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International Centre for Theoretical Physics

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Abdus Salam on Science and World Development

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Like Albert Einstein and a handful of other scientists, Abdus Salam can enjoy the quiet pride that comes from seeing a major theory that was first neglected because of its innate difficulty later vindicated by experimentation. His achievement is to have predicted that the so-called weak force, which drives every neutron to decay into a proton plus an electron, can be "unified" with the far more familiar electromagnetic force that operates between charged particles. In 1979, 13 years after Salam suggested this possibility, he shared a Nobel Prize with Steven Weinberg and Sheldon Glashow, who had worked on the theory independently. Discoveries at CERN and at the Stanford Linear Accelerator Laboratory proved them correct.

The author of some 250 papers on elementary particles, Salam has, in John Ziman's words, *"played a major part in every act of the unfolding drama of the*
discovery and understanding of the
discovery and understanding of the primary entities of quantum physics." His arrival at the center of 20th-century science can be attributed in part to his father's determination that he should become a scholar - and to a bizarre piece of luck. Born in 1926 at Jhang in what is now Pakistan, Salam took a mathematics degree at Lahore before winning an extraordinary new scholarship to Cambridge, England, in 1946. A pro-Britain Indian politician had created five scholarship for overseas education, financed by money that had been collected to purchase armaments for the war just ended. But the politician promptly died, the project was canceled, and the four other putative students never made it.

After taking his Ph.D. at the Cavendish Laboratory, Salam returned to Pakistan at the Punjab University. He soon realized that there was virtually no opportunity for doing research, journals were non-existent, and the nearest fellow physicist was in Bombay - which by that time was in another country. Faced with the agonizing choice of physics or Pakistan, Salam returned to England and in 1957 was appointed to the theoretical physics chair that he still holds at Imperial College, London.

Salam's unhappiness at having to leave his homeland prompted the development that has brought him particular fame; his singlehanded creation of the International Center for Theoretical Physics in Trieste, Italy, which opened in 1964. A *"bustling railway junction of the intellect"* (Ziman's words again) for Western scientists, the center also provides unique facilities for researchers who come from the developing countries to pick up the latest ideas and techniques. While fulfilling many other commitments to the causes of science
and peace, Salam commutes regularly
and peace, Salam commutes regularly between Trieste and London. He was interviewed there on November 23 by Bernard Dixon, European editor of *The Scientist*, to which Salam is an editorial consultant.

Q: How do you see the role and standing of the scientist in society today?

SALAM: I tend to echo Plato's approach here. I believe that scientists should play a far greater role in public affairs. There are two reasons for saying this. First, science and scientific ideas have been and are enormously powerful forces capable of promoting human welfare, and they should not be underrated, as so often happens these days. Second, we have to accept that it is we scientists who have created many of the world's problems. Think of the relationship between antibiotics like penicillin and the population explosion, between nuclear physics and nuclear weaponry. Whatever they require in political terms, these problems will not be solved *without* science.

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Q: You feel that science gets the blame, but not the public regard for its positive value? Why should this be so?

SALAM: Because scientists and their various organizations have not been sufficiently assertive or sufficiently active in proselytizing on behalf of science. Consider the enormous influence which Third World scientists could wield over the cultural development of their countries, but which the do not always recognize. The educative effect of the cultivation of science even by non-scientists can be sensed particularly strongly in countries that have recently embarked on the development process. I am fond of telling research workers in those areas that the victories they win can demonstrate the triumph of rationality and empiricism. The search for objectivity, the avoidance of exaggeration, the discipline of testing hypotheses through experiment and observation - all of these have spillover effects, helping to lend balance to the mental outlook and culture of these societies.

Third World Academy

Q: Was this the basis for your initiative in founding the Third World Academy of Sciences in July 1985?

SALAM: Yes, indeed, but there was a wider purpose too. I have often reflected on the great Islamic physician Al Asuli, who lived nine centuries ago and who compiled a pharmacopeia which he divided into "Diseases of the Rich" and "Diseases of the Poor". If Al Asuli were alive today, he would make the same distinction - between the threat of nuclear annihilation inflicted on humanity by its richer half, and the malnutrition and associated disease which affect the world's poor. But he might also observe that these twin afflictions have a common cause: an excess of science and technology among the rich and a lack of science and technology among the poor.

Q: How does the Academy hope to alter this imbalance?

SALAM: Our diagnosis is that mankind lacks real political determination to harness science and technology for economic development, determination to harness science and technology for economic development, and that research expertise and capability are unevenly distributed in the world. Although individual scientists have been concerned about these issues hitherto, with the establishment of the Academy they have gained a forum that can be used in mobilizing a worldwide endeavor. One of our principal aims is to strengthen science in Third World countries, so that young research workers there who long to participate on equal terms with Western colleagues will be able to do so. Through our research grants to Third World scientists, South-South exchange fellowships between developing countries, and grants for researchers to spend a year or so in a laboratory in the developed world, I believe we are already doing something to enhance the quality of Third World science. Another major theme is to promote the direct application of science for economic development. It is to wealth-producing sciences of physics and geophysics, and the survival sciences of medicine and molecular biology, that less developed countries will have to turn if they are to surmount their pressing problems.

Linking Science, Development

Q: If the potential of science as an engine of economic growth and development is so striking, who have these countries not seized the opportunity for themselves?

SALAM: It's simply a failure of national ambition. Countries the size of Turkey or Egypt, for example, and indeed my own country of Pakistan, do not have science communities geared to development because they apparently do not *wish* to have such efforts. And our lack of ambition and confidence about science is sometimes coupled with a sense of inferiority and even hostility towards scientific developments.

Q: Are there *any* developing countries you believe to be taking the right path in linking science with development ?

SALAM: From my experience at Trieste, I would say that there are just five that, whatever their economic and other difficulties, clearly value science and have made major decision to invest in science and technology on a proper scale: China, India, South Korea, in science and technology on a proper scale: China, India, South Korea, Argentina and Brazil. The rest of the Third World, and even the aid-giving agencies of the U.N. and the richer countries, still appear to perceive science as a marginal activity.

