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Professor Abdus Salam, Director, International Centre for Theoretical Physics (ICTP) and President, TWAS, inaugurated the 25th Anniversary Symposium on Frontiers in Condensed Matter Physics, on 10th July '92, in the Main Lecture Hall of the ICTP. Prof. John Ziman is on the left and Prof. Stig Lundqvist is on the right.

Inside:

25th Anniversary Symposium on Frontiers in Condensed Matter Physics

It was a rare intellectual feast on all two days of the "25th Anniversary Symposium on Frontiers in Condensed Matter Physics" of the International Centre for Theoretical Physics (ICTP) Matter Physics" of the International Centre for Theoretical Physics (ICTP) held on 10-11 July 1992 in the Main Lecture Hall of the ICTP in Trieste, Italy.

Apart from an ornamental session at the start, the rest on the agenda comprised presentations on "Frontiers in Condensed Matter Physics".

In the galaxy of scientists, one could easily spot two Nobel Laureates from abroad, Prof. J.R. Schrieffer and Prof. K.A. Müller, the 3rd being the host, Professor Abdus Salam, Director of the ICTP and President of TWAS.

Professor J.R. Schrieffer had come from the Department of Physics, University of Florida, USA. The subject of his presentation was "Anomalous long period exchange oscillations in magnetic multilayers".

Prof. Karl A. Müller, IBM Zurich Research Laboratory, Switzerland, gave his presentation "On the existence of a coherent quantum paraelectric state in his presentation "On the existence of a coherent quantum paraelectric state in $SrTiO_3$ — A Sherlock Holmes Story".

Professor John Ziman, ex Chairman, Advisory Committee of the Condensed Matter Physics Programme of the ICTP, presented his keynote paper on "A neural net model of innovation". The latest experimental results from the general public discourse on science and technology is based almost exclusively on the linear model. Other ways of viewing the situation are explored by 'unpacking' more dimensions, introducing a 'department store' model and knowledge domains in cognitive space, and ending up with a neural net model which allows for 'learning' to take place much as in the human brain. This simplistic investigation cannot be a guide for policy-makers but might throw light on certain puzzling features of contemporary R&D institutions.

The opening session was graced by contemporary R&D institutions.

The opening session was graced by Professor Abdus Salam, Director of the ICTP and President of TWAS. In his inaugural address he said, "It is a great pleasure for me to open this symposium to celebrate the 25th anniversary of the Condensed Matter Physics Programme at the Centre. As you know, the Centre was established in 1964 with the programme on Nuclear and Particle Physics. Substantial effort was made by Prof. Paolo Budinich and Prof. Ziman in 1967 to open the programme on Condensed Matter Physics, firstly as a Winter College, followed by a Summer Workshop in 1970 with the initiative of Prof. Stig Lundqvist".

Lastly Professor Abdus Salam said,

"The Condensed Matter Physics Programme of the Centre has been very successful, so successful that it is the most successful programme in the whole European Community. It has had several ramifications, a number of branches which have grown out of the first programme and which have been very successful, like the Technology Centre which is becoming High Technology — this is becoming a whole new activity as a centre and I hope that it will flourish in the International Centre for Science and that it will give rise to 20 new centres which we are planning in the developing countries themselves".

Professor Stig Lundqvist, Chairman of the Scientific Council of the ICTP and Chairman of the Condensed Matter Physics Programme, also described how the Condensed Matter Physics Programme came into the mainstream of the path and its success during the last 25 years. He said it is really the success of Prof. Abdus Salam and Prof. John Ziman who had the initiative to organize this project and later on came up with a committee. Originally the committee consisted of Prof. Federico García-Moliner, Prof. G. Chiarotti, later Prof. Norman March joined it. While everybody was thinking of a next college in 1970 Professor Abdus Salam came with a new idea to set up a summer workshop and make this into a continuous programme. The man to lead that was of course John Ziman.

"How we can start a three-month workshop with participants from the Third World. That was something we are talking about", said Prof. Lundqvist. "John had a tougher attitude. He thought
"John had a tougher attitude. He thought
we will write to them a long list of problems that they should solve while they are here. In 1970 the Spring Seminar was a success and many known scientists like Prof. Toyozawa and Prof. Matsubara from Japan attended it. The thing changed dramatically around the mid '70s when Prof. Erio Tosatti and Prof. Mario Tosi accepted full-time positions here in Trieste, respectively from SISSA and Trieste University. Then we got a stable research group and a stable research activity throughout the year and that was a major step towards the present situation. That added more programmes, more visitors, more symposia etc. In that way it went on into the '80s and in the mid '80s we needed more money and more space so we rented the Hotel Adriatico for a long time and we still have it".

"Another thing we started at that time was a series of conferences that is called the Adriatico Research Conferences which were not only meant for solid state physics, but also on other related topics. In those conferences the participation from the Third World countries unfortunately has been fairly low".

