH-SOUTH COLLABORATION

As emphasized earlier, no nation alone can achieve a completely independent capability to pursue all its science and technology requirements for sustainable development. Capacity-building and capacity-enhancement, needed to meet the ever evolving challenges of a nation for its sustainable socio-economic progress, is also an ever- growing process. The costs involved for the independence of science and technology and the upgradation of related capacities are so high, that the developing and the least- developed countries cannot afford them easily. The rich and industrialized nations, on the other hand, are in a much better position to meet such costs to a much greater extent. Most of the marketable knowledge generated by the national spendings or through corporate agreements is kept confidential. Pooling intellectual and financial resources to meet this kind of challenge has been in practice for quite some time now and it has been found to be working well for the cartels based on mutual economic and political interdependencies. Such relationship, if realized between the industrially advanced and economically poor countries having lower science and technology base, can also work to an appreciable extent. If it happens, the countries with lesser capacities will be in a much better position to gain rapidly from the wealth of knowledge and experience of the advanced countries. Political will and honesty of purpose will be essential to establish such relationships. Inter Academy Council has recognized the various entities and some activities, which can formulate the basis for useful joint collaboration. The summation on next page represents some of the salient points in this regard:

The summation shows common activities of interest to several categories of countries and regional and/or international entities working for strengthening science and technology and building capacities. The central aim of these entities and activities is to help promote socio-economic development in the fairly-developed, developing and lesser-developed countries. The role of very advanced countries is basically to act as supporters and facilitators for the benefits of fairly-advanced and less-advanced

Summation of S&T Developmental Activities of Common Interests to Various Countries/Entities

S&T
Developmental
Activities

Countries and Entities

	Very advanced	**Fairly Advanced**	**Less Advanced**	**UN Agencies/ Regional organizations**	**Regional/ International Organizations**	**Int. Develop. Organizations**	**Foundations**	**Int./Nat. Private Sectors**
Identification of national goals and priorities		x	x	x		x		x
Assessment of strength & weakness of S&T capacities	x	x						
Govt-Univ.-Industry partnership for capacity building		x						x
Creation of Centres of Excellence for research		x						
Upgradation of research programmes and institutions		x	x	x	x	x	x	x
Mechanisms to advise Govt. on S&T		x	x		x			
Information to public on S&T resources		x	x	x		x	x	x
Upgradation of educational programmes	x	x	x		x			
S&T regional and international research programmes		x	x	x		x	x	
S&T career opportunities		x	x					
S&T digital information sources		x		x		x	x	
Policies for Intellectual property rights		x						

(Source: Inter Academy Council Report – 2004)

countries, in the fields of science and technology, education and training, economy, environmental sciences and other related areas. All activities are linked with capacity-enhancement, either directly or indirectly. Most commonly shared activities, on which international and North-South collaboration can be built, are the identification of national goals and priorities, upgradation of research programmes and institutions, information to public on S&T resources, upgradation of educational and training programmes, S&T regional and international research programmes and S&T digital information sources. Very few are interested in policies for intellectual property rights, career opportunities for scientists and engineers, creation of centres of excellence, establishment of govt-university-industry partnership for capacity-building and also for the assessment of strengths and weaknesses of current S&T capacities. These areas have been envisaged to be the sole responsibility of the country itself as the issues involved are either too sensitive or are very specific to the each country concerned. In other areas, each country will have its limited choice to enter into collaboration with the advanced or very advanced countries in only a few areas of immediate interest. Thus, country specific North-South patterns of collaboration can have some chances of success, as shown in the above summation.

The international experience on North-South and South-South collaboration for capacity- building in science and technology is full of successes and failures. The unhindered transfer of knowledge and technology from North to South, in areas of real economic and security interest, has been extremely limited. On the other hand South-South collaboration shows some encouraging signs, although the quality of knowledge and technical expertise transferred has not been of very high-standards. Continued and progressive transfer of science and technology among the developing countries (TCDC) must be vitalized, in order to avoid total dependence on the industrially rich nations. International organizations like TWAS, Abdus Salam International Centre of Theoretical Physics, ISESCO, COMSTECH, COMSATS, etc., and the regional agreements like SAARC, ASEAN, OIC and others have to attach much more importance to science and technology than they have done uptil now, in their agendas of work and for mutual collaboration, if they wish to attain a more meaningful and respectable place in the developing and developed world. South-South collaboration, though useful for the developing countries, cannot totally replace the North-South collaboration. After all, the latest science and technology in all conceivable fields of human-interest are created and commercialized by the countries of the North. Slow and steady build-up of collaborative partnership between North and South with strong planning should be geared up in the coming decades. Capacity-creation and capacity-enhancement in the developing countries is, nonetheless, a prerequisite for any kind of international collaboration, North-South or South-South. Various specific aspects of the necessity of North-South and South-South collaboration are very aptly documented in COMSATS' Series of Publications No. 5, entitled South-South and South-North Collaboration – Present Scenario and Future Prospects (2005).

North-South collaboration for strengthening capacity in science and technology can effectively be achieved through a scheme of joint projects, where the interests of the advanced countries can be amply secured by outsourcing a set of scientific and technical activities to the relevant institutions of the developing country or countries. The major advantage for the advanced partner would be the sizeable cost saving in terms of manpower and infrastructure, whereas the developing partner gains in the areas of knowledge, expertise and technology. Exchange of scientists, engineers and technicians during this process adds more benefits to the underdeveloped partner, but at the same time the project is carried out much more cheaply and in a timely manner for the benefit of the advanced country. Such coordinated research projects (CRP's) have been tried bilaterally and also under multilateral arrangements, such as under the aegis of the International Atomic Energy Agency's technical cooperation programme of the CRP's. This programme has rendered significant contributions to the developing countries for enhancing their scientific and technical capacities and in successfully completing many of their technical programmes linked to socio-economic development.

Several other mechanisms exist internationally which support North-South collaboration in scientific and technical education, basic and applied research and projects targeted to the needs of the developing countries. These include networking, scholarships, on the job training, regional and interregional projects, transfer of equipment, etc. These are sponsored and guided by the government organizations, NGOs and private enterprises (detailed case-studies given in the Inter Academy Council Publication; Inventing better future, Jan 2004). An extensive body of literature on this aspect of North-South collaboration is available for comparative study, analysis and policy purposes from a variety of information sources. However, it is evident that the ongoing objectives of North-South collaboration and the previous patterns of such collaboration do not overwhelmingly support direct programmes of institution-building or capacity-building in the developing nations. The collaboration, by and large, focuses on utilizing the existing capacities and, at the most, enabling the institutions and organizations to enhance the capacities in the narrow areas of certain mutually agreed disciplines. It is then upto the recipient country, to expand its capabilities, competence and capacities in the light of assistance received from the advanced countries in certain segmented spheres of science and technology. It is also the responsibility of the recipient state to transform the assistance received into the appropriate designs of its basic or applied research. Many developing countries often fail to adopt and implement this strategy in a proper manner. North-South collaboration, therefore, requires pre-collaborative design studies, which could later on provide sufficient inputs to improve the research capacities at the conclusion of the collaborative projects in the developing countries. An effective CRP has the potential to considerably enhance the capacity of research and development in the partner recipient country in such diverse areas of importance as trained-manpower, better equipment, strong contacts among scientists and engineers access to modern scientific knowledge and better dissemination of research outputs over a large number of other developing countries.

NETWORKING AND CAPACITY-BUILDING

Joining efforts by the science and technology organizations in the developing countries in the pursuit of common interests, has the potential of achieving better and cost effective results in the organizational, national and regional programmes. Networking of research organizations within a developing nation or extending it to the other developing countries and also to the developed countries is an effective mechanism of this promising strategy. Whereas, on practical grounds, this mechanism has worked well in the advanced countries, its full potential has not been utilized in the developing and the least developed countries. Cultural, professional, political, economic and management dimensions are important in such arrangements. Networking of scientific and technical research and relevant resources can cause what is known as "leapfrogging" on the path to progress, yet a large majority of the developing nations are not in a position to do so. Adequate knowledge is an essential prerequisite for such an arrangement. Developing nations' research organizations must embark upon vigorous campaigns to network among themselves and among the research laboratories of the advanced countries and not remain handicapped due to isolation which is a proven cause of scientific and technical marginalization.

Networking also means to come closer, know more about one another and share resources as much as possible. Traditionally, this is achieved through information and telecommunication technologies (ICTS), joint projects, joint planning, exchange of expertise and equipment, opening the doors to students for higher-education, private-public partnerships, sharing the intellectual property rights and sharing of results and publications. Easy and cheaper commercial availability of internet, telephone and tele-conferencing facilities is rapidly increasing the connectivity potential among the people and organizations. The prospects of networking have, thus, ameliorated manifold which is a good omen for the developing countries to invigorate their efforts to enhance their scientific and technical capacities.