Q: What is your view of efforts to help the less developed countries through technology transfer from the West, particularly of what is sometimes called "appropriate" or "relevant" technology?

SALAM: There are obviously examples of the successful spread of particular technologies from the North and their establishment in the South. But I am appalled that many organizations seem to think that technology is all that matters. *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. Sometimes I am even driven to suspect the motives of some of those who try to sell us technology alone. As for the slogan of "relevant" science, this has done considerable harm by stifling the growth of other areas of science, in their richness and variety.

Q: But surely the Third World simply cannot afford to train and retain large teams of scientists working at the frontiers, like their colleagues in richer parts of the world?

SALAM: The truth is that developing countries cannot afford *not* to do this. There is, of course, an acute shortage of staff. Turkey, for example, has some 7,000 Ph.D. scientists (apart from clinical personnel). That is about one-tenth of the number found in the United States, Japan and Europe in relation to population size, and is insufficient to create the critical mass which science as a communal activity requires if it is to thrive. But again I want to emphasize that this is not the entire problem. Another significant difference is that even high-level scientists in Third World countries have not been allowed to play a role, alongside professional economists, planners and technologists, as equal and valued partners in building up their nations.

Funding for Science

Q: Given the more obvious practical

Q: Given the more obvious practical demand on their finances, how much money should developing countries be putting into science?

SALAM: I believe we can compute a realistic figure by comparing science with those other demands. Consider some of the disparities between budgets in countries at opposite ends of the development scale. In round figures, the North spends 4.8 percent of its GNP on health, compared with 1.5 percent for the South. On education, the North spends 5.2 percent of GNP and the South 3.8 percent of GNP. For defense, the figure is identical: 5.6 percent. But when we look at science and technology, there is a whole order of magnitude difference. The North allocates 2 to 2.5 percent of GNP, compared with 0.2 percent for the South.

When we look at the breakdown of spending in the North, we find that funds equal to 4 to 10 percent of a country's educational budget are spent on basic research - about the same as on applied research and twice as much as on R&D in technology. So, assuming that an ifrastructure for basic and applied research exists, I propose that Third World countries should allocate to basic research an amount at least equal to 4 percent of their educational budget. A similar amount should go into applied sciences, and twice the amount to technological R&D.

Benefits of Basic Science

Q: But even in the more privileged parts of the world, countries such as Britain are putting increasing emphasis on science that promises fairly immediate practical rewards. How do you feel about this?

SALAM: I am not at all happy about policies of that sort, which overlook so much that has been of both theoretical and practical value in the emergence of modern science. Just reflect for a moment on Jim Watson and Francis Crick's DNA double helix - the greatest discovery in molecular biology, which is now being harnessed through what we call biotechnology. This occurred at Cambridge, while I was there in 1953, in the world-famous Cavendish Laboratory - which specializes in *basic physics* - and was made with modest Laboratory - which specializes in *basic physics* - and was made with modest equipment by men trained in the use of X-rays.

Think, too, of Walter Gilbert, who left me after completing his Ph.D. in theoretical physics in 1956 with me and who, when I next met him in 1961, confessed rather sheepishly that Watson had seduced him into studying bacteria. He later received a Nobel Prize for his elegant technique of deciphering the genetic code, and then resigned his Harward chair to establish the biotechnology company Biogen. (He since has returned to Harvard.)

Q: And the lesson behind events of that sort?

SALAM: The first lesson is the mutuality and interplay of science and technology, which go hand in hand. The second lesson is the premium placed on excellence and brain-power in some societies - but which, again, I emphasize, is not found in many parts of the world whose backwardness means that there is most to gain from the support and application of science.

Putting the message the other way around, if we in the less developed world wish to defend our culture and our civilization, and to live honorably in the 21st century, we must ensure that we do not lose out in new physics, physics-based technology or biotechnology. We have to ensure that our scientific enterprise in these disciplines is of the highest quality - as the South Koreans have done - and that it maintains living contact with international science.

Q: Some people still have difficulty in appreciating the importance you attach to basic physics in relation to Third World development.

SALAM: But physics is the science of wealth creation *par excellence*. If a nation wants to be wealthy, it simply must acquire a high degree of expertise in both pure and applied physics.

Let me give just one example. Last year Zhau Zhong Xian and his colleagues in Beijing made some very important discoveries in high-temperature superconductor science, extending the work of the IBM workers in Zurich. As you know, J. Georg Bednorz and K. Alex Müller were awarded the Nobel Prize for their discovery and the U.S. government is currently spending $55 million for discovery and the U.S. government is currently spending $55 million for exploiting these discoveries of high-temperature superconductivity. But any nation can still join this potentially rich yet still-open quest if it can afford just $30,000 for equipment and money for the physicists' salaries. Incidentally, Zhau Zhong Xian received the annual $10,000 Physics Prize of the Third World Academy of Sciences last of September.

Role of UNESCO

Q: What role does UNESCO have in promoting the health of science in less developed countries?

SALAM: UNESCO has, of course, major achievements in that area already, but I would like to see this potentially great organization being far more effective in attracting the idealism of creative minds in all countries throughout the world.

Q: What specifically should UNESCO be doing?

SALAM: First, it must take active steps to close the growing gap in so-called hard sciences between industrialized and developing regions, by building up the scientific communities in the poorer countries, together with libraries, communications and other necessary infrastructure, and by emphasizing the importance of scientists as professionals in the development process.

Second, UNESCO ought to highlight the role and value of fundamental science and take initiatives again - as it did many years ago - to foster international collaboration in chemistry, physics and biology. UNESCO headquarters in Paris should not be an entrenched bureaucracy but a genuine house of science, with continual through-put of scientists from all the nations of the world. It's a great pity that UNESCO in the past has not attracted the best brains.

National Specialties

Q: You have some novel ideas for possible divisions of tasks among various member countries in promoting these ends.

SALAM: Yes, the type of thing I have in mind is for, say, Switzerland and Austria, with their pharmaceutical have in mind is for, say, Switzerland and Austria, with their pharmaceutical expertise, to accept responsibility for medical education; for the Scandinavian countries to take on the scientific aspects of ecology; and for the U.S.S.R. to make to make the major contribution in eradicating illiteracy through primary and secondary education.Even some of the poorer countries, such as Egypt, Brazil and India, could make very valuable *intellectual* inputs in a division of labor of this sort.