"To improve the situation, the Committee had decided to hire a full-time scientist, which was done through Vienna, and that was Prof. Yu Lu. He played the key role of running the entire programme and also help formulating new activities through his personal contacts throughout the world. Also we hired Prof. Hilda Cerdeira from Brazil on a full-time basis and Prof. Tosatti and Prof. Mario Tosi as consultants which gave a tremendous strength in making the Condensed Matter Programme a success".

Prof. Lundqvist narrated the later '80s activities e.g.: conferences, courses, spring colleges held every alternate year. Now there are 10-12 Post- docs every year in the Condensed Matter Physics Programme. The goal is to develop this Centre not only into a meeting place but also a real research Centre.

So this is the position of the Condensed Matter Physics Programme after 25 years, which is rather a successful activity. His last comment was, "I am ending now hoping that my colleagues and successors will convert the next 25 years into something that is really visible and really great physics".

The opening session was followed by a scientific presentation by the eminent scientist Prof. John Ziman. His keynote speech is as follows:

A Neural Net Model of Innovation

by John Ziman

Courtesy of
Science and Public Policy,
Vol. 10, No. 1, February 1991.

One of the main objectives of science and technology studies is to uncover some of the principles that will help firms, industries, countries and global regions improve their competitiveness through technological innovation. Most of the actions required for worldly
of the actions required for worldly
success are tactical: the principles that determine them are largely tacit, and are acquired mainly through practice. We can only take conscious account of the principles that ought to govern our actions when we articulate tactics into a strategy. The aim of this paper is to improve this strategic thinking in the general area between the research laboratory and the marketplace.

Good strategic thinking is not just a matter of stating objectives, determining the boundary conditions and laying down a set of rational principles to achieve them. These elements only make sense because they are intuitively placed in relation to one another in some larger pattern whose structure is taken quite for granted, without further analysis. In other words, underlying any rational strategy there has to be a coherent mental model of the world where it operates.

For a strategy to be successful, this model must also be realistic. The basis for Napoleon's strategy in 1812 was the
for Napoleon's strategy in 1812 was the
map of Russia, with Moscow at its heart. This model of the situation was coherent enough to provide a rationale for his actions, but insufficiently realistic in its representation of the effects of winter. The question to be asked is: what sort of mental model of the whole process of technological innovation is required for successful strategic thinking in that field?

Linear Model

General public discourse on science and technology is still based almost exclusively on the linear model, depicting a simple process of development from fundamental research through applied science and technological development, to the design and manufacture of new products. The frequent reference to the 'spectrum' of R&D shows that this model is one-dimensional. The conventional use of terms such as 'strategic science', 'pre-competitive research', 'near market R&D', indicates that it is uni-directional.

This suggests that most people see it as a horizontal line, along which time's moving finger writes inexorably from left to right (see Figure 1(a)). But talk of 'moving upstream in the R&D process' suggests a vertical arrangement, with the causal direction from top to bottom, as natural as the force of gravity (see Figure 1 (b)). Or is it the other way up, with technological progress rising heavenwards out of 'basic research'?

The linear metaphor is so firmly entrenched in the language of public speeches, editorials, and official reports that we must assume that it relates to a widely shared mental model. Speakers and writers evidently take this model as given, without further explanation. This is not just a dead metaphor. Sophisticated policy analysts remind their audiences that there are not just two distinct categories of research — pure science and applied science, or perhaps science and technology — but they usually go on to say that "really there is a continuous spectrum covering the whole range between these extremes" (see Figure 1 (c)).

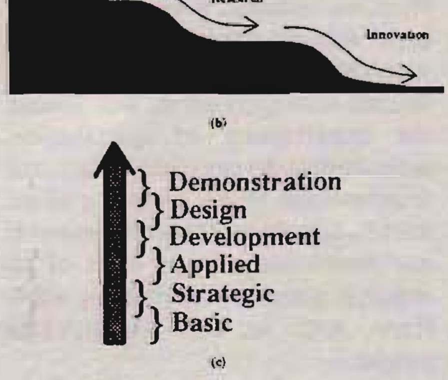


Figure 1.
Various versions of the linear model.

People who know anything at all about the actual processes of technological innovation do not suppose, of course, that such a simple model could ever fully represent the true course of things. They would say that it is a very crude description, with many much more complicated details smeared out. They might also agree that there could be quite different views on the way that the real world should be mapped on this model or how it operates in practice.

Yet an underlying belief in the linear model shows up clearly in the disputes that often arise over the interpretation of national R&D statistics. Otherwise, what would be the point of arguing, for example, that a certain fraction of the money spent on defence R&D should really be classified as basic research, and aggregated with the sums going to universities for specifically academic studies? People evidently think that all the knowledge and activity under this heading is alike in its origins and effects.

Cycles of discovery

Perhaps there were occasions in the past when the linear model was not inappropriate. Historians of science and technology must decide whether it is at all useful as a very approximate description of the way in which, for example, Faraday's discovery of electromagnetic induction eventually led to the electric power station, or Perkins' exploration of the basic chemistry of aromatic compounds was transformed into marketable aniline dyes.