Capacity-building in applied or basic research in science and technology, through networking, requires a multifaceted approach, both in concept and practice. A sense of give and take, sacrifice and tolerance among the networking partners must remain supreme for the sustainability of the networking arrangements. The following points are noteworthy, while considering the planning and implementation of networking for capacity building:

i. Capacity-building in science and technology research, basic or applied, should be taken as a shared regional and global responsibility. This means that more advanced research centres in the more advanced developing countries or in advanced countries, should play the lead role in building capacity. The already existing networks in diverse fields should help train new scientists and engineers. The networks must get the persistent support of the academic, governmental, intergovernmental and private entities.

ii. Wide dissemination of knowledge can be achieved by the establishment of digital libraries of science and technology. Proper harnessing of digital technologies is necessary for science and technology capacity-building in developing countries. Major efforts are needed by them, to provide adequate infrastructure and trained-technical manpower in ICT's, for their learning and research institutions.
iii. The worldwide webs should be enriched with information needed to promote and build science and technology capacity and made available to scientists and engineers from the developing countries at very modest costs. International organizations like UN, development banks and foundations, are the major entities to lead the way for this objective. This should be further supported through provision of digital copies of scientific literature to the developing world, ensuring that a digital-format basic science library is made accessible to the libraries of the developing countries, posting maximum literature in science and technology on the web, organization of major hubs in the developing countries for sharing digital knowledge in research, maintenance of electronic gateways by the libraries for sharing digital information among researchers and finally encouraging interlibrary loans in electronic form for the interests of efficiency and effectiveness.
iv. It is a very well -established fact that strong universities are essential for enhancing national science and technology capacities. Strong universities, possessing quality and independence, will produce strong research outputs. Explicit national commitment is necessary to strengthen universities, and to achieve a critical national capacity in science and technology. Universities must enjoy enough autonomies in seeking and to strengthen their ties with regional and international research, teaching and data creating institutions and networks.
v. Links among the scientific talent of the region and the globe can be effectively built through virtual networks of excellence, extending throughout the developing world. The virtual institutes created through virtual networks of excellence can work to blend their activities into coherent programmes with the freedom of individual research groups, to work in the areas of interests of their own countries. These virtual networks of excellence should be created nationally, regionally and globally, utilizing the new ICTs.
vi. National academies of science and professional associations can play an important role in capacity-building of scientific and technical institutions through policy facilitation and provision of special research grants. The developing countries should make utmost efforts to create and sustain these academies and associations. The agendas of the academies and the professional societies in the developing countries should be oriented specifically to the objective of capacity-building and for raising the quality of basic and applied research. They should also act as effective channels of creating links and networks with the science and technology organizations of other countries, developing and developed alike, through their counterpart academies and professional organizations operating in those other countries.
vii. Private-public partnerships for the promotion of science and technology research and strengthening the capacities, are the most effective means to achieve

sustainable progress and tangible benefits. Networking among developing countries' private and public research organizations, universities, academies of science and the scientific societies, can have great potential in the fast improvements of the quality and quantity of research which in this particular arrangement, primarily gives rise to a profitable blend of basic and applied research. However, establishing private-public partnership is not an easy task. Advanced countries have lesser of this difficulty but the developing countries have to go through a long and painful process before such an arrangement, indeed, takes place. The developing countries set upon the course of such an enterprise have to formulate clear legal frameworks, particularly on the protection of intellectual property rights and clear mechanisms for dispute resolutions. Often the international private sector has the possibilities of sponsoring science and technology research that has great potential for addressing challenges related to capacity enhancement. Governments of developing countries need to create an enabling environment in their societies to allow and flourish the infusion of foreign assistance. Success, on such account, will depend upon the strength and efficiency of the networks involved.

viii. The most crucial aspect of networking for capacity -building in science and technology is the availability of funding. The funds should not only be adequate and timely but also assured. The developing countries must enhance funding for their overall development work` and high-priority should be given for capacity-building in science and technology. Regional science and technology networks should share the responsibility for funding research. The S&T-proficient countries should cooperate with S&T lesser-advanced countries in quality research through regional networks. Research nodes of the networks should be the centres of excellence in the developing countries. This mechanism has strong potential to enhance the S&T capacities among the less-developed network partners. The networks should stimulate interdisciplinary research, and establish links with partner countries' private sectors. Once the developing countries gain sufficient experience in sectoral and regional funding networks, the possibility of extending it to the global funding can also be tried. However, for this experiment to succeed, the participating governments have to be extremely committed to the cause of partnership.

ix. Networking among the scientific community for capacity-building through resource and information sharing can be greatly enhanced through efficient utilization of modern information and communication technologies (ICT's). ICT's are progressively increasing their potential and, at the same time, the accessibility to them is also increasing rapidly with respect to costs and equipment. Both, the scientific community and the common citizens, are now becoming ICT conscious at an amazing rate even in the developing and the least-developed countries. This is a healthy sign for the strengthening of capacities of the S&T organizations, universities, industry, policy-makers and the government. ICT societies are better placed to reap the benefits of knowledge generated through research. Strong ICT base, thus, becomes a necessary requirement for the developing countries to strengthen their research programmes in science and

technology, and also enhance their competence and capacity.
It is an established fact that a failure to build a national information infrastructure, adversely affects the scientific and technical research communities in developing countries. Capacity-building involves the accumulation of scientific and technical knowledge, skills and competencies to enable assessment, selection, application, adaptation and development of ICTs. The existing expertise in the developing countries and the one they receive from abroad has to be coordinated and strengthened on a continuous basis. Improved "early-warning" of new technical, market, policy and regulatory developments is feasible if networks of expertise are coordinated (SPRU Research Report 1998). In networking for capacity-building in science and technology, it may not be ignored that developing countries have to lay maximum emphasis on indigenous efforts. This will give the developing countries dependable and sustainable capacities.

CONDITIONALITIES FOR SUCCESS

Capacity-building measures discussed and analysed in the context of basic and applied research in science and technology, in the above sections of this write-up, can be successful, subject to the following conditionalities, as recognized by the IA Council Report 2004,

a. Political stability in the developing country
b. Firm commitment of national political leadership
c. Existence of appropriate national laws and efficient administration
d. Practice of good governance
e. Presence of intellectual freedom
f. Adequate empowerment of various actors whose interaction is necessary for research and development.

One cannot resist quoting the same Report (IAC – 2004, p.12) on the optimism for a better future for the developing countries, by indigenously strengthening their S&T capacities, in the following words,

"It is absolutely necessary for developing nations to strengthen their S&T capacity. And they must do so soon, through their own focused efforts, with help from their friends. Given the currently rapid rate of change in science and technology, there is no time to waste if the majority of humanity is not to suffer further marginalization. We must, by our actions from this day forward, lay down the foundations for better tomorrows, when the benefits of science and technology will reach the traditionally detached, include the excluded, serve the unserved, and give hope to every human-being on our planet that he or she, too, has a chance to live in dignity, comfort, health and happiness. If we truly believe in our common humanity, we must aim for no less".
These words must serve as a source of hope and encouragement for the developing and

the developed countries together. Let the humanity take quick action to implement the wisdom of these words so as to rid our planet of poverty, disease, indignity and insecurity, and create a better world to live in."

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DEVELOPMENT OF INSTITUTIONS:
A KEY TO S&T CAPACITY-BUILDING IN SOUTH

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1. INTRODUCTION

Institutions are more important than individuals, as they survive even when the hands that make them are no more. There is an organic relationship between them as institutions create people and people create institutions.

Capacities in building Science and technology requires a focus on institutions. Individual, no matter how brilliant they are, cannot function and perform without a fundamental framework for research and innovation. The current science and technology development of the industrialized nations has its roots in institutions created in last centuries. These institutions attracted best minds of their times and provided them conducive environment to be innovative and productive. Throughout the years, Western governments provided them sustained and generous support, while society at large recognized and respected their role in the generation of knowledge and economic growth. S&T institutions in the West are now associated with the traditions of scholarship, and carry the legacies and culture of knowledge. In contrary, nations of the South, spent most of their energies initially struggling for independence and then for meeting the essential needs of their massive population. As a result, most of the developing nations now lack quality scientific and technological infrastructure, a major shortcoming that needs to be corrected. Unless developing nations establish such institutions, along with a suitable mechanisms for their effective interaction with the production-sector, it will be difficult to develop scientific and technological capacity in the South, and consequently to achieve sustainable socioeconomic development.

Following is a brief account of the need and role of quality S&T institutions for socio-economic development for slowing down the brain drain and for equal partnership in global knowledge-generation.

2. TYPE OF SCIENTIFIC AND TECHNOLOGICAL INSTITUTIONS

Science and technology advances in a framework of institutions, each performing a different function, but work in harmony to support innovation and its applications in production-sector. These institutions include:

a. Ministries and Central Organizations for S&T

There is a need of focal institution(s) for policy formulation of S&T, coordination and implementation. In many countries, various Ministries (such as Ministry of Higher Education / Education, Science and Technology, Agriculture, Energy, Health, etc) perform these functions in their own fields. They formulate strategy, make plan and implement. Their vision is largely focused on the promotion of the discipline they represent. Each ministry establishes and oversees S&T establishments, including subject-specific educational institutions, and support research projects and human-resource development. However, along with these ministries, there is certainly a need of a central organization, which support activities such as development of manpower through institutions of higher learning, foreign fellowship programs, interaction with international agencies, addressing the issue of brain-drain, financing of projects of interdisciplinary nature, etc., as these programs often do not fit easily into any single ministry. It is, therefore, important that nations of the South not only develop powerful ministries, but also create central organizations for the promotion and effective management of S&T infrastructure.

b. Quality Education-System

High-standard universities educate and train new generation of scientists and engineers, and perform fundamental research without expecting immediate financial return. More importantly, they promote appreciation of science and technology and generate thrill and excitement of research and enquiry in young minds. No nation in the world has progressed in science and technology without quality educational institutions of tertiary. Developing nations, no matter how poor, must strive to create strong system of higher educations.

c. Centers of Excellence

Centers of Excellence, mostly located in universities or associated with R&D institutions, play a crucial role in generation of knowledge, innovation and providing advanced training to young researchers. These centres often work in focused areas and have the highest quality personnel, infrastructure and research output. In order to develop S&T capacity, the developing nations should create centers of excellence in key disciplines, whether of local, national or regional stature.