Q: Such proposals sound highly idealistic.

SALAM: And why not? I am by no means putting forward these ideas as fixed, concrete proposals but I do really believe in the principle of specialization - the idea that individual countries could and should accept responsibility for specific fields and for completing particular programs by particular dates. That is the element that has not always characterized UNESCO's work in the past.

Q: But nothing comparable with your proposals has ever worked before.

SALAM: Maybe not on the same scale. But I do have one model in mind: the setting up of four institutes of technology by India during the 1960s. One in Kanpur was created by a consortium of U.S. universities, which helped to build and furnish the institute and provide teaching staff for several years. A British university consortium created and staffed the one in Delhi, the Soviet Union built the institute in Bombay, and West Germany set up the one in Madras. Even the healthy rivalry which developed between the donor nations helped to foster excellence in these four institutes. Why shouldn't something of the same sort happen today on a larger canvas? It could be done by the year 2000.

Science as a Religious Search for Knowledge

Q: What is your view of the burgeoning of Islamic fundamentalism in the Middle East today?

SALAM: I am well aware that I have made myself unpopular in certain quarters by refusing to endorse many of these developments. I believe that some of the things now happening in those countries are not in line with the of the things now happening in those countries are not in line with the teachings to be found in the Koran. For me they represent an aberration of true Islamic teaching.

Q: One of your interests is the relationship between science and religion. How do you personally reconcile the conflict between the two?

SALAM: I do not see that there is a conflict. As a practicing Muslim, I find many reflections on the laws of nature in the Koran, with examples drawn from cosmology and physics, biology and medicine. The Holy Prophet of Islam emphasized that the quest for knowledge and science is obligatory on every Muslim. Secondly, I have yet to find a verse of holy scripture which describes natural phenomena and which contradicts the finding of science. Thirdly, you will not find a single incident like the persecution of Galileo throughout the history of Islam.

Q: But what of the contrast between religious beliefs and rational, scientific analyses of, for example, the randomness or gene shuffling, which would seem to conflict with the idea of purpose on direction in evolution?

SALAM: The idea that science must lead to a rational denial of metaphysics is a legacy of yesterday's battles, when so-called rationalists, with what were actually irrational and dogmatic beliefs inherited from Aristotle, were unable to reconcile these with their faith. My own faith was predicted by the timeless spiritual message of Islam, on matters on which physics is silent and will remain so.

The ICTP Training Activity in Microprocessors

by L. Bertocchi,
Deputy Director, ICTP

In the framework of its training programme, in 1981 the Centre started a series of Colleges on Microprocessors, organized with the scientific and technical cooperation of CERN. The reasons for introducing training on microprocessor technology and its applications in physics are obvious:

- microprocessors are cheap;
- their use is extremely flexible, either as a control device (of scientific - their use is extremely flexible, either as a control device (of scientific instruments, for instance, or of physical parameters), or as a data acquisition device;
- they can be programmed directly by the user, or through relatively cheap development tools;
- they can be easily inserted as a component of a more complicated and advanced system.

Microprocessors are therefore a technology where scientists from the Third World can keep the pace with advanced countries.

The Colleges on Microprocessors, organized by the Centre, have a 4-week duration, and are based on an integrated hardware-software approach, with formal lectures coupled to an intensive programme of practical exercises. The purpose of the Colleges is to bring participants, in a period of 4 weeks, to a level which will enable them to develop microprocessor-based systems and to use them efficiently. The programme covers the following topics:

1. General introduction to micro-processors;
2. Microcomputer hardware: architecture, interfacing, etc.;
3. Assembly language programming;
4. Techniques for microprocessor project development;
5. Applications of microprocessors in various fields.

The practical exercises, which form the backbone of the Colleges, are performed with the use of:

- 22 special workstations (ROSY: Resident Operating System) constructed at CERN, consisting of a Micromodule MM17 (containing a 6809 processor), extra memory, a floppy disk driver and an alphanumeric terminal. The workstation also includes additional parallel and serial interfaces. The software running on a station consists of an elaborate monitor, and the FLEX operating system, which contains an editor and an assembler. This enables the participants to write, debug and preserve all the software they need to develop for the practical course;
- 22 sets of so-called "Logidules" (easy-to-use electronics educational material); they are meccano-like building blocks, which were material); they are meccano-like building blocks, which were developed at the "Ecole Polytechnique Fédérale de Lausanne" by Professor D. Nicoud. These Logidules make it possible to build quickly the necessary circuitry to interface the microprocessor to external equipment.

Each day, four hours are devoted to practical work, through a shift system. For the first three weeks during the laboratory classes, all participants perform the same exercises (of hardware, software, or a combination of the two), under the guidance of a group of instructors. During the last week they work, in teams, on a number of independent small projects.

The first of these Colleges was organized in 1981 at the ICTP in Trieste, with the participation of about 150 scientists; the success of this first College induced the Centre to repeat the Colleges, in Trieste in 1983, 85 and 87, and in the form of Regional Colleges (fully organized and sponsored by ICTP) in Sri Lanka in 1984, in Colombia in 1985, and in the People's Republic of China in 1986. Moreover, local Colleges (with ICTP financial support) have been held in Portugal (1985) and Mexico (1986). Both the Regional and local Colleges make use of the ICTP equipment (about 70 boxes, for a weight of about 1,500 Kg, are sent forth and back by air cargo). The total number of participants from developing countries, who have attended these activities, are as of today 678; to this one must add about 100 more names from advanced countries (who take part in the activities at their own expenses). The Colleges are expected to continue in the future, with a Regional College in Côte d'Ivoire in 1988, and a College in Trieste in 1989; two local Colleges are also planned, one in Argentina in 1988 and one in Indonesia in 1989. These activities have received support from various institutions (in addition to the main support of the Italian Government); particularly important has been the political, organizational, and financial support of the United Nations University (UNU).