Perhaps the sheer simplicity of this one-dimensional account does tell us something important about the role of basic science in society. But it is something important about the role of basic science in society. But it is certainly grossly oversimplified, ignoring the many other novel discoveries, and the pre-existing ideas, skills and practices, entrained along the way from the laboratory to the factory. And also the unidirectional relationship is only 'enabling', not deterministic — a necessary cause, but not a sufficient one, for the eventual embodiment of the original scientific discovery in a commercial product.

Elementary knowledge of the historical record reminds us, moreover, that the relationship between a scientific discovery and a technological invention is not always causative in that direction. It is well known, for example, that the technical development of the steam engine owed little to basic science, but gave rise to a whole new branch of fundamental physics in the form of thermodynamics.

In the same way, the very practical technology of animal and plant breeding was a highly significant and causative precursor of the basic science of genetics. Thus, even if we take the standard linear model as only a 'zeroth-order approximation', we must include a very strong element of feedback 'up the stream'.

Most serious metascientists have already consigned the linear model to the scrap heap of history. Amongst economists it has largely been replaced by various schemes allowing for such feedback. Mathematically speaking, the simplest scheme of this kind is the elementary cyclic model illustrated in Figure 2.

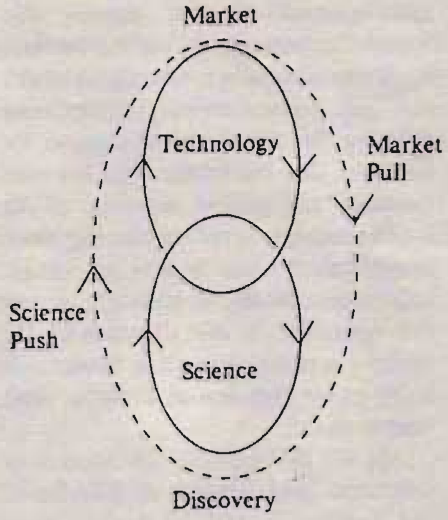


Figure 2. Cyclic model.

Figure 2. Cyclic model.

In micro-economic terms, the 'science push' from the basic end is not only reinforced by 'market pull', but also paralleled by a counterflow of concepts, capabilities and desiderata, from each of the subsequent stages, back into basic research. More generally, the macro-economic analysis of technology not only requires that new practical inventions be conceived to meet market needs: it also takes account of the contemporary practice of fostering basic research as a strategic resource for further invention in due course.

More dimensions

The elementary cyclic model may

have its uses in macro-economic theory, but it is quite inadequate for looking in more detail at the way in which the various phases of the innovation process are linked. For example, it gives a misleading impression of the 'institutional distance' between the knowledge-creating activity labelled 'science' and the 'market' where this knowledge is often urgently needed. In more sophisticated models, the various boxes representing sub-processes or sub-institutions, such as research, development, design, are more carefully differentiated and distributed around the page to indicate their relative closeness.

Nevertheless, such a model is not topologically distinct from a more elaborate cyclic model with, say, a chain of many stages which may be connected back and forth over several steps. As in the simplest one-dimensional model, whether uni-directional or cyclic, these connections will still be represented by unstructured arrows across the boundaries between the various boxes.

If we were really to take such a model seriously, it would severely constrain our thinking. We would have to suppose, for example, that the relationship between the basic and applied segments of the R&D spectrum involves nothing more complicated than a flux of ideas, capabilities, needs, or whatever, across this boundary, in one direction or the other — a two-way fax link between an ivory tower and one of Blake's "dark satanic mills".

As the literature on 'the sources of invention' demonstrates in abundance, the reality is always much more complicated in a cognitive sense. We all know that a marketable product is generated through a complex of social processes involving a variety of different types of institution. But we also know that it is put together out of many different elements of fundamental knowledge and of technical capability. To talk intelligibly about such relationships to one another, or even to ourselves, we must all have in mind a 'mental model' in which these various elements can be separately represented.

When people talk, for example, of 'restructuring the links between academia and industry', they need to have a more complex image than opening a wider door between two adjacent boxes labelled 'academia' and 'industry'. They need to be thinking about the numerous paths along which a variety of specific academic research findings actually get transferred and transformed into a range of specific industrial products.

The mental image that this evokes is a very complex whole with many different interconnected elements. Whether concretely elaborated or abstractly simplified, it cannot be linear. Of mathematical necessity, this image must span a space of more than one dimension.

There is no saying how such a mental model actually evinces itself to the inward eye. For one person, perhaps, it might just be a map, or blueprint; for another it might be more like a Meccano model, or an oil refinery. But stripped to its bare essentials, it has to have the general characteristics of a spatial network, a multidimensional lattice. In abstract mathematical terms, it is a graph of distinct 'nodes' related to one another, geometrically and topologically, by 'links'.

Institutional space

This is not an unfamiliar idea. The question is: in what abstract space should this image be located? One standard convention is to introduce time as one of its coordinates. Thus, for example, anyone thinking or writing about the evolution of a scientific discipline or technological artifact will use such a diagram to represent the way that various discoveries or inventions have influenced one another, with a date scale running down the edge of the page. But many people are confused by this device of treating time as a dimension, and are happier with mental models that actually change with the passing of time in much the same way as our perceptions of the real world.