d. Public Funding Institutions

Key to S&T development is a generous and sustained mechanism of funding. No nation of the world has been able to develop world-class S&T and higher-educational institutions without the provision of generous financial support from governmental funding (supplemented with private-sector funds in some cases). A key to promote scientific excellence is the merit-based allocation of resources, based on rigorous review. Every nation should create viable public funding institutions with sustained and generous budget and a mechanism to support and promote S&T institutions and fundamental research for public good.

e. Libraries, Museums and Science-Parks

Science never emerges in a vacuum, it always has a cultural context. For the promotion of innovation in S&T at the highest level, culture of science and respect of knowledge needs to be created at the grass-root levels. Libraries, museums and science-parks play a fundamental role in the promotion of scientific culture in the society. These institutions signify the role which science plays in our lives and thus, earns respect for the practitioners of science. Apart from their archival responsibilities, these institutions motivate young-minds to opt for science as their future profession and as their life-long passion. It is therefore absolutely essential that every nation create public libraries and science-museums as integral components of their overall S&T infrastructure.

f. Industrial Park and Technology-Incubators

Science & Technology research draws its strength and support from its perceived contribution in rapid economic growth. Scientific discoveries and innovation must be translated into marketable products and services, in order to ensure a sustained and generous financial support from the national government. It is also critically important for retaining the constituency of support from the public domain. Industrial parks and technology-incubators provide a mechanism to translate laboratory level discoveries into marketable goods. Over the years, developing nations have created networks of industrial and research-parks, in addition to their elite S&T institutions and universities. Technology-incubators perform translation-research and pilot-level studies worldwide, and attract private-sector to exploit S&T discoveries for economic gain. They play a pivotal role in linking academic R&D with the industries and end-users. Developing nations need to establish demand-driven networks of industrial parks along with their R&D establishments. Such industrial parks can also be created at regional levels, where free-trade regime and economic cooperation between the countries exists.

g. Independent National Science-Academies and Professional Societies

Science-academies have played a key role in S&T development of industrialized countries. These member-based autonomous institutions perform a number of important functions. They, on one hand, recognize members for their distinguished and continuing professional achievements and, on the other hand, serve as independent advisory bodies for decision-making on S&T aspects of public polices. These institutions also inform the general public about the merits and demerits of new technologies and review the impact of various S&T related initiatives.

Creation of each of these types of institutions is critically important for developing capacities in science and technology. The absence of these institutions can lead to a situation where new S&T is either not created or do not function for public good. It is also important for developing nations to create an enabling environment, where S&T institutions and scientists can collaborate and cooperate for innovation. This includes aligning economies in a way where innovation becomes the cornerstone of material development.

3. ATTRIBUTES OF CENTERS OF EXCELLENCE

Centers of Excellence are the physical locations where frontier research and advanced training are carried out. These centers generally emerge automatically from many others created at the same time. These are supposed to have the highest international standards. They generally work in focused disciplines and excel by contributing at the frontiers of their specialized fields. Although each center of excellence has a unique character and history, there are some common attributes which makes them different from others. These includes.

a. Institutional autonomy with an independent governance structure (Board of Directors), which selects its own members, appoint the Director and review the institutional progress. Such autonomy ensures an intellectual pursuit without any political pressure and beauracratic hurdle.
b. Sustainable financial support, which is not only sufficient for current activities but also allows the future growth. Such financial support should only be tide to the productivity and performance of institutions, measured through a transparent criteria.
c. Able leadership, which is widely recognized for his/her professional contributions by peers, and endowed with effective managerial skills.
d. Mechanism to ensure quality, including quality of graduate level training, research publications, and contractual research-projects.
e. Merit-based hiring and promotion of faculty members and scientists.
f. International collaborations and institutional linkages.
g. Focused research agenda and an atmosphere, which encourages interdisciplinary and goal-oriented teamwork.
h. Activities that include not only research but also applications of research-results and extension-services.
i. Encouragement to young scientific talent.
j. A mechanism of review by foreign experts and, most importantly, the will to implement their recommendations.
k. Confidence of decision-makers and bipartisan support from politicians of entire spectrum.

4. CREATING SCIENCE AND TECHNOLOGY INSTITUTIONS

Science and technology institutions are not bricks and motor, they have to be created around quality manpower. These institutions do not necessarily have to be created from scratch since the strengthening and reforming of existing but promising research- institutions can lead to desired results. However, the existing institutions must have some, if not most, of the attributes mentioned above.

Each center of excellence should be given a clear mandate along with measurable criteria on which they will be judged in future. Genesis of S&T institutions generally follow a sequence given below:

- a. Identification of a theme /discipline/area in which a nation wish to develop indigenous S&T capacity.
- b. Careful selection of the venue of the proposed center such as a university, R&D institution, or as stand alone.
- c. Careful identification of an outstanding person for the leadership of the new center.
- d. Allocation of resources and enabling environment for the hiring of qualified and motivated S&T manpower.
- e. Sustained and adequate financial support.
- f. A clear vision for future growth and institutional strengthening.

5. PROBLEMS OF S&T ESTABLISHMENTS IN DEVELOPING WORLD AND POSSIBLE SOLUTIONS

Science and technology institutions face multiple problems in developing world. Many of them are debilitating in nature, however many can be resolved with hard work and intelligent planning.

a. Lack of Political Will

Generally Science & Technology in the countries of the South lack of political support. National governments and politician in charge of affairs, do not understand the role of science and technology for national development. They consider expenditure on S&T capacity-building as a luxury, which only rich nations can afford. Some do understand the importance of S&T, but cannot wait for the time, which indigenous scientific and technological resources take before resulting in socio-economic development. As a result, these countries keep relying on imported technology and remain in the circle of economic deprivation.

The issue of lack of political will can be resolved through sustained efforts. This scenario may be changed by: sensitizing media to report success-stories whereby S&T has contributed in rapid economic development; developing a research-agenda, most relevant to national needs; findings champions of science in the ranks of political leadership; and, presenting the case of science as a matter of national survival. Media can certainly play a vital role in presenting the case for S&T to political leadership. Politicians inherently like to take credit of their contributions. If they know that support to S&T can bring them extra political mileage, they will certainly do so. Initially, it seems to be a tough agenda, but this has worked in many countries of the South.

b. Lack of Qualified Manpower

S&T institutions in the developing world often face serious shortage of qualified manpower. This certainly requires a careful planning. In many fields, it is difficult to find skilled manpower. It is therefore important that S&T institutions gradually develop their faculty by hiring young and promising scholars and sending them to top institutions of the world for Ph.Ds., sandwich Ph.D. program and post-doctoral trainings. Such foreign trainings are not necessarily very expensive, as in most of the European universities there are no tuition fees and only living expenditure and health insurance needs to be covered. Quick training of some young scholars in pertinent fields; rehiring of active retired senior scientists and inviting foreign and expatriate scholars can be an effective way of starting research-activities in the initial phases. However, any faculty-development programs in foreign institutions should account for the risk of loosing some of the brightest scholars. Therefore, slightly higher number of recruitments may be a good idea.

c. Sustained Financial Support

Sustained and adequate financial support remains one of the most important constraints of S&T institutions in the South. However, global experiences suggest that quality S&T manpower can bring funding from all possible sources. Critically important are development and operational grants, for which national governments are the most likely sources. It is therefore important that relevant governmental ministries and institutions are approached with well-planned projects with clearly identified deliverables. A phased, modular, slow and steady growth, is always a good idea in the special circumstances of developing countries. Contributions from private-sector (Foundation, trusts, and industries) can also play a very important role, as this further motivate the national governments to support the institution from public funds. There are numerous international and multilateral agencies, as well as foreign governments, which support S&T establishments based on their track-record and research-agenda. In an efforts to secure funding for S&T institutions, old saying of “knock as many doors as you can and some one will answer” is still true.

d. Balance between Basic and Applied Research

S&T Institutions of the South often loose track of their original mandate and slowly become irrelevant to the society needs. Most often they fail to achieve a balance between academic research (which sustains interest of genuine scientists alive, bring international recognition and create new knowledge) and applied research (which develops confidence of general public, bring economic gain in short-time span and fulfill the initial promise). This, however, can be achieved by carefully laying down the criteria of promotion and recognition. Clear performance-indicators should demand from researchers both academic excellence and successful applied research.

As stated above, problems of S&T centers in developing world are numerous and complex, but can be solved with commitment, hardwork, intelligent planning and resilience. These are all the attributes of an able leadership, without which nothing much is possible.

6. ESTABLISHMENT OF H. E. J. RESEARCH INSTITUTE OF CHEMISTRY - A CASE STUDY

In 1966, University of Karachi invited Prof. Salimuzaman Siddiqui, FRS (Chairman, Pakistan Council for Scientific and Industrial Research (PCSIR) to establish a post-graduate chemistry institute at the University of Karachi. Prof. Siddiqui, who was recently retired from the PCSIR, moved to University of Karachi, along with two young colleagues Dr. Viqar Uddin Ahmad and Dr. Zafar H. Zaidi. This dedicated group of scientists, along with a few students, established the nucleus of the institute in a small laboratory of old chemistry department. In 1969, Prof. Atta-ur-Rahman, who was serving as a Don at Kings College Cambridge (UK), after completing his Ph.D. on the total synthesis of anticancer drug-vinblastine, visited this nascent center and met with Prof. Siddiqui. Old and wise Prof. Siddiqui was able to convince young, dynamic and able Dr. Atta to return to Pakistan and lead the establishment of a new institute. In 1973, Prof. Atta-ur-Rahman permanently returned to Pakistan to join Prof. Siddiqui's Laboratory. He brought with him some essential equipment from Cambridge, which he obtained as a donation after many efforts. This was the first set of modern scientific tools that the new institute acquired and which attracted many young and talented students to join this institute.