These Regional Colleges, but especially the local ones, are very good examples of a multiplicative effect: they are organized and conducted by former
examples of a multiplicative effect: they
are organized and conducted by former
participants and instructors, who have previously taken part in the ICTP Colleges and acquired the necessary know-how. Moreover, other training activities at institutional level have also been organized by former participants and lecturers, using some equipment borrowed from ICTP.

The success of the training activity in the area of microprocessors at ICTP has led to the proposal, submitted by the United Nations University to the Italian Government, for the establishment of a laboratory on microprocessors at the ICTP. This laboratory has the following purposes:

a) To give the necessary hardware and software back-up to the Colleges;
b) To offer to scientists from developing countries the possibility of implementing technical projects related to their research;
c) To perform original research in the area of microprocessors.

This proposal has been accepted by the Italian Government, which has approved and funded a four-year project in microprocessor technology (1985-88); the laboratory is a joint endeavour with INFN (the Italian Istituto Nazionale di Fisica Nucleare). One of the primary technical projects already implemented in the laboratory is the design and construction of a new, inexpensive monoboard version of the ROSY development station (called ROSY Junior).

Another aspect worth emphasizing is the team of instructors. For the first College, it was only possible to find the necessary expertise only in advanced countries; therefore, all the instructors were recruited in Europe (mainly CERN, Italy and UK). Starting however, with the second College in Trieste, 12 of the best students from developing countries of the first College, (3 from Asia, 3 from Africa, 3 from Latin America, 3 from the developing nations of Europe) were invited to attend a special training session for new instructors, and later joined the team of instructors. This system also was implemented for the subsequent Colleges, and now a team of about 40 instructors from developing countries collaborates with the Centre in running the Colleges. Several of these instructors have either organized
running the Colleges. Several of these
instructors have either organized
Regional/local Colleges, or imparted local training using equipment donated or loaned by ICTP.

The Colleges organized by ICTP have also formed the basis for local training at the University level; one simple example is the following: the full text of the lectures and practical exercises (including detailed solutions!) have been translated into the Chinese language by a former participant and collected into a booklet, which is now used as a textbook at the University of Beijing.

The future directions of activities in the area of microprocessors are:

a) continuation of the Training Colleges;
b) strengthening of laboratory activities at the ICTP;
c) A new project, consisting in the creation of a network of laboratories in developing countries, with hardware and software compatible with those existing at the Trieste laboratory. This would allow training on a broader basis and start, locally, the implementation of technical projects, which then can be completed at Trieste.

These laboratories would be installed at those scientific institutions, in developing countries, were Regional or local activities had been previously held, and in those institutions were active instructors are present.

The preliminary list of such institutions consists of:

Asia:
- Institute of Technology Bandung (Indonesia)
- University of Kuala Lumpur (Malaysia)
- Asian Institute of Technology (Thailand)
- University of Moratuwa (Sri Lanka)
- University of Colombo (Sri Lanka)
- University of Science and Technology, Hefei (China)
- National Institute of Physics, Manila (Philippines)
- Centre for Development of Telematics, Delhi (India)

Africa
- University of Dar-es-Salaam (Tanzania)
- International Centre ,Yamoussoukro
(Tanzania)
- International Centre ,Yamoussoukro
(Ivory Coast)

Latin America
- University of La Plata (Argentina)
- University of San Luis (Argentina)
- Centro Internacional de Fisica, Bogota (Colombia)
- University of Medellin (Colombia)
- Universidad Nacional de Ingenieria, Lima (Peru)
- University of Colima (Mexico)

More institutions will be selected in the near future.

The minimal equipment needed for each of these laboratories is 3-4 ROSY Junior development stations and the same number of sets of logidules. This equipment would result in the improvement of local teaching of electronics and microprocessors, both at the university level (in the form of courses taught during the academic year by local instructors), and in the form of local/regional courses, organized by pooling for a few weeks, equipment and instructors from nearby institutions (with limited financial assistance from the Office of External Activities of the ICTP).

For this purpose, the ICTP will construct and donate 50 ROSY Junior development stations, using the prototype developed at its laboratory. These stations will have the commercial value of about 3,500 US$ each and the corresponding funds will come from the budget of the Project on Microprocessor Technology, funded by the Italian Government through the United Nations University. Unfortunately, it is not possible to fund the sets of Logidules (each ROSY Junior should be accompanied by a set of them) and for this purpose another source of funding should be found.

Environmental Influences of Climate Variability

(The Physics of Clouds and Climatology)

Part A: Contribution from Directors and Lecturers

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Cloud Physics is a branch of Physics which is very much closely related to climate. This is because it is the development of clouds (its dissolution) which produces significant weather (fine weather) over a given place on the Earth's surface. Indeed, defining climate as either the expected weather or the observed character of weather over a given area within a specified period, we note that climate is the total manifestation of the rather complex microphysical processes associated with cloud growth. Climate has for long ceased to be regarded as invariant in time and space. In fact, climate is the most variable aspect of our natural environment. It varies at all time scales (Ausubel and Biswas, 1980). Climate variability thus introduces an important stochastic element into those human activities, such as agriculture and water resources management, which it strongly influences. The extreme climatic events that are inevitable consequences of this variability pose particularly great risks of different dimensions to the successful functioning of these human activities. Moreover, there is reason to believe that human activities themselves may lead to long-term climatic changes, with variation in the statistical characteristics of climate and the return periods for defined risks. The return periods for extreme climatic events such as drought are long relative to current development time-scales of human society. Thus, the disastrous Sahelian drought of 1968-1973 (and thereafter) pressed upon a far different society than the earlier droughts in this region this century. As a result, old relief plans and measures undertaken to respond to the regional climate crisis were largely inadequate. The Third World countries in particular are called upon to address themselves seriously to the issue of climate influences through its variability syndrome.

In any part of the world which has experienced severe climate variability –
In any part of the world which has experienced severe climate variability –
either in the form of climate change, where the climate does not revert to its original state (i.e., it is irreversible), or in the form of climate fluctuation, in which case the climate may revert back to its original state after perturbation, long-term climatic variability is usually noticeable from the cloud pattern over that region. We, therefore, view cloud physics as the most fundamental science to climate. It is therefore timely that the International Centre for Theoretical Physics (ICTP) has arranged its Second Workshop on Cloud Physics and Climate to coincide with the time of world food crisis in most parts of the world, especially the developing countries (Revelle, 1981). This food shortage no doubt results from the variability of climate. Although the developed (industrialized) nations of the world are still affected by the vagaries of climate variability, it is the developing countries, especially those in the so-called Third World, who are facing the brunt of climate variability. In some cases, the economy of many nations has been shattered by adverse climate.