What we want to do is to retain the principal characteristic of the linear model — the notion of a spectrum of R&D activity from basic science to the market place. Although this notion is over-simplified, it does represent a genuine feature of the real world. The component elements of an innovation do tend to arise from different types of activity that can be roughly characterised in those terms.

The simplest way of keeping this useful feature of the linear model, is to 'unpack' each of the spectral regions along it into several more dimensions. Each point along the line of Figure 1 has to be extended out at right angles, into a line or a plane, as in Figure 3.

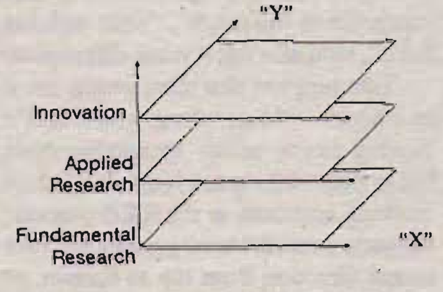


Figure 3. Unpacking more dimensions.

The question now is: what do these new dimensions represent? More precisely: what features of the real world do we choose to represent along each of the new lines or planes that we have drawn? Even more precisely: what characteristics do points on the same plane share, and what characteristics differentiate them?

To stop talking in windy abstractions, let us think of a much more concrete image — a many-storied building (it might be a department store) traversed by a vertical elevator shaft (see Figure 4).

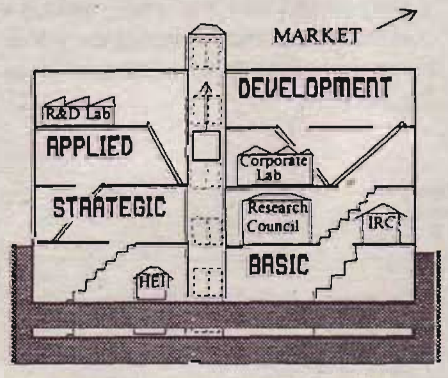


Figure 4. Department store model.

From the basement floor of absolutely basic research (the metaphor comes alive!) we move upward to a ground floor labelled strategic research, then through the departments of application, technological development, design, and demonstration to the open sky of the market. The elevator cage only moves in one-dimension, but at each of its stopping places we envisage a whole floor, with its own complicated geometry.

This department store model is fun to build, and very easy to elaborate. It is natural to interpret each of its 'departments' as a social institution — universities and fundamental research institutes in the basement, national laboratories and Fraunhofer institutes on the ground floor, the central corporate laboratories of multinational firms at first floor level, and so on. In effect, the linear model is unpacked into a three-dimensional institutional space, where the 'linkages' represent normal social interactions such as transfers of information, or of goods.

This model can certainly be instructive. For example, each floor of the building can be thought of as a marketplace, where information is traded by independent producers or proprietors for an appropriate consideration. In the basement, this consideration may not be cash at all but recognition. According to some sociologists of science, the traditional academic world is a community where the reward for making public a significant contribution to knowledge is enhanced esteem. One could say that it is a reputational market, where the goods on show — published scientific papers — are appraised by potential customers — other scientists — and are 'purchased' symbolically by being favourably cited.

Indeed, contemporary talk about the inputs and outputs of the national R&D system suggests that the traditional 'store' has been transformed mentally into a 'factory', where a production line for innovations trails upwards from floor to floor, picking up the necessary knowledge and techniques along the way. The discussion then turns to such matters as the relative benefits and costs of supplementing the old-fashioned elevator with numerous passageways, of supplementing the old-fashioned elevator with numerous passageways, staircases, escalators, and a noisy public address system!

Cognitive space

This representation of R&D activity as a system in institutional space can be very instructive, but it is seductively naturalistic. This means that it tends to impose its own specific interpretations, which are often very misleading. We begin to ask silly questions, like whether the 'factory' should have 'windows', or what would be the function of the 'production manager'?

Remember that our basic requirement is simply an extension of the concept of a spectrum into a notional space in which to locate and interrelate the actual entities in which we are interested. We might as well give this space three dimensions, since that is the most that the human mind can visualise. Mathematically speaking, however, our interests are topological rather than metrical. As with 'institutional space', we have no need to be precise about the coordinates we are using, except that one axis must still span the spectrum of the linear model.

A less vivid, more abstract representation of technological innovation can be generated by bringing into play another very conventional metaphor. It is almost impossible to talk about the bodies of knowledge involved in science, technology or commerce without using terms derived from the language of geography. We say quite naturally "molecular biology was originally an interdisciplinary *area*, covering various *regions* of physics, chemistry and biology", or that "opto-electronics is becoming an important *field* of technological development", or that "Japan is now dominant in the *domain* of dynamic RAM micro-chips".

We thus draw upon an intuitive notion that we are dealing with collections of many distinct items of knowledge — cognitive elements — that can be located in relation to one another as if they were points in an abstract space of two, possibly more, dimensions.