Realizing the importance of in-house maintenance staff, Dr. Atta-ur-Rahman hired two competent technicians. He then convinced the local banks to grant small loans, with which he approached some international funding agencies for matching grants for the purchase of scientific equipment. This team of four outstanding scientists, working in an environment constrained by resource and space, soon attracted the attention of Prof. Dr. Wolfgang Voelter, who was visiting Pakistan as a representative of the German Government to select an institution for support. This led to a grant of 8 million DM for equipments and chemicals. However, proper building-space to be remained a constraint, which was soon resolved through a magnificent and largest donation to any science-institution in Pakistan (at that time) by Mr. Latif Ebrahim Jamal (Chairman, Husein Ebrahim Jamal Foundation). The Institute was accordingly named as Husein Ebrahim Jamal (H.E.J.) Institute of Chemistry. At this stage, the Government of Pakistan realized the emergence of an outstanding institution under the able leadership of Prof. Atta-ur-Rahman and decided to support the efforts. The first grant from the national government was accordingly received in 1979. The same year, the institute moved to a brand new building. In the initial years of institutional development, the major challenges were to develop a world-class faculty, hire competent engineering staff for the maintenance of sophisticated equipment and to establish international linkages. The institute decided to hire several young scholars that were sent abroad for trainings in fields such as, pharmacology, protein-chemistry, single-crystal X-ray diffraction techniques and establishment of biological screenings. On return of these scholars, the institute became a unique center where chemists and pharmacologists were working together to conduct a meaningful research in the field of natural products-chemistry. Running of sophisticated scientific equipment in a country where even stable electricity is a problem was a major hurdle. To meet this challenge, institute created in-house electricity-generation and UPS facilities, gas-liquification units, electronic and electrical workshops, etc., several young engineers were then sent abroad over the years until they became genuine experts of modern equipments, such as NMR and mass-spectrometers.

In January 1984, the Institute organized the first International Symposium on Natural Product-Chemistry, which brought many distinguished chemists of the world, including several Nobel Laureates, to the institute. Subsequent conferences and symposia played a very important role in raising its international profile, initiating collaborative research projects with foreign scientists and training of young scholars. In 1987, Prof. Dr. Atta-ur-Rahman won a major grant of US$ 8.0 million from Japanese government. This grant was used to modernize the instrumental facilities, and for the establishment of several new laboratories and training of manpower. Competent faculty of the institute was able to win large competitive research grants from international funding-agencies. The Institute soon became the oasis of scientific excellence, where dedicated group of researchers were working in the focused areas of natural-product isolation and synthesis and protein-chemistry.

Along with this another world class research institution, Dr. Panjwani Center for Molecular Medicine and Drug Research, was established by Ms Nadira Panjwani S. I., H. I. (Managing Trustee Dr. Muhammad Hussain Panjwani Memorial Trust). These two premier research centers of Pakistan are now collaborating with each other in field of drug-development against prevalent diseases, as well as for training of Ph. D. scholars

This is an example of genesis of an excellent S&T institution in which private-sector, national government and international donors have all contributed. Behind the success was the leadership and hard work of Prof. Atta-ur-Rahman FRS and his outstanding team.

The H. E. J. Research Institute of Chemistry (of International Center for Chemical and Biological Sciences), is now among the best academic-research establishments of the developing world, recognized for the quality of its graduates, world-class research-publications, excellent instrumentation, and its contribution towards national development. The institute has the single largest doctoral program in Pakistan. The facilities of the institute are at par with any good institution West. Some of the most distinguished scientists of Pakistan work in this institute, who have brought Pakistan on the scientific map of the world. The Institute is perhaps the only place in the developing world where students from Western countries, including Germany, regularly visit for research-training and collaborative studies in the field of chemical sciences.

7. CONCLUSIONS

Science and Technology institutions can play a key role in socio-economic progress of developing countries. Their creation and sustenance is a difficult task, but not impossible, as demonstrated by the existence of many world-class institutions in the South. What it needs is an outstanding leadership, teamwork, academic excellence and support from various sectors. They perform best in an environment that supports innovation and scholarship. Strong educational system, world-class S&T institutions and appreciation of the role of science as driver of change are the key ingredients for socio-economic progress of the developing world.

CLIMATIC-CHANGE AND SUSTAINABLE DEVELOPMENT

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1. INTRODUCTION

Sustainable development and Climate-change are two vitally important and interrelated challenges, facing us in the 21st century. Our ability to develop more sustainably will determine the speed and degree of climate change we experience and, as the climate changes, the choices available to us to develop sustainable will also change.

We need to significantly reduce our greenhouse gas emissions, so that we can change the course of climatic change. Furthermore, some climate-change is now inevitable due to our past greenhouse emissions. We need to adapt - at the same time as we act to reduce emissions - to better manage the future impacts of climate-change on the environment, economy and society. Fair or not, climate change is very unfair. The bulk of impact will fall on the low-latitude countries, which are also the poorest. Most of the big emitters will face the least effect. Those that will suffer have hardly anything to do with the emissions!

2. BACKGROUND

Sustainable development is development that meets the needs of the present without compromising the ability of the future generation to meet their needs. This definition of World Commission on Environment and Development (WCED) reflects three key concepts:

i. First is human need; in particular the basic needs of the world's poorest people for adequate food, water and shelter.
ii. Second is intergenerational equity; our responsibility towards future generations to leave them an environment with a sufficient variety and abundance of resources to meet their own needs.
iii. The third concept, embedded in intra-generational equity, draws attention to issues of access to resources and other development opportunities within the present generation.

2.1 Kyoto Protocol

In December 1997, over 160 nations met in Kyoto, Japan, to discuss the United Nations

Framework Convention on Climate Change (UNFCCC). The outcome of the meeting was the Kyoto Protocol, in which developed nations set targets for limiting their greenhouse gas emissions. Countries that ratified the Protocol could engage in emission-trading with each other, which would reward countries achieving reduction in excess of their targets. (The world's largest emitter - US has not yet signed the Protocol, whereas, Pakistan has signed it last year).

2.2 IPCC's WG-I, Fourth Assessment Report (2007)

Intergovernmental Panel on Climate Change (IPCC's) Working Group-I has concluded that global climate-change is "very likely" to have been human-induced. Very likely has been defined by the panel as more than 90% probability of occurrence. This is the very significant conclusion.

Other key findings are given below:-

- Probable temperature rise by the end of the century will be between 1.8°C and 4°C.
- Sea levels are likely to rise by 28-43 cm (probability more than 50%).
- Arctic Summer Sea Ice likely to disappear in second half of the century (probability more than 50%).
- It is very likely that parts of the world will see an increase in the number of heat waves (probability more than 90%).
- Climate-change is likely to lead to increased intensity of tropical storms.

2.3 Accessible Scientific Knowledge

Sustainable development is about making better-informed choices: finding ways to integrate economic, environmental and social dimensions into decisions about the development of natural resources. Governments at all levels require appropriate data and knowledge, on which to base policies and programs. Organisations, large and small, require information that is specialized to their needs. Individuals also need objective information in this regard. In all cases, we all must have access to scientific and community-based knowledge, in an easily accessible format.

3. THE CHALLENGE OF CLIMATE-CHANGE

Over the past decade or so, changes in climate and the accelerated pace of the earth's warming have moved the issue of climate-change to the top of the global agenda. Climate-change is a global problem that requires global action. It requires all of us, governments, industries and consumers, to come together to play our part in dealing with climate-change.

The challenges of climate-change illustrate the complexities of sustainable development. The build up of Green House Gases (GHGs) in the atmosphere-mainly a result of the production and combustion of fossil fuels – could contribute to climate-change by increasing the earth's mean temperature, which many models predict could include: an increase in the earth's temperature, altered precipitation-patterns, rising sea levels and more frequent extreme weather events (tropical cyclones, floods, heat waves, etc).

At the same time, these fossil fuels have been a part of the high standard of living and contemporary life-styles. As such climate change is a crucial sustainable development issue, with implications for the environment, the economy and society.

4. ADAPTATION TO CLIMATE-CHANGE

The conventional approach to understanding climate-change was limited to identifying and quantifying the potential long-term climatic impact on different ecosystems and economic sectors. But this science-driven approach failed to address the regional and local impacts of climate-change and the local abilities to adapt to climate-induced changes.

So, the impact-driven approach gave way to a *vulnerability* approach that assessed past and current vulnerability, existing adaptation-strategies, and how these might be modified with climate change. Kelly and Adger (2000) define the vulnerability as the "ability or inability of individuals or social groupings to respond to, in the sense of cope with, recover from, or adapt to, any external stress placed on their livelihoods and well-being".

Since *vulnerability* and its causes play essential roles in determining impacts, comprehending the dynamics of vulnerability is as important as understanding climate itself.

In climate-change research, vulnerability is used as an integrative measure of the threat to a system (IPCC-2001). Broadly there are two interpretations of vulnerability – as an endpoint or as a starting point (O'Brien et al. 2004), As a starting point, vulnerability is a characteristic or state generated by multiple environmental and social processes, but exacerbated by climate change (Kelly and Adger 2000). Vulnerability provides a means of understanding how impacts of climate change will be distributed, primarily to identify how vulnerability can be reduced, i.e., the focus is on adaptive capacity and systemic properties, and solutions can be found in sustainable development. As an end point, vulnerability is viewed as a residual of climate-change impacts minus adaptations. It serves as a means of defining the extent of the climate-problem and providing inputs into policy decisions regarding the cost of climate change versus cost related to efforts to mitigate GHG.