The world has become very much more conscious in the present decade than ever before in reacting to problems which are climate-related as can be evidenced by several international conferences on climate and there is no doubt that the Second Workshop on Cloud Physics and Climate is meant, among other things, to arouse the scientists from developing countries to think very seriously on how to solve some national development problems in their countries through active research in climate and cloud physics. This is particularly true for the Third World countries who have found themselves faced with double problems. These are, first, problems related to political and economic independence, and second, the problem associated with the prevalence of harsh climatic situation, notably droughts, desertification, flood and related geophysical problems like soil erosion. Although more advanced countries of the world have been able to solve, to a certain extent, the first type of problem, they have not been able to completely solve the second type. However, the situation in developing countries is completely different. They
However, the situation in developing countries is completely different. They
are facing these two types of problems rather simultaneously, as most of them are usually (and rightly too) in a great hurry to become developed.

Weather and climate are dynamic features of our environment and impinge in various ways upon all the activities of man to a greater or lesser degree (Hobbs, 1980). The ways in which the elements of weather and climate affect all forms of economic and social life are now receiving new impetus from both meteorologists and governments as the latter have discovered very lately, sometimes, after most costly experience, for example, the problem of prolonged drought and desertification, that they cannot plan very successfully without taking climate into consideration. This is particularly true for the developing countries where economy is largely dependent on agriculture.

Scientists from developing countries should try to understand the other domains of the production section of their national economy and in what ways climatic maxima may have some direct or indirect influences upon these domains. Agriculture and water resources are obvious and have already been mentioned in the discussion. What influence has climate on energy systems and vice-versa and how shall we cope with the threat posed to human comfortable existence on the Earth by the increased release of carbon dioxide (and other pollutants) and possible increase in ozone concentration through increased production inadvertently of fluorocarbons? Scientists believe that this could lead to ozone depletion in the stratosphere (Hobbs, 1980).

A World Meteorological Organization (WMO) statement on the anthropogenic modification of ozone (WMO, 1976) concluded that evidence supports the view that a continued release of fluorocarbon into the atmosphere would lead to a reduction of stratospheric ozone. The climatic importance of O_3 in the stratosphere to man's comfortable existence on planet Earth is no longer in doubt. This is because of the attenuation of solar radiation through ionization of oxygen molecules to form O_3. This process removes some parts of the ultra-violet component of the incoming solar radiation on passing through the ozone
violet component of the incoming solar radiation on passing through the ozone
layer in the stratosphere before reaching the troposphere. A decrease of O_3 concentration, otherwise known in the literature as ozone depletion, will lead to increased insolation on the Earth's surface with a high susceptibility to skin cancer. We hope this does not happen. But it all depends on how man manages atmospheric resources.

There are, however, still great uncertainties about the size of the possible impact of fluorocarbon on ozone (Anon, 1977). Perhaps, a more decisive influence on the global climate through the actions of man is the phenomenon of the greenhouse effect through increase in the CO_2 content of the atmosphere. Carbon dioxide is a trace gas in the atmosphere that is virtually transparent to sunlight. But is absorbs upwelling long wave-radiation emitted by the Earth's surface. As a result, the lower atmosphere and the Earth's surface are warmer than they would otherwise be. Increased concentration of CO_2 enhances the greenhouse effect – an effect which will make the ground surface still warmer. Its other possible danger is the possible melting of ice in the higher latitudes which will indirectly increase the sea-level with danger to coastal stations and islands in the higher latitudes (AAAS, Annapolis, 1979).

Many knowledgeable observers feel that the most serious climate issue of our century which is related to the world future energy strategy and balance of power concerns the release of carbon dioxide by fossil-fuel burning and its built-up in the atmosphere (Jager, 1983). In recent years mankind has become more aware of the sensitivity of the climate system. This awareness arises partly from an improved understanding of the physical basis of the climate system together with the related field like cloud physics and partly from observational evidence of its impacts upon our environment through variability of climate.

Realistic cost-impact analysis is therefore desirable to understand that sensitivity and risks in economic and development policies and long term plans that may lie unnoticed until after some climatic shock or disaster has revealed them in a most undesirable way
some climatic shock or disaster has revealed them in a most undesirable way
and cost to the society and governments concerned.

Furthermore, it has become evident that human activities themselves can lead to global climate change (being pronounced regionally in different degrees as in our present century). While other aspects of global carbon dioxide cycle (Bach *et al.*, 1980) are also extremely important on the point of view of potential climate change, it is this link of climate to energy that probably accounts for the larger share of interest on climate in industrialized countries of the world.

A result of the various forms of climatic stress experienced in many parts of the world resulting from climatic variability, for example, the historic climatic episode now tagged in the literature as the Sahel drought of 1968-1973, mankind has become more aware of the sensitivity of the climate system to man's economic activities. This first alerted the world of the possible consequences of climate fluctuation and its present impact on a regional scale on man and his society. In particular, climatologists have become increasingly concerned that human activities could lead to local, regional and, perhaps, global climatic changes especially in view of the projected increase in population and demand for energy. Our understanding of the climate system is not yet good enough to make detailed predictions of future trends of climatic change due to natural or anthropogenic causes. However, existing knowledge and methodology are enough to be able to suggest or assess the order of magnitude of potential climatic changes and perhaps to point to the parts of the climatic system that should be carefully monitored by man. Our climate scientists should be vocal enough to direct the attention of the government planners of the national economy to possible climatic trends (and not forecast as this is still very difficult). Our fault as meteorologists is that we are rather too cowardly in our approach to climatic variations as far as national issues are concerned. We believe the scientists from various parts of the world who gathered in the famous Adriatico Guest House of the International Centre for Theoretical Physics (ICTP), Trieste,
House of the International Centre for Theoretical Physics (ICTP), Trieste,
Italy, 23 November - 18 December, 1987, have received a new mandate to be their individual nations' watchdog as far as climate variability is concerned. As Johaan Wolgang (Bach, 1980) has noted:

"It is not enough to know,
application is required;
It is not enough to wish,
action is required",

we in the developing countries should try to apply our knowledge in a most practical way in the management of our atmospheric resources.