This usage is so commonplace that we seldom bother to activate the underlying mental model. All that I am suggesting is that this almost dead metaphor should be revitalised. The idea is, quite simply, that each 'point' along the R&D spectrum — fundamental is, quite simply, that each 'point' along the R&D spectrum — fundamental research, or applied research, or whatever — should be extended outward into a surface on which just such a map of the corresponding cognitive domain can be drawn. To put it the other way round: a very instructive mental model of technological innovation can be constructed by stacking up the successive domains of scientific and technological knowledge into an extended cognitive space covering the whole R&D process (see Figure 5).

Scientific ideas

Any attempt to formulate a definition of cognitive space is almost certain to lead up a philosophical blind alley. Our best guide is our intuitive grasp of the 'area' metaphor that we use so naturally in talking about different types of knowledge. We find that it makes sense, to others as well as ourselves, to refer to particular scientific facts or theories as if they were similar to one another in the same way as adjacent features in a landscape.

What we probably have in mind is that there must be a coherent pattern in what we know about the world, but that this pattern must be far more complex and subtle than a decimal classification for ordering books along a library shelf. We cannot possibly represent the full diversity of natural affinities in such a scheme, but we must at least have enough dimensions to indicate multiply-connected associations into 'multi-disciplinary areas', and so on.

Beyond that, the 'map' metaphor itself is easier to understand than any interpretation of it into quasi-philosophical terms. What we do have to be clear about is that we take the elementary objects in this space to be items of knowledge, stripped of any personal, social, or other contextual attributes. At the most fundamental level, for example, these elementary objects are what we might call, for simplicity, ideas, of the kind normally produced by basic research — scientific facts, data, concepts, theories, and so on, unattached to any specific uses.

This is obviously a very shaky way of talking. A scientific idea is not really a primitive entity that can be defined or located, except by reference to a particular context of use. The occasion by which it can be said to have been discovered or established is equally by which it can be said to have been discovered or established is equally questionable.

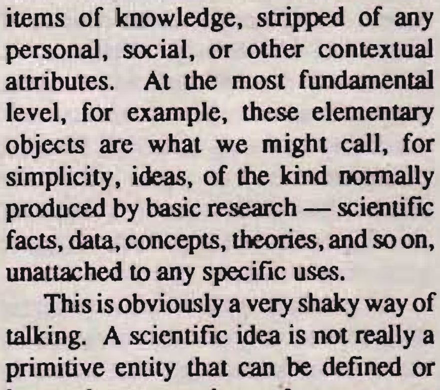


Figure 5.
Knowledge domains in cognitive space.

Nevertheless, if we are to make any progress in schematising the process of technological innovation we are bound to itemise the particular elements contributed to this process by fundamental research. We have to be able to say that at a certain moment a particular fact or theory was known scientifically (however uncertain and imperfect that supposed knowledge might have been), and that an active linkage developed between that particular piece of knowledge and a practical invention.

The detachment of fundamental scientific ideas from their eventual or potential applications is, of course, associated with their supposed universality. Here, again, we are always on shaky historical and sociological ground. It is not feasible, in practice, to separate the intellectual substance of a scientific discovery from the social interests and aspirations of the discoverer.

Nevertheless, we often find that a fact or principle that happens to have come to notice, or been sought, under conditions contrived for another purpose, is deliberately decontextualised for report and archival storage. It is just this possibility of being detached from its immediate use, or other particular context, that gives value to a scientific idea by making it applicable in other contexts.

In general, technological progress does depend very greatly nowadays on the type of knowledge that arises in fundamental research, without specific applications in mind. For our present purposes it does not matter whether this research was driven solely by curiosity. purposes it does not matter whether this research was driven solely by curiosity, or whether it was motivated by long term utilitarian possibilities.

It is the wisdom, or folly, or business of an advanced society to produce vast quantities of discoveries whose potential applications are not envisaged, and it is also our experience that many of these do get used in the production of useful objects or techniques. Our mental model of the innovation process undoubtedly has the domain of scientific ideas at its base.

Techniques

Now let us move to a higher level in our model, to the layer associated with applied research. At this level, therefore, we must be thinking of knowledge items that can be formulated and mapped out according to their perceived applications, that is, as technical procedures, design principles, instruments, methodologies, and so on. In other words, we are in the domain of techniques, where knowledge is not valued for its own sake, but as a means of attaining a variety of desirable ends outside the knowledge system.

In the past, a technique was usually a form of tacit knowledge, manifest, for example, in the craftsmanship of the woodworker, potter, farmer or sailor. Individual know-how is still an indispensable component of modern industry, but the main source of advanced technical knowledge is applied science and technological development.

This knowledge seldom remains secret or tacit for long, and is often published and codified in patent specifications. The hunt is on for powerful new techniques, in the form of 'generic' or 'enabling' technologies such as opto-electronics or enzyme catalysis, which are applicable in a great variety of processes or functions in the manufacture of a wide range of products.

Again, the notion of a technique is impossible to define precisely, especially if we insist on separating it from the particular goods, services or processes where it is actually employed. Does it really make sense to define the technique of cabinet-making as a particularly refined form of wood-working, without any reference to particular types of cabinets and other furniture? Nevertheless, this separation of means from ends is important in principle because it allows for one of the most from ends is important in principle because it allows for one of the most significant features of technological innovation — the exploitation of an established technique for quite new purposes.