It is now important that we integrate adaptation issues into core policy and decision-making processes. The question that needs to be addressed is how adaptation to climate variability and change can be more fully integrated into developmental policies and what are the funding instruments for adaptation? The rationale for integrating adaptation into developmental strategies and practices is underlined by the fact that interventions required to increase resilience to climate variability and change generally further the developmental objectives.

Adaptation calls for natural resource management, ensuring food security, development of social and human capital and strengthening of institutional systems. (Adger et al.2003). Such processes, besides building the resilience of communities, regions and countries to all shocks and stresses, including climate variability and change are good development practice in themselves. Hence the inclusion of climatic risks in the design and implementation of developmental initiatives is vital to reduce vulnerability and enhance sustainability.

5. IMPORTANCE OF ADAPTATION

Traditionally, mitigation has received greater attention than adaptation, both from a scientific and policy perspective. One plausible reason for this could be that climate-change emerged as a problem related to the long-term disturbance of the global geo-biochemical cycle and associated effects on the climate system (Cohen et al. 1998).

The focus on mitigation was later reflected in the work of the IPCC, an organisation jointly established by the UNEP (United Nations Environment Programme) and the WMO (World Meteorological Organization) in 1988 to “assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change” (Najam et al. 2003).

However, there are convincing arguments for consideration of adaptation as a response measure. First, no matter how robust the mitigation measures are, a certain degree of climate-change is inevitable due to historical emissions and the inertia of the climate-system (IPCC 2001). Second, while the effects of mitigation may take several decades to manifest, most adaptation activities take effect almost immediately. Third, such measures can be applied on a regional or local scale, and their effectiveness is less dependent on actions of others. Fourth, adaptation besides addressing the risks associated with changes in the climate in future typically reduces risks associated with current climatic variability.

6. UNSC DEBATE ON CLIMATE-CHANGE

In mid April, 2007 for the first time in the history of the UN Security Council a discussion was initiated about the impact of climate-change on international peace and security. The very fact that a climate change debate has now moved to the realm of the UNSC, and the very realisation that the traditional concept of security at UNSC has moved beyond the application of brute diplomatic, economic and military force on to a broader understanding of environmental sustainability, speaks volumes about the emerging threat that climate change poses to the world. The meeting was triggered by a landmark report released last year in London, in which economist and climate change expert Nicolas Stern Warns said that climate change can create economic disaster on the scale of the world wars and the great depression of the 1930, unless urgent action is taken.

7. IMPACT ON PAKISTAN

The UNSC debate and recent IPCC-2007 reports on climate change were of special relevance to Pakistan, as millions of us are living along the Indus, the tributaries of which depend on Himalayan glaciers for water, and a recent IPCC report says that these glaciers are retreating in the face of accelerating global warming. The country banks on thousands of dry-land glaciers, some of them are the world's largest storehouse of frozen fresh water out side the polar ice caps. These frozen sheets of ice are like bank accounts storing snow in winter and releasing water when people living in the lowlands need it the most in the smouldering dry heat of the summer before the monsoon arrives. The water is then channelled to the irrigated plains or is used for drinking purposes downstream. IPCC's recent report says that if the current rate of melting of glaciers continues our Himalayan glaciers may disappears altogether. If the planners in the country fail to build additional water reservoirs and to work towards conservation of glacier ecosystem, the glaciers, natural God-gifted water reservoir may eventually get empty causing catastrophic consequences for the entire population in and around the Indus valley.

Most of the regional experts say that the flow of water from glacier fed rivers in the whole of the Himalaya, Karakoram and Hindukush mountain ranges are on the decline, primarily due to climate change patterns and resultant reduction in the glacial cover in the mountains. Mountain ecosystems particularly glaciers, are considered extremely sensitive to climate change. They generally provide early glimpses of what may occur in the lowlands. According to scientists, the worldwide glacier-melting rate has doubled since 1980. This is not entirely surprising given the fact that 1990 was the hottest decade on the earth during the last 1000 years.

However, the most disturbing point about this whole situation is the sheer lack of awareness and anticipation concerning the conservation of glacial resources in the country. Though Pakistan is known for its rich glacial resources worldwide, and people from all parts of the world come down to catch a glimpse of these wonders of nature, but within the country awareness about glaciers is abysmally low, at both the public and policy level.

Similarly, Pakistan is witnessing an increased frequency of extreme weather events in the recent past. In the years 2001-2003, the country experienced the worst drought of its history. In July, 2001 Islamabad / Rawalpindi received the heaviest rainfall of its recorded history about 625 mm in 8 hours. This caused loss of billions of rupees and death of over 50 persons. In the year 2005, Balochistan received very heavy winter rains which caused devastating flooding in the province. In June, 2006 Northern areas suffered from a historic snowmelt flooding which caused extensive damages to property and loss of human lives. All these events indicated that as far as Pakistan is concerned the climate change has already started affecting us.

8. CONCLUSIONS

After the release of the recent IPCC 2007 Fourth Assessment Reports, there is now hardly any doubt that the global climate change is human-induced. The economic cost of inaction would be too high, and Nicolas Stern has warned that climate change can create economic disaster on the scale of world wars.

Thus integrating considerations of climate change adaptation into policy-processes and decision-making across a range of sectors and scales is critical in managing the impacts of climate change. Efforts to achieve this objective might be undertaken under the direction of the UNFCCC, and through actions supported by the private sector, finance ministries and international financial institutions.

There is a need to develop, disseminate and implement the knowledge, tools and technologies required to effectively engage in an integrated approach. There are several assessment-frameworks in place that can potentially help to reduce vulnerability to climate change. Financing adaptation-activities and costs associated with impacts of climate change is a key concern for the developing countries. Long term, firm and regular support is indispensable.

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DEVELOPING COUNTRIES AND SCIENTIFIC RESEARCH

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1. INTRODUCTION

A finer aspect of human-activity is based on intellectual pursuit to expand the human knowledge relating to this world and beyond. The pursuit relies on the application of scientific methods, based on information and theories, for the explanation of nature followed by practical applications. Scientific research is normally funded by the state. Charitable organizations and private groups including many commercial enterprises also conduct research to improve their products. In view of the meagre resources, some countries in Eastern Europe concentrated only on theoretical aspects of science, producing good work of academic interest, but the countries as a whole lagged behind in progress and prosperity of their people. A balanced approach is, therefore, needed between basic and industrial research for long-term sustainable development.

The developing countries lag far behind in R&D activities as compared to the industrially advanced countries. In fact, their contribution to the world's scientific pool of knowledge is insignificant while their compatriots sitting in advanced countries are making a great contribution to science and technology. Because of the lack of sufficient R&D activity, the Islamic countries, some of them being very rich in natural resources also belong to the category of developing countries.

2. APPLIED AND BASIC RESEARCH

Contrary to basic research, applied research may entail new knowledge-creation and applications of existing knowledge, but it is addressed towards clearly defined problems (usually but not always of companies or industries), and leads to products or services that may be exploited in the near-term. Applied research is carried out to find practical solutions for current pressing needs. In essence, the problems of society, in general, and the industry, in particular, are assessed and addressed by applied research, which results in the improvement of a product or a system. This research is primarily done because the performer expects to benefit from it in some direct way, such as through a future business return or direct financial interest [1].

Basic research (fundamental or pure research) is essential for the advancement of knowledge and theoretical understanding of physical phenomena. It is exploratory and conducted without any practical end in mind. However, it may have unexpected practical applications, which may lead to further investigations termed as applied research. Obtaining funding for basic research is difficult, as there may be no short-term practical gains in sight. Traditionally, basic research activities are followed by applied research leading to the developments into practical applications. However, fundamental discoveries may be made alongside the work intended to develop new products. An important aspect of applied research is the industrial research and development activity, in which scientific and engineering knowledge is used to create and market new products, processes, and services. The R&D encompasses several different activities that can occur in any order. Basic research is aimed purely at the creation of new knowledge with the purpose to create new understandings of physical phenomena. The applied research has practical applications but not entirely with commercial benefits. Boundaries among different research activities are not well-defined and the way these have been organized and linked, have changed with time.

3. EXCELLENCE IN SCIENCE

It is the industry that derives maximum benefit from the applied research to improve the quality of their products and services. Industry began in its present form during the eighteenth century, aided by the technological advances, and it has continued to develop. High standard of living and quality of life in the developed countries may be attributed primarily to their highly-developed industry. Industry is, therefore, the key-sector in providing amenities of life at affordable prices. The emergence and growth of industrial research and development during the twentieth century, ranks as one of the most important economic development of modern times.

Technological innovation stimulates economic growth where business enterprises are at the core of the innovation. Industrial research, conducted and substantially funded by private enterprises and business firms has played a key role in the American prosperity. It greatly affected the results in both world wars, and possibly to the ending of the Cold War. The American industrial research in the late nineteenth century began when a significant amount of science and technology was applied to industry. During this period, science-based industries in chemicals, electricity, and telecommunication began to emerge.

4. DEVELOPMENT OF SCIENTIFIC ACTIVITIES

Investment in S&T and infrastructure over the past 15 years has resulted in more and broader excellence in science. Once limited to a few advanced countries, scientific capacity can now be found in more than 50 countries of the world.