We would like to conclude this survey with a simple question – which nation in the world today would not want to become industrialized? It is true that developing countries are usually in a great hurry in their effort to catch up with the industrially developed nations of the world. However, experience so far has shown that, in the course of achieving this objective of getting developed industrially, they may neglect the important role of climate as a *common denominator* to all facets of economic growth and in so doing become careless of the stability of the atmospheric environment and landscape in their region. The consequences of such inadvertent actions of man on climate and, on the other hand, climate on society, have been briefly surveyed. Our capability to manage and profitably harness atmospheric resources to improve our environment and the quality of life of people living within it is a goal of the atmospheric scientist and depends largely upon our understanding of the interaction between cloud physics and climate.

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Part B: Contribution from a Participant

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The workshop, which has attracted participants from all over the world, has had a lot of impact on the study of atmospheric physics and meteorology. The views of the cross-section of participants are very positive on the usefulness of the workshop, especially on the aspects of bringing the scientists together to share ideas and views on the physics of the atmosphere. The availability of equipments for both solar radiation measurement and computer facilities really exposed the participants from the Third World countries to greater insight into the science. The lecturers were really devoted and the experiments were very exciting and every participant has a lot of rich experience to go home with.

The coverage of the lecture topics were so high and different ones were discussed, however the participants would wish for a narrowing down of the areas to be covered in one workshop. This is to make for a higher concentration and attendance. The participants also wanted more time devoted to experiments and field observations.

devoted to experiments and field observations.

On the whole, the lectures were well planned, ranging from dynamic and synoptic meteorology to actual observations from research, for example the lectures on monsoon meteorology, African monsoon and Asian monsoon systems were very exciting and stimulating. They almost related theory to the observations from research. The lectures on numerical models were also interesting.

The participants wanted more time given to them to present their work, either through seminars or poster session. The few participants who gave talks on their current work did so very well. Some topics generated discussions and with some corrections from more experienced meteorologists. The presenters were grateful for the corrections. This is a very good innovation to this type of workshop.

The experience gained in this workshop will equally enhance our teaching and research in our various institutions. The organizers and directors were very active and dedicated throughout the workshop, thus creating an atmosphere of friendliness which is conducive for actual teaching and learning.

Acknowledgements

The Directors, lecturers and participants in the Second Workshop on Cloud Physics and Climate wish to take this opportunity to thank the Director of the ICTP, Professor Abdus Salam, the local coordinator of the course, Professor G. Denardo and all those who have contributed to the successful completion of the Second Workshop in Cloud Physics and Climate. We hope we could be given yet another opportunity in not too distant future.

The Second Autumn Workshop on Cloud Physics and Climate was held from 23 November to 18 December 1987. It was attended by 100 lecturers and participants of whom 78 were from developing countries.

Soil Physics at ICTP

by E.L. Skidmore,

by E.L. Skidmore,

U.S. Department of Agriculture, Manhattan, Kansas, USA

In 1980, while at ICTP to lecture at a course on Flow in Deserts, Oceans, and Atmosphere, Dr. Donald Gabriels (Department of Soil Physics, State University of Ghent, Belgium) suggested to officials of the ICTP that they consider adding soil physics course to their curriculum. ICTP responded to the suggestion by inviting Gabriels and another soil physicist, Dr. Edward L. Skidmore who also lectured at ICTP in 1980 during a workshop on Physics of Desertification, to prepare an outline of a course on soil physics for scientists from developing countries. Gabriels and Skidmore responded with similar outlines for a College on Soil Physics at ICTP.

The Academic Board of ICTP approved the College on Soil Physics. It was held for the first time September 19 - October 7, 1983, and directed by Gabriels and Skidmore. Lectures were given by well-known scientists from several countries, mostly European. Approximately 80 participants from about 35 developing countries were enthused with the activity.

A second College on Soil Physics, also directed by Gabriels and Skidmore, was held April 15 - May 10, 1985, with a one-week Colloquium on Energy Flux at the Soil Atmosphere Interface, the Colloquium was organized in cooperation with Commission I (Soil Physics) of the International Society of Soil Science (chairman: Dr. S.S. Prihar, Department of Soils, Punjab Agriculture University, India).

Dr. Ildefonso Pla Sentis joined Gabriels and Skidmore as a director for the third College, November 2-20, 1987. A fourth College is planned for October 2-20, 1989.

The first three Colleges were both theoretical and descriptive with special attention given to measurement of soil physical properties and processes in the soil and at the soil-atmosphere interface.

It is expected that future courses will be less general than past ones and deal more directly with specific soil physics problems encountered by participants from developing countries.

from developing countries.

Soil Physics Described

An examination of the nature of the basic substrate of all terrestrial life, the soil, exposes a bewildering array of complex relationships among chemical, physical, and biological components. In order to begin to understand these complexities one needs background in varied sciences.

One of these sciences, physics, as applied to soil is the study of the state and transport of all forms of matter and energy in the soil. Fundamental aspects of soil physics aims at achieving a basic understanding of the physical processes governing the behavior of the soil and transport of mass and energy. Applications of soil physics aim at managing the soil by means of irrigation, drainage, soil and water conservation, tillage, regulation of heat, aeration, etc. to provide an environment favorable for crop production.

The problem of soil physicists is to define, quantify, and optimize the physical factors of soil productivity in relation to interactive chemical and biological factors.

A soil physicist observes the world, the earth as a dynamic system in which matter and energy are in a constant state of flux. The soil interacts both with the atmosphere and with underlying strata. The soil also interacts in numerous ways with surfaces and underground water.

Rapidly increasing demand for irrigation, fertilizer use, and intensive cropping in developing countries necessitate critical examination of the concepts and techniques of soil and water management. Three quarters of the earth's surface is occupied by water, the latter cannot always be found where, when, and in the amount and quality needed. It is the ability of the soil to serve as a reservoir for water which must bridge the gap between plant requirements and the supply of water.