Commodities

The problem of differentiating techniques from their specific applications becomes more acute as we move from the domain of applied research towards that of the market. Indeed, the transition from pre-competitive to near-market R&D is ill-defined, and may depend on the political or commercial context where these terms are used. Remember, after all, that the cognitive space that we are exploring must have the same degree of continuity from domain to domain as the spectrum in the linear model from which it was unpacked.

Eventually we reach the commercial market-place, which has to be, so to speak, the top face, of our model. This is where the products of the innovation process emerge and become commodities, ready for entry into commerce and use. Again, we must take a broad view, including under this heading not only consumer goods, such as cameras and aspirin tablets, but also intermediate technical goods, such as ball bearings and crude oil, and useful services, such as banking and weather forecasting.

For our present purposes, however, the significance of a commodity is that, being an artifact, it is a product of human thought and intention. It can thus be defined abstractly as the embodiment of a certain amount of knowledge and given a notional location in our cognitive space. Much of this knowledge is associated with the various ideas and techniques that have played an essential part in its design and manufacture, but a more subtle analysis would surely reveal a further component — the knowledge of how to combine these ideas and techniques to produce a marketable commodity.

The market domain is obviously immensely complex and diverse. The traffic through it is not simply an outward flow of ever-more sophisticated commodities: powerful forces feed back through it on various internal components of the R&D system. But these forces are economic, social, political, fiscal and so on, and cannot be these forces are economic, social, political, fiscal, and so on, and cannot be directly represented by connections in 'cognitive space'. They are important for our understanding of the innovation process, but this would require quite a different type of mental model.

Specialisation

The principal weakness of both the linear and cyclic models is that they have no means of showing the sheer multiplicity of the items of knowledge that go into the making of a novel commodity. It is a commonplace of modern science, technology and commerce that ideas, techniques and commodities are highly diversified and specialised — that each of the domains into which we have sliced our cognitive space is densely packed and minutely sub-divided (see Figure 6). This is not just an unfortunate consequence of academic or bureaucratic zeal: it is essential for the division of labour that empowers modern technological innovation.

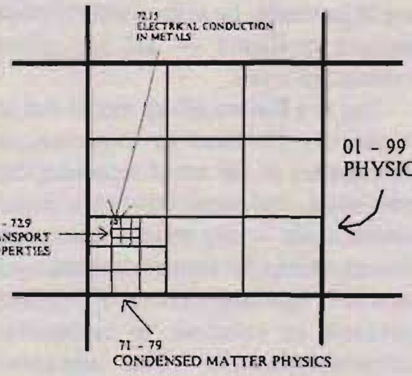


Figure 6.
Specialisation in a knowledge domain.

Consider first the differentiation of basic science into specialities. A familiar image of the tree of knowledge shows it branching out successively into academic disciplines, sub-disciplines, fields, sub-fields, problem areas, and so on. In a hierarchical decimal classification, each branching would introduce a factor of ten in the number of sub-categories.

It is no exaggeration to say that the domain of ideas is divided into ten thousand different specialities, each with its characteristic facts and theories, data and concepts. The specialities, moreover, cannot really be ranged along a single spectral dimension: they need at least two dimensions to indicate the complexity of their adjacency relations, least two dimensions to indicate the complexity of their adjacency relations, and many, many dimensions to place than in a fully ordered framework. For our present purposes, two points stand out:

The actual items of knowledge that eventually get transformed into particular techniques and commodities are usually highly specialised and narrowly defined. For example, the idea from materials science that might turn out to be crucial in the design of a new turbine blade would not be an all-embracing concept such as dislocation theory, or a general understanding of the properties of grain boundaries in alloys: it is more likely to be knowledge of the way in which the particular constituents of a particular type of alloy segregate to particular types of grain boundary over a particular range of temperatures. This item of knowledge would certainly not be widely known across a whole discipline. It would be in the possession of a specialist who is thoroughly familiar with the sub-field in which it lies, or would be reported in an article which would only be retrievable by quite an elaborate literature search.

The specialised items of knowledge required to develop a new technique, let alone a sophisticated commodity, are seldom to be found closely clustered in a single, recognisable sub-discipline, or even in a single discipline. To take another example, the modern technique of semiconductor electronics depends on an enormous variety of specific concepts and data derived from solid state physics, inorganic chemistry, crystallography, electro-chemistry, optics, and many others, dotted in an apparently random pattern over the whole landscape of the physical sciences. Notice, moreover, that the scientific ideas required for the development of an apparently similar technique, such as opto-electronics, are quite different, even though drawn from the same disciplines.

This highly differentiated and selective distribution of knowledge sources over the domain of ideas applies with equal force in the domain of techniques. The value that is added to the inputs to a manufacturing operation stems from the application of many quite different techniques, in many quite distinct processes, to the initial raw materials. The minute division of labour distinct processes, to the initial raw materials. The minute division of labour in fundamental research is paralleled in the specialised skills used by craftsmen and engineers in the design and production of complex commodities.