Based on their scientific achievements, different countries are categorized as follows [2]:

i. Scientifically-Advanced Countries (SAC): 22 countries with scientific capacity well above the international mean.
ii. Scientifically-Proficient Countries (SPC): 24 countries which also have positive

standing in scientific capacity as compared to the rest of the world.

iii. Scientifically-Developing Countries (SDC): 24 countries with some features of scientific capacity and spending but their scientific capacity is below the international mean.

iv. Scientifically-Lagging Countries (SLC): 80 countries with little data indicating scientific capacity.

The scientifically-advanced countries account for 90 to 95 percent of all research and development spending, an estimated $450 billion per year, including both publicly and privately-funded R&D. Although there have been small increases in the percentage of R&D spending in developing countries, estimates made in the 1990s indicated a decreasing trend.

Legal boundaries are a ready method of classification, relying on nation-states as a grouping for scientific activity but it does not represent the whole picture. Often, a world-class capability may exist in what would otherwise be called a developing country. An example cited by scientists, is mathematical research in India, which is considered among the best in the world. Other examples are: China for world-class seismology research; the Philippines for leading in rice research and Chile for astronomy. In these cases, expertise grew out of deliberate government policies to support S&T capacity-building, actions by international development organizations, unique geography, ecology, history, or social conditions in a country or the presence of special research equipment and laboratories. An examination of fields of specialization shows that the position of a country on a list of scientifically-developing or lagging countries, does not always reflect these pockets of excellence [3].

Scientists from developing countries, often work and study in the advanced countries, leading to links with their counterparts. The scientists from developing countries working in advanced countries do not necessarily represent a net “brain-drain” as they may retain close ties with the laboratories in their countries of origin, help to channel resources there, and frequently train young scientists from their home country. While a large percentage of these scientists choose to reside in an advanced country, for some countries, an increasing number returns home to establish labs or otherwise enrich existing scientific research [4].

4.1 Categorization on the Basis of Scientific Capacity

The numerical value of the capacity-index was used to bring countries in a particular order and group them into four classes of S&T capacity. The following sections provide a description of the four groupings of countries in term of S&T capacity that emerges from this index. In each section, the combined S&T indices for the nations in that class, are represented graphically on the charts.

i. Scientifically-Advanced Countries: The 22 nations having the most positive ranking in scientific capacity are termed scientifically-advanced countries (SAC).

They show a positive value on the index, meaning that they all have greater S&T capacity than the international mean. These countries generally have capacity in all major areas of S&T and they are responsible for 86 percent of all scientific articles published in internationally-recognized journals, and they fund between 85 and 90 percent of the entire world's R&D[5], (Figure - 1).

ii. Scientifically-Proficient Countries: The next group of 24 nations termed as scientifically-proficient countries (SPCs) possess an overall S&T capacity index value at or over the international average, but they are not as uniformly capable as the advanced nations. Values for some capacity components may exceed the international average, while others may fall below the mean. Some of these countries display world-class strength in particular areas or subfields of science. Investments in the infrastructure and R&D required for building a science-base, are showing results. Some countries, notably Spain, Brazil and Poland, have experienced significant gains over time in their roles in international S&T, (Figure - 2).

iii. Scientifically-Developing Countries: The next 24 countries are termed scientifically-developing countries (SDCs). Although these nations have made some positive investments, reflected in the fact that some components of the index exceed the international mean, their overall scientific capacity is below the world's average.

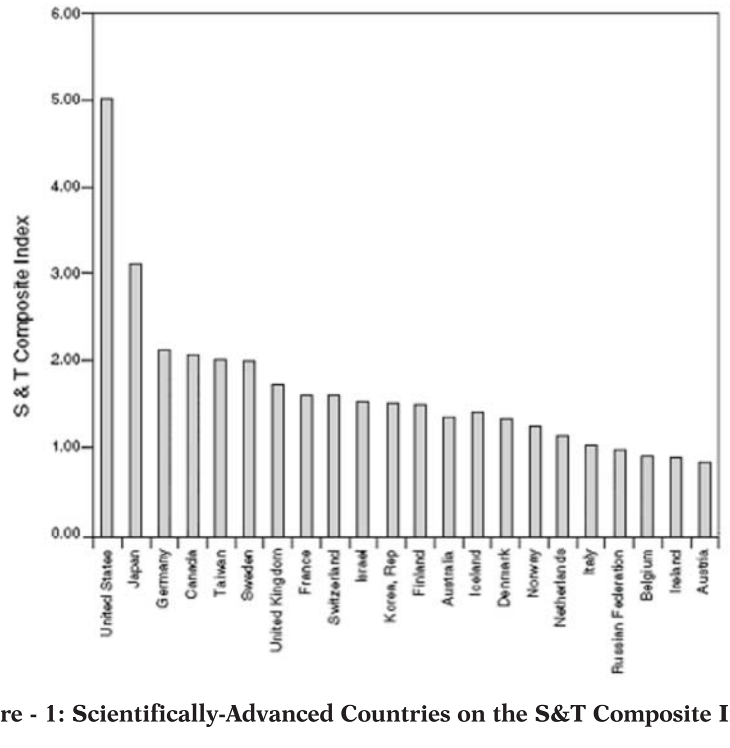

Figure - 1: Scientifically-Advanced Countries on the S&T Composite Index

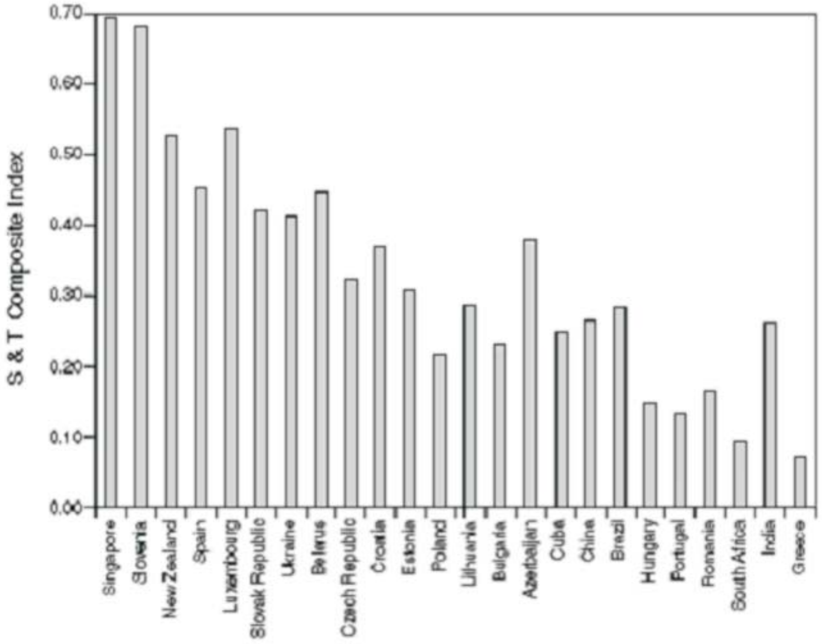

Figure - 2: Scientifically-Proficient Countries on the S&T Composite Index

The investments that have been made, however, do allow these countries to participate in international S&T. These countries are seeking to invest further in science and, in some cases, they have good capabilities which attract international partners. Several of these countries are poised to move into the "proficient" category but factors such as overall GNP or other infrastructural factors are keeping these countries from being considered among the scientifically-proficient countries. This is the case, for example, of Latvia, Argentina and Chile, (Figure - 3).

iv. Scientifically-Lagging Countries: The remaining 80 countries assessed in this index are in the category of scientifically- lagging countries. They fall below, and in most of the cases, well-below the international mean for all the components of the S&T capacity index. In many cases, these countries have little or no capacity to conduct international-level science. Only Malaysia, Uganda, Thailand, United Arab Emirates, Saudi Arabia, Iraq and Guinea-Bissau, have some positive S&T activities. In a number of cases, scientific capacity that does exist has resulted from a natural or geographical resource located in these countries. In other cases, problems with infectious diseases, natural disasters or pollution, means that international partners are interested in helping these countries but they often find little indigenous-capacity to tap for collaborative projects. This may offer opportunities for capacity-development over time.

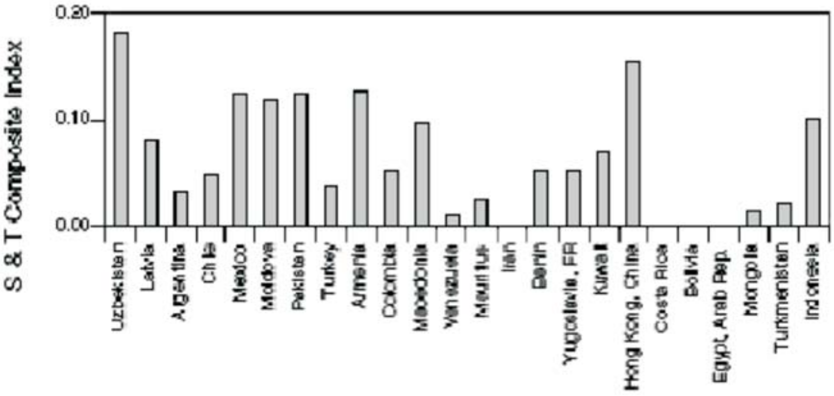

Figure - 3: Scientifically-Developing Countries on the S&T Composite Index

5. INTERNATIONAL INTERACTION AND LINKAGES

Patterns of cooperation or interaction do not change quickly, as shown by Okubo and others in previous studies. Scientifically-advanced countries share similar research and development profiles that stimulate interaction among them, resulting in collaboration in all major scientific fields. Developing and lagging countries, in contrast, are more likely to specialize in a few areas of science, often in the fields that relate directly to some national need, like disease-control. Among new scientifically-advanced countries, such as South Korea, the patterns of cooperation still look like those of developing nations. The majority of their international interactions are with other Scientifically-Advanced Countries, rather than extending to scientifically-developing and proficient countries [6].