In order to manage the system, man has to control the mechanisms of the processes. He will only be able to do so if he can measure and quantify the processes. Therefore, soil physicists often build mechanistic models to study the behavior and movement of water, solutes, energy, gases, and the soil itself to control and predict the changes in soil solutes, energy, gases, and the soil itself to control and predict the changes in soil environments in response to physical and biological factors.

Applications of Soil Physics in Developing Countries

In developing countries, with very few exceptions, not only soil physics research but also soil physical information are extremely scarce. This is a severe limitation for applying soil physics to management and conservation programs and practices. As a consequence, soil resource in developing countries is not only being improperly utilized but is rapidly degrading mainly from erosion and salinization. The problem is most severe in tropical areas.

The deficiencies in part are due to the fact that in the past, more emphasis was given to the study of chemical than physical aspects of the soil influencing crop production. This happened because the initial results were more striking and easily reached and understood. After initial selection of the land, the physical aspects were only seen in a very general way as fixed limitations to the use of the soil for agriculture or other purposes. With the intensification of agricultural practices in the already cropped lands and the requirement to expand cropping areas to not previously cropped lands, it has been realized that the soil physical problems, natural or induced by men, are more important to consider. Soil physical problems must be solved to sustain food production in many critical areas of the world.

The study of physical problems has suffered, especially in developing countries, from the lack of people with an adequate knowledge and comprehension of the physical processes occurring in the very complex soil system and from the lack of standard methodology and equipment for evaluating soil physical properties and their influences on soil occurring processes. Therefore, it becomes very important, through international cooperative work and activities like the College on Soil Physics, first, to make technical and research personnel of developing countries aware of the importance of studying, correcting, and preventing the soil physical problems; and secondly, to provide them with the preventing the soil physical problems, and secondly, to provide them with the required basic and practical training to understand and to study the soil physical processes leading to such problems and to find and select the best alternatives for soil and water use and management practices to avoid such problems. The College on Soil Physics held in ICTP may contribute very successfully to such a purpose by providing the people with previous field experience on the soils of their own developing countries with a solid theoretical basis to understand and interpret the physical processes occurring on them and with the available alternative methodologies, adequate to their economical and social conditions, for evaluating such problems and for finding solutions to them.

The Third College on Soil Physics was held from 2 to 20 November 1987. One hundred and five lecturers and participants - 81 from developing countries - took part in it.

Riemann Surfaces and the 'New Physics'

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The new physics referred to in the title is, naturally enough, that of superstring theory. The great interest in this theory stems from the hope that it can allow a sensible theory of quantum gravity as well as unify the forces of nature. Strings – one-dimensional objects – are the first big step from point particles. String theory itself goes back to the dual resonance model of the mid-60's which was to be developed in order to explain the linearly-rising spin V(mass)2 plot of the hadronic resonances. Such and approach had the problem of the appearance of a massless particle in the spectrum of the bosonic string, but in 1975 D. Schok and J. Schwarz pointed out that for the closed string such massless particles included the graviton. The way for unification via string theory was open! Inclusion of space-time supersymmetry (which had been developed in the early 70's from fermionic string theory) in the string was achieved explicitly by M.B. Green fermionic string theory) in the string was achieved explicitly by M.B. Green and S.H. Schwarz in the early 80's. Their proof in 1984 that three and one loop superstring amplitudes were finite and anomaly-free for the special gauge group SO(32) (and in addition also for the phenomenologically more interesting group E8 x E8, which required the construction of the 'heterotic' string achieved by the Princeton group of Gross, Harvay, Matinee and Rohm a year later) was what caused the present explosive interest in superstrings. Very soon beliefs were strongly expressed that superstrings were the ultimate theory of nature, the end of physics was in sight, and the explanation of the Universe was just around the corner.

Since that time it has been realised that superstrings (and very likely the Universe) are not that simple. The early results on superstrings were based, as remarked above, on the calculations of three and one loop amplitudes. Naturally, strong efforts were then made to enter the proof of finiteness to the multi-loop level. Two main methods have proved of interest in that attempt, that of the covariant, as the Polyakov, approach and that of the light cone gauge, whilst a third, that of covariant string field theory, is still waiting to be thoroughly developed. In the covariant approach quantisation is achieved by a Feynman-like sum-over-paths method in which the paths are all loops of strings in space-time and all metrics on the resulting string surfaces (or world-sheets). The former of these is a straightforward Gaussian integral, whilst the latter requires care, since the phase factor – the action – is invariant under co-ordinate and conformal charges on the string world-sheet. Gauge fixing is thus required, with effective division by the volume of the set of all conformal and co-ordinate charges being needed.

In any case, as is usual in quantum field theory, the sum-over-paths is most easily made well-defined for Euclidean space-times, by complexifying the time variable so that the embedded world sheets of the strings or superstrings become Riemann surfaces which are 2-dimensional complex manifolds, with beautifully smooth properties. Necessarily, the technical machinery of that branch of mathematics, and help and involvement of the experts in that field, that branch of mathematics, and help and involvement of the experts in that field, has proved increasingly important to solve some of the detailed problems in the construction of the multi-loop amplitudes. That the theory of Riemann surfaces was intricately involved with string theory was clear to those working in the subject in the early 70's, such as Alessandrini, Amati and Lovelace. However, superstrings bring a whole new host of problems to light, such as the definition of determinants of Laplacians or ∂, β operators acting on various tensors on a Riemann surface, as well as the development of the theory of super-Riemannian surfaces (obtained by adding Grassmann variables to the complex variable Z and extending the notion of conformal map to a superconformal one). Quellan and others have given important contributions to the problem on the determinants, but there are still various outstanding technical problems.