These skills, moreover, are not clustered in a single area, as in the old-fashioned metal-working workshop, where a well-trained instrument-maker would know how to use a certain number of different machine tools on a relatively small range of basic materials. An engineer or other professional technical worker may still be trained and formally qualified to perform the whole range of techniques supposedly required in a particular branch of his or her profession.

But innovative technologies keep bursting the boundaries of such disciplines. The techniques required in genetic engineering, for example, are highly specialised in themselves, yet they come from practical disciplines as different as chemical engineering, microbiology, genetics, physiology and biochemistry.

Cognitive roots of innovation

A mental model of the emergence of a particular technological innovation can thus be constructed by drawing lines to represent causal or interactive linkages between various points in cognitive space. Thus, scientific ideas are linked to the techniques to which they have contributed, and these techniques in turn are linked to the commodities where they have been used.

The resulting image is similar to the roots of a tree, stretching down into the domain of fundamental research. We can represent the cognitive history of the innovation as a sequence of such images, showing the development of these linkages over time.

Let me emphasise that this is a genuine mental model, not just an abstract diagram designed for a visual presentation. This, I believe, is how we might naturally represent to ourselves in thought, the cognitive relationships in technological innovation. When, for example, we argue that a basic scientific discovery has led directly to the invention of a new technique which was then used to produce a novel commodity, we probably have in mind a very thin, loosely articulated skeleton, for which a linear model might be a fair enough mental approximation.

As we have seen, however, such cases mental approximation.

As we have seen, however, such cases are now very rare. The cognitive roots of a technological commodity normally spread out over a large region of the domain of techniques, and tap down to numerous quite distinct fields of fundamental research. For at least the past century, a 'broad-based cone of finely-divided roots' would be a more appropriate image of the cognitive linkages in technological innovation (see Figure 7).

It is a matter for the historians of technology to trace the evolution of this root cone model, both as an image of the innovation process and as a realistic description of it at various times in the past. The surprising thing is that this

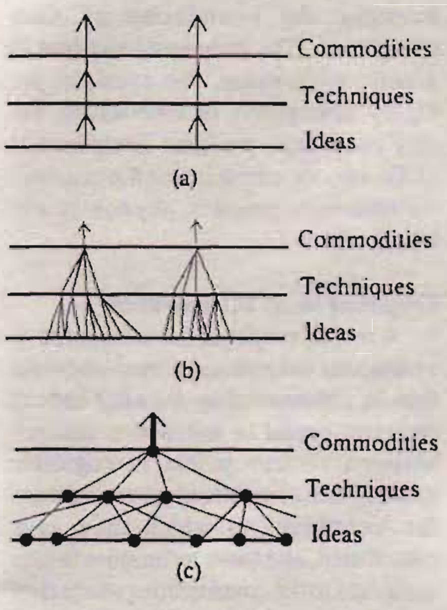


Figure 7. Spreading root cone of sources.

model is not always implicit in much that is said in broad terms about the economics and politics of industrial innovation. Do the proponents of 'technological trajectories' suppose, for example, that these trace out recognisable paths in cognitive space, or do they also involve institutional relationships? The mixture of metaphors here might be very confusing. This is clearly a theme for much more thorough exploration.

Interdependence

Introspective examination of cognitive space goes beyond the root cone image. Another feature of the whole process of technological innovation is that its cognitive elements are rapidly becoming more and more interconnected in every direction. As we have already remarked, the many distinct scientific ideas that go into the making of a technique are necessary constituents, without which the technique could not succeed, or would have to be drastically modified. The same applies to the techniques that enter into the final product.

What this means is that quite disparate techniques are linked indirectly by the scientific ideas that they share, and that apparently quite different commodities rely on the same techniques. These relationships are not simply causal, from the root-tips upwards. Quite apart from the market forces that most economists now include in their cyclic models, there are cognitive feedback loops in the R&D process. Fundamental research is a major customer for novel instrumental techniques, and many techniques are built up simply by combining tools and instruments that are already available commercially.

In addition, there are sideways linkages across each domain. The ideas that are current in one scientific speciality are suddenly discovered to be enormously fruitful in another very distant area. Indeed, it is sometimes asserted that all scientific progress is the outcome of this type of cross-fertilisation. It often turns out that two unrelated techniques — witness many novel developments in biotechnology — can be married to produce a commercially valuable technical process, without either having previously become commodities (see Figure 8).

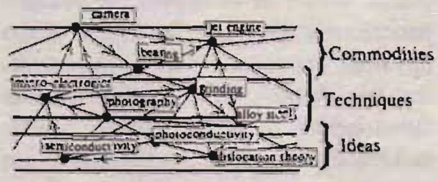


Figure 8. Interdependence.

This extraordinarily complex web of linkages in cognitive space has a significant counterpart in the real world: take the final products to be military weapons, such as aircraft, belonging to rival nations, and the indispensable techniques that go into them to be the manufacture of high-performance engine bearings, or of high density micro chips. Now observe a situation where these techniques are almost the monopoly of one or another of the rival nations — or of a third or fourth nation, such as Sweden or Japan. Then we have what is coming to be recognised as a major factor in world strategic analysis: the interdependence of the weapon systems of supposedly sovereign nations.