6. R&D IN DEVELOPING COUNTRIES

Political stability and economic prosperity are described as the basis for the development of science and technology in the early Muslim World, where the Islamic religion was the main driving force. After an initial period of scientific activity, innovation in science and technology in the Islamic World began in the 12th century and ended in 16th / 17th century. This is the period when the Islamic empire rose to become a world power. Science and technology flourished with the political stability and enlightened state policies and patronage. The decline began with the religious extremism against science, political instability and economic deterioration, soon followed by the decline of science and technology in the Muslim states [7].

Muslim countries, many of them called "Oil Producing Countries" where natural resources are plentiful, the people have a high standard of living but they are heavily dependent on the import of consumer goods and high technology utility items from the technically advanced countries. Their raw materials and natural resources are being sold to other countries without value addition and the imported high technology items consume their natural resources with a lot of exploitation.

Sustainable development for a country is most desirable for the progress and prosperity of it's people. There are different parameters for the research and development activities, which play an important role for the development of a country. To promote R&D efforts in developing countries, particularly the culture of research and development, a measure of "merit" and "high-quality" needs to be built up. The countries where research and development have been well-cared for, consistently over a long period, are the most powerful and economically well advanced. Their people have a very comfortable life with high-standards of living and better quality of life. Where research and development activities are lagging behind the people have a poor quality of life.

Apart form natural resources of a country, the most important resource is "human resource". Even if the natural resources are limited, but the human resources well developed in the field of research and development, the countries are well-advanced and their people enjoy a high-standard of living. The noticeable example is of Japan and in the South Asia of Singapore, Korea, Malaysia, Taiwan and Thailand. To strengthen the R&D in the developing countries, first of all it is necessary to improve their economic conditions through mass production of low-technology consumer goods, initially by the R&D efforts, thus, gradually improving job opportunities and earning power of their people resulting in a better standard of living of the common man. There should be a stress on higher education, particularly related to science and technology to boost research and development activities as a vehicle of high value addition to local products as is done in USA, Japan and in most of the West European countries. Here exclusive stress on mass literacy through primary education is not optimally useful but it is the necessary requirement for higher education supported by a strong culture of quality research and development, which is essential for proper high-tech developments. Here there is a need to emphasis the education and training of skilled manpower which is an essential part of R&D activities. Higher education backed by a strong research and development activity for the production of high technology items could also be a model for economic development of Pakistan. A balanced and systematic attention to all ladders of education in science and technology is the most appropriate strategy for Pakistan.

A better approach for the developing countries like Pakistan, to enhance their prestige in the advanced countries, is to achieve sustainable economic stability, which in turn contributes to progressive strength of a country. Then a move towards high quality of scientific research and development would follow leading to long term progress and prosperity as has been achieved in the history of advanced countries like USA, UK, Germany and China.

7. COLLABORATION BETWEEN ADVANCED AND DEVELOPING COUNTRIES

International collaboration for building scientific and research capacity in developing countries is apparently producing positive results and it has started building international-level scientific and research capacity in developing countries. As a result of collaborative research between the scientists of advanced and developing country, there has been an increase in the number of scientific papers published jointly by the scientists from these countries.

International scientific collaboration in R&D is growing as a percentage of all scientific activity. Researchers from developing countries are benefiting from this activity. The collaboration takes a number of forms including sharing of research data, joint experimentation, conferences and meetings. Problems of worldwide interest, such as global climate change or infectious disease control, can be a primary motivating force behind the collaboration, followed by the location of specific resources, unique expertise, and the location of large-scale equipment [8].

In industrially-advanced countries, S&T has been shown to contribute significantly to economic growth and productivity enhancement. Similar benefits for developing countries need to be demonstrated with a clear theoretical or quantitative link between S&T investment and development in developing countries. Many policy-makers think that investment in S&T will be beneficial. For example, this has occurred in Japan and more recently in South Korea, India, and Brazil, suggesting that S&T investments can stimulate economic growth. The advanced countries have a high number of collaborations and interaction with Middle Eastern countries. Egypt, Turkey, Kuwait, Saudi Arabia, Kenya, and Iran have 30 to 49 percent of their co-authorship with the scientists of advanced countries. The high number of linkages can be attributed to the presence of pockets of excellence connected largely to particular social and natural conditions within this region. The high number of collaborations between the United Kingdom and the countries of this region is also an evidence of Britain's continuing interaction with its former colonies. Similarly Algeria, Tunisia, and Morocco each have over 70 percent of their collaborations with France.

8. INTERNATIONAL EFFORTS

European Union's massive research and development programme (Seventh Framework Programme) launched on December 22, 2006, aims to increase the Union's growth and competitiveness, recognizing that knowledge is the greatest resource of Europe. With funding of more than 54 billion Euros, it is the largest investment to date on the European level in a common research and development program over a seven years period from 2007-2013.

In order to harness benefits from the expertise of other countries the scientifically advanced countries spend a portion of their budgets on international interaction or collaboration. This ranges from 5 percent for the U.S., which is the lowest figure amongst industrially advanced economies, to about 25 percent in the case of other advanced economies. Allocation of funds is based on a peer-reviewed process, with funds granted to scientifically-excellent research, regardless of the partnering arrangements made by national scientists. The level of collaborations differ spending viz the earmarked amount for foreign research-aid programmes, estimated at approximately $865 million a year for the major donor countries. Funds dedicated to collaborative research amount to about $1.4 billion per year. Very little is spent on collaboration with scientifically less developed countries. United States is the largest in gross-expenditures on collaborations, at about $600 million per year, mainly with advanced countries. The European Community reports that they spend about 5 percent of their public funds or approximately $122 million per year on collaborative research with other countries outside the European Union. The Union spend the highest proportion on collaborations with scientifically developing countries, mainly in the "research-for-aid" category rather than being true collaboration. Japan also commits public funds for these types of collaborations with an emphasis on engineering and standards-setting projects. These programmes have two-way benefits, on the one hand it helps the needy countries to come up to the developed level and on the other it helps the advanced countries to benefit form the talented scientists of less advanced countries. The dilemma is that the developing countries are not proactive and aggressive to collaborate with the advanced countries and advance the pace of research in their countries. This aspect should be catered for.

Information and communications technologies have played an important role in encouraging international interactions. After some initial interaction, scientists use the full range of information technologies and research, to continue formal or informal collaboration. The internet has become an effective mechanism for communication and information exchange. The proliferation of Internet access in developing countries has helped to cut costs and reduce time spent in communication and information exchange. Telephone calls, facsimiles and postal or courier services have become secondary to the internet. Although the Internet has revolutionized communication and information exchange, it does not substitute for the face-to-face interaction to discuss ideas or work on experiments. Personal interaction is the key to many capacity-building and research activities that require the learning of physical skills and exchange of ideas. However, currently the system of video-conferencing is compensating to some extent the face-to-face discussions needed in scientific research [9].

9. SUGGESTIONS AND CONCLUSIONS

In many cases, international interaction is having a positive impact on S&T activity, which may not automatically result in a high-quality research and windfall of benefits. However, it is questionable that whether the knowledge created is relevant or S&T capacity, built as a result of international interaction, is relevant to the real needs of developing countries. In some cases, the topics of joint R&D depended upon the interest of the scientists from advanced country. The scientists from developing country sometimes choose research-problems that have more appeal to international partners than any real value to their own country. Scientists from a developing country may also be motivated to participate in international interactions with an advanced-country researchers, in order to elevate their status and standing in domestic science and technology and policy circles.

Research that is most likely to build capacity arises out of complementary-research interests of the participating scientists. The shared project should be of interest to both participating countries, either side contributing something (expertise, equipment, data bases, laboratories, etc) to the activity. If possible, proposals should be drafted jointly and any decision about the purchase of instrumentation be made jointly. Information and communications technologies should be used to ensure transparency of activities and continuous updates on progress. Project parameters should be determined ahead of time, built into the proposal, accounted for by all teams and collected regularly by all parties to ensure objective evaluation and feedback into the ongoing activity. Finally, the presence of a few dedicated personnel can positively affect the success of an interaction. Studies have shown that such individuals can play key roles in mustering the necessary resources and expertise to launch and sustain collaborative R&D projects.

While the fact is that developing countries have a low level of R&D, both at the international level as well as at the national level, in terms of utility of applications. The main reason is a poor levels of education and R&D culture in these countries. As a result, the benefit of indigenous R&D developments in science and technology are not available to the people of these countries. Huge money is spent by these countries on the import of high-technology products, some necessary for essential needs and some as luxury items, which results in perpetual poverty in these countries. There are several other factors that add to the dilemmas of these countries. Some of these are:

- Poor literacy-rate and lack of higher-education and quality R&D human-resource with reference to science and technology.
- Lack of dedicated individuals with leadership quality imbibed with national spirit to work for the uplift of the country.
- Lack of political will for focusing on education and R&D in science and technology.
- Poor salary-structure and poor environment for S&T.
- Poor funding and budget-allocations for education, and S&T.
- Poor quality education at all levels from schools to the university.
- Relatively large malpractices and lack of dedication of scientists and educationists.
- Lack of international interaction in R&D.
- Lack of provision of financial support to scientists to participate in international conferences.
- Poor facilities for S&T infrastructure.
- Brain-drain due to poor financial emoluments, scientific environment and

quality of life for bright young scientists.
- Lack of mutual cooperative spirit among the scientists and scientific organizations.