Naturally the material presented at the 1987 ICTP College on Riemann surfaces is ideal to someone wanting to enter the field, as well as for those interested in recent developments. For example, the notions of Teichmüller space and the related moduli space of stable curves are essential for string amplitude constructions, since after division by the gauge group volume there is still the finite-dimensional space of quadratic differentials (which give co-ordinates for the Teichmüller space, for example) which arise as residual degrees of freedom of the world-sheet metric, and which have not yet been integrated over. The application of the algebraic geometry of moduli to string spaces, especially in the hands of Belavin and Knizhnik and their Russian colleagues, has allowed for a very elegant representation of multi-loop string amplitudes, although similar elegance and beauty is missing, as yet, from the superstring constructions.

The covariant multi-loop construction of superstring amplitudes has not yet been completed. Summation over different spin structures (which correspond to the different ways spinors can transform on being transported around the handles of the surface) is required on a Riemann surface to project onto the correct supersymmetric spectrum. This leads to quite onto the correct supersymmetric spectrum. This leads to quite complicated expressions. Nor is unitarity of the amplitudes guaranteed. These latter defects can be avoided by working in a non-covariantly gauge-fined version, the light-cone gauge, well known from the work of P.A.M. Dirac on forms of dynamics. This light-cone version is manifestly unitary, and provided care is taken in working with the complete Hamiltonian (involving quantic terms for the closed superstring) will lead to completely covariant S-matrix elements. It also has the advantage of containing only the physical modes of the superstring, unlike the ghost-ridden covariant approach. In this approach Riemann surfaces also occur, as was already shown by Kahn and Kikkawa in 1974. The form of the variables involved in integration over moduli-space in a multi-loop superstrings amplitude now turns out to be particularly suited to analysing the finiteness of the integrand, as uses a particularly simple representation of a fundamental domain of moduli space. In the process new problems again arise, especially associated with the Green's function of the scalar Laplacian on the Riemann surface. Points are now recognisable on that surface which correspond to the points where strings interact; close approach of these interacting points is of great interest since that can lead to divergence in the multi-loop amplitudes. The light-cone gauge appears to lead to move explicit forms of multi-loop amplitudes, and also to a possible proof of their finiteness. It may also lead to non-perturbative effects, since there is now available a complete superstring field theory for the heterotic string.

The third avenue, that of covariant superstring field theory, has proved very difficult to follow due to the lack of existence of a viable closed field theory. Various suggestions have been made, but have yet to overcome the difficulty of obtaining multi-loop amplitudes which only involve a single integration over fundamental domain of moduli space. Possibilities of using infinite dimensional Grassmannians, and embedding Riemann surfaces in them (as done by Krichever) is currently being investigated, as is that of constructing a universal moduli space on which string amplitudes would arise as a connection. But these are not yet completely formulated to comment on further. Possibly outside the direct aspect of Riemann surfaces is that of superstring compactification. There are now myriads of superstrings (some in 4 dimensions with almost realistic gauge symmetries) so the problem of dynamical compactification must be tackled. Recent suggestions of using the Krichever map to include infinite genus Riemann surfaces bring us back to the Riemann surface yet again. There is no doubt that the cross-fertilisation between the two subjects of superstrings and Riemann surfaces can only lead to better 'new physics', and has already lead to new mathematical problems.

The College on Riemann Surfaces was held at the ICTP from 9 November to 18 December 1987. One hundred and thirty-two lecturers and participants (81 from developing countries) took part in it.

Activities at ICTP

1988	
College on Variational Analysis	11 January - 5 February
Spin and Polarization Dynamics in Nuclear and Particle Physics	12 - 15 January
Second School on Advanced Techniques of Computing in Physics	18 January - 12 February
Workshop on Functional-analytic Methods in Complex Analysis and Applications to Partial Differential Equations	8 - 19 February
Workshop on Applied Nuclear Theory and Nuclear Technology Applications	15 February - 18 March
Winter College on Laser Physics: Semiconductor Lasers and Integrated Optics	22 February - 11 March
Workshop on Optical Fibre Communication	14 - 25 March
Impact of Digital Microelectronics and Microprocessors on Particle Physics	28 - 30 March
Large-scale Structure and Motions of the Universe	6 - 9 April
Experimental Workshop on High-Temperature Superconductors	11 - 22 April
Large-scale Structure and Motions of the Universe	6 - 9 April
Experimental Workshop on High-Temperature Superconductors	11 - 22 April
Spring School and Workshop on Superstrings	11 - 22 April
School on Non-accelerator Physics	25 April - 5 May
Spring College in Condensed Matter Physics: The Interaction of Atoms and Molecules with Solid Surfaces	25 April - 17 June
Workshop on Modelling of the Atmospheric Flow Field	16 - 20 May
Course on Physical Climatology and Meteorology for Environmental Applications	23 May - 17 June
Mini-Workshop on "Mechanisms of High-temperature Superconductivity"	20 June - 29 July
Summer School in High-Energy Physics and Cosmology	27 June - 5 August
Research Workshop in Condensed Matter, Atomic and Molecular Physics	20 June - 30 September
Unoccupied Electronic States	21 - 24 June
Computer Simulation Techniques for the Study of Microscopic Phenomena	19 - 22 July
Towards the Theoretical Understanding of High T_c Superconductors	26 - 29 July
Fifth Trieste Semiconductor Symposium (IUPAP): 4th International Conference on Superlattices, Microstructures and Microdevices	8 - 12 August
Summer School on Dynamical Systems	16 August - 9 September

The Application of Lasers in Surface Science	23 - 26 August
Working Party on "Electron Transport in Small Systems"	29 August - 16 September
Frontier Sources for Frontier Spectroscopy	30 August - 2 September
Summer Workshop on Dynamical Systems	5 - 23 September
Fourth Summer College in Biophysics	12 September - 7 October
African Regional College on Microprocessors (Yamoussoukro, Ivory Coast)	19 September -14 October
Course on Ocean Waves and Tides	26 September - 28 October
College on Medical Physics	10 October - 4 November
First Atumn Workshop on Mathematical Ecology	31 October - 18 November
College on Neurophysics: "Development and Organization of the Brain"	7 November - 2 December
Workshop on Global Geophysical Informatics with Applications to Researchin Earthquake Predictions and Reduction of Seismic Risk	15 November - 16 December
College on Global Geometric and Topological Methods in Analysis	21 November - 16 December

For information and applications to courses, kindly write to the Scientific Programme Office.

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