The cognitive interdependence of modern technological trajectories has very important implications for national and corporate competitive strategies. These strategies cannot be founded on the assumption that any one nation, let alone any one industrial firm, can be self-contained in the knowledge base that it needs to produce novel commodities.

This is not only because this would involve an impossibly extensive 'root cone' of in-house linkages right into the domains of applicable techniques and fundamental scientific ideas: it is also because many of the most important ideas and techniques that it would require would inevitably be in the hands of other nations or firms — all too often commercial rivals.

This is a feature of our model that is intuitively obvious to experienced practitioners of the art of technological innovation, and must now be a major consideration in any serious discussion of restructuring the institutional linkages between fundamental and applied research in relation to industrial competitiveness. The apparent advantages to a firm or a nation of striving towards technical autonomy are illusory and eventually counter-productive. What is really required nowadays for technological progress can only be obtained by free trade — that is unrestrained participation and fair exchange in the global markets in ideas, techniques and intermediate commodities.

Neural net model

The question we now have to ask is whether this model has more general properties, from which we can gain better understanding of the real world. At first sight, it seems no more than a hopeless tangle of linkages, an apparently random network in three (or more) dimensions. But it does retain the general structure imposed on it by the gradient of 'exploitability' along its original linear dimension. The R&D 'spectrum' can still be recognised in the way that the various domains, from fundamental research to marketable commodities, are stacked in successive, multiply-interconnected layers.

It also incorporates a notion widely accepted amongst philosophers of science, that scientific knowledge is best represented as a network. That is to say, theories do not depend on single items of evidence, but are multiply connected and embedded in a tangled mass of data, concepts and arguments. Our model already displays these relationships in the domain of ideas. It is instructive to extend the philosophical metaphor by showing how basic scientific ideas are connected to practical techniques and marketable goods.

Think of it, however, simply as a layered structure, connected both within each layer, and also from layer to layer, in both directions. What is this reminiscent of? Surely we have here something very like a neural net, of the kind to be found in a living brain. The nodes are neurons — nerve cells — connected both locally and over large distances by fibrous dendrites and axons. In some parts of the brain, such as the cerebral cortex, such networks often show a pronounced layer structure, corresponding in many cases to the successive transformations of incoming signals to achieve various physiological functions (see Figure 9).

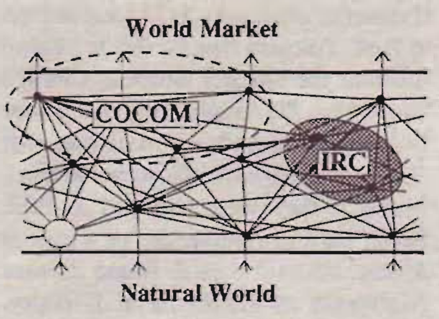


Figure 9. Neural net model.

This analogy would have little operational significance if it were not for current interest on the computational properties of such networks in artificial intelligence. The theoretical and practical implications of 'connectionism' are still very open and very much debated, but it does seem that a layered system of many signal-processing units, interconnected and interacting in parallel within and processing units, interconnected and interacting in parallel within and between layers, has some remarkable properties which might possibly be related to the behaviour of R&D systems.

In particular, by allowing the response of each node to incoming signals to change in the light of experience, a neural net can be 'taught' to perform quasi-intelligent processes, such as pattern recognition, which have not been programmed into it in advance. Metaphorically speaking, technological innovation is a process of this kind, where knowledge derived from study of the natural world is transformed into the design of useful artifacts.

The linear model represents this process much too naively, as if it were carried out by a very simple sequential computer. A connectionist device of at least three layers is a much more realistic conception of the whole system and of the way it works.

Unpredictability and adaptability

It would seriously overstep the bounds of the present analysis to elaborate this metaphor into a formal model, but it does suggest a helpful way of looking at several recent developments in the institutional structure of national R&D systems. One major trend, for example, is the attempt to bridge the gap between fundamental academic research and its industrial applications by linking them more closely through what are called in the UK Interdisciplinary Research Centres (IRCs). It seems to make sense, in our 'department-store' model, to introduce new institutions on a 'mezzanine' floor, with open access from below and above.

Experience is showing, however, that it is not easy to lay down long-term objectives or scientific priorities for such an institution. This is just what would be expected for an entity located in an intermediate layer of an active neural net.

The device is surprisingly effective as a whole, because the 'interior' processing units are not programmed in advance, and are free to adapt their response functions to a changing local information environment. Indeed, neither the actual response functions that evolve at such nodes, nor their pattern over an intermediate layer, can usually be related intuitively to the overall task being carried out by the system as a whole. For this reason, the attempt to programme the work of an IRC in whole. For this reason, the attempt to programme the work of an IRC in advance over a long period is likely to prove counter-productive.

Another strategic question of science policy is the desirability of maintaining a