Having listed some of the major factors causing dilemmas in R&D in science and technology of developing countries, the important matter is how can we overcome these difficulties and lead to the progressive path to benefit to the society. Based on the experience of Pakistan faced with some of the above-mentioned difficulties we would say that in some ways the developing countries can still get on the path of progressive development which will contribute to the welfare of people in a systematic and continual manner. There may not be shortcuts to a gradual and systematic development, but it could be possible to overcome these difficulties with optimum pace of development in terms of economy of time and financial input. Some of the suggested ways to develop are recommended as follows:

- To support the dedicated individuals and institutes trying to serve with quality and real work as indicated through their past performance.
- To develop cooperative projects on the regional-basis; to pool human and financial resources of developing countries. There are several successful examples from the advanced countries of Europe, such as CERN in Geneva (Switzerland), which is a world renowned centre for research in physics and related sciences.
- In developing countries focus should be on value-addition to the items of their natural resources; for example, the agricultural items/products if the economy is agricultural. The export of raw-materials should be minimized and focus on R&D, which adds value to such raw-materials.
- There should be a focus on developing minimum and critical sized groups of highly-professional R&D scientists, to assess the purchase of expensive importable items so that public funds of the country are utilized with minimum of wastage.
- Maximum investment in regular and sustainable manner should be made by the government in higher education and R&D in the S&T sector.
- A balanced emphasis should be made in planning of basic and applied R&D, so that a systematic flow from basic research to applied research to pilot scale production and then finally to the industry for the development of products of international quality standards and leading to the export earnings.

With this strategy in mind, it is hoped that the dilemma of basic and applied research in developing countries may be harmoniously resolved.

10. SUMMARY

Research and development (R&D) in any area is the life-line for a successful outcome and for science and technology (S&T) this is more than true. This chapter gives some brief description of R&D on the basic and fundamental level and applied level of some countries. It explains that where R&D in S&T is strong, the countries are enjoying a higher standard of living, and where R&D is poor, such as the developing countries, the standard of living is poor as well. The dilemma of developing countries has been described where basic and applied R&D in S&T is poor. The chapter opines that a balanced approach between the basic and applied R&D is essential for the progress of the developing countries. The notion that basic research is not needed in the developing countries is not supported as the applied research and industrial products of high-quality are the result of a strong basic research, necessary for good applied R&D, as well as for good industrial products. Some suggestions have also been given, which can be useful for an R&D strategy for the developing countries to go on a progressive up-going slope.

11. ACKNOWLEDGEMENTS

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EPILOGUE

The debate on basic versus applied research in science and technology, for the purpose of sustainable socio-economic development, has been going on for a long time. Whereas the rich and industrialized nations have been successful in addressing & resolving this dilemma to a large extent, many poor and developing countries are still entangled in the intricacies of this seemingly bothersome policy-challenge. Nevertheless, the challenge is genuine and valid for the poor and developing societies, and needs a satisfactory solution. The contributing factors, commonly found in the developing societies and leading to this policy-dilemma, are resource-constraints; implicit political and economic risks; weaknesses in coordination; knowledge-inadequacies; social resistance, international influences and stakeholders' rivalries. Dilemmas and intellectual uncertainties are not only the sad consequences of these contributing factors, but they are also the dreadful precursors for the perpetuity of the state of indecision and dilemmas, which prevent nations from taking the right steps in the right direction and at the right time. Indecision regarding basic or applied research is no exception to this unfortunate and pernicious phenomenon.

Although the decisive importance of science and technology, based on sound foundations of quality-knowledge, has widely been recognized by the nations across the globe, yet many developing countries tend to sideline scientific research because of their other priorities and pressing needs. This creates an ever increasing knowledge-gap between the developed and the developing nations. The pursuit of prosperity by the poor countries thus becomes no more than chasing a mirage. The developing countries must not allow themselves to become the victims of such dilemmas and should be able to set aside the fears and risks, by taking the right decisions with the support of sound and quality-knowledge. This book very aptly attempts to address such aspects and provides highly-considered knowledge-based opinions of a variety of experts on various aspects related to the question of basic or applied research. The material presented in the book will, definitely, embolden the strategists and policy-makers in the developing countries to arrive at appropriate decisions, in their best national interests, and will consequently break the inertia prevailing in the domain of science and scientific research in these countries.

This book draws richness and authenticity of its contents from the considered opinions of the contributing authors who are reputable scientists, engineers, educationists, researchers, policy-makers, economic-planners and administrators of S&T organizations, including some prestigious foreign universities. The representation from academia, R&D establishments, NGOs, education and research-policy organizations, etc., supporting their arguments with examples from case studies, has added additional benefit to the present endeavour to seek a more or less clear answer to the problems arising out of the dilemma of basic versus applied research. As a result, the overwhelming opinion expressed in the book trickles down to the conclusion that each society should adopt an optimum mix of basic and applied research, after accurately identifying and assessing its needs and priorities. However, this is not an easy task for the underdeveloped nations, who have limited competencies and capacities to make such assessments. Adequate and high-quality knowledge is an essential prerequisite for such competencies and capacities. Thus, quality-education must be ensured, so as to acquire and utilize quality-knowledge in the developing countries. As the creation of knowledge is an expensive affair, the developing countries must cooperate with the developed nations for acquiring quality-knowledge. The role of the governments of the developing countries, thus, becomes extremely important. They must establish centres of excellence and provide them with adequate and assured funds for providing world-class scientific education and conducting meaningful research in basic and applied sciences

The arguments about basic versus applied research have largely assumed a multifaceted approach in the present discourse. It is logical that both basic and applied research in science and technology are important, the former being frequently the source of the latter. Economic uplift depends largely on applied research; however, the strength of applied research mostly depends upon the competency acquired through basic research. The fundamental requirement of the developing nations for their socio-economic progress is the strength of both basic and applied research, which will also serve to build the reservoirs of quality-knowledge for them.

Exhaustive discussions of the main theme have been presented in several chapters of the book. All the pertinent aspects of basic and applied research, knowledge, sustainable socio-economic development, role of various stakeholders, international cooperation and networking, social and political parameters and several others, have been lucidly explained. It is fairly easy for the interested readers to synthesize the arguments, conclusions and correlations given in the book, to arrive at workable-solutions. However, a related area of importance, dealing with feasibility of the proposed workable ideas in the developing societies, needs more attention and further discussion. It is a general observation that the implementation-capability of a large number of poor and developing countries is weak, which results in underachievement of their national goals. In a way, this aspect also contributes significantly towards the creation of dilemmas, such as the one taken up in the present compilation. It may be worthwhile to consider initiating a related study on the interrelationship between the dilemma of basic versus applied research and the practicability-aspects confronting the poor and developing nations.

The Future: The content of this book may provide useful inputs for the proposed investigations on practicability aspects, related to basic and applied scientific research for sustainable socio-economic development in the developing countries The most pressing issues facing the developing countries in the twenty first century include: population explosion; environmental degradation; clean- energy deficiencies; quality knowledge and education; research-industry relationship and North-South cooperation. These fields could be taken up, in conjunction with competencies and capacities for implementation of specific and concrete recommendations for the developing countries in the aforestated study. It is hoped that the contents of this book will prove to be of some assistance to the developing societies, and their science and technology establishments, paving their way forward to promote basic and applied research for their much cherished socio-economic progress.

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Author Name	Chapter Title
A.H. Zakri	Balancing Basic and Applied Science and Research: A Dilemma for Developing Countries
Abdullah Sadiq	Role of Science and Education in National Development: Basic or Applied Research - Dilemma of Developing Countries
Aijaz Karim	Developing Countries and Scientific Research
Anwar Nasim	Basic and Applied Research: Role in Economic Prosperity
Balakrishna Pisupati	Balancing Basic and Applied Science and Research: A Dilemma for Developing Countries
Hameed A. Khan	Creation & Utilization of Knowledge: Relative Importance and Inherent Limitations of Developing Countries
Hasibullah	Capacity-Building and Networking for Basic and Applied Research: Importance of International Collaboration
Ikram Abbasi	Basic and Applied Research: Role in Economic Prosperity
Irfan Hayee	Creation & Utilization of Knowledge: Relative Importance and Inherent Limitations of Developing Countries
Ishtiaq A. Qazi	R&D in Developing Countries: Case for Applied Research
Jean-Pierre Revol	Fundamental Research: The Engine of Innovation - Example of Particle Physics
Kausar A. Malik	Goal-Oriented Research: A Recipe for Economic Development
M. Iqbal Choudhary	Development of Institutions: A Key to S&T Capacity-Building in South
Malik Irfanullah Khan	Developing Countries and Scientific Research
Mazhar M. Qurashi	Research and Socio-Economic Development: A Comparative Analysis of Pakistan, Malaysia and India

Mazhar M. Qurashi	The Mainsprings Driving Research, Discovery and Innovation
Mustanser Jehangir	Putting One's Money Where the Mouth is
N.M. Butt	Developing Countries and Scientific Research
Parvez A. Butt	Linking Industry and Research
Qamar-uz-Zaman Ch.	Climatic Change and Sustainable Development
R.J. Peterson	How to Develop Scientists in the Developing World
Reinhard Brandt	Search for a New Kind of Nuclear Energy: Suggestion for a Broad International Collaboration in Basic and Applied Research
Riazuddin	Can Applied Research Survive without Basic Research?
Riffat M. Qureshi	Putting One's Money Where the Mouth is
Sadia N. Swati	Creation & Utilization of Knowledge: Relative Importance and Inherent Limitations of Developing Countries
Shaukat Farooq	R&D in Developing Countries: Case for Applied Research
Tajammul Hussain	Research and Socio-Economic Development: A Comparative Analysis of Pakistan, Malaysia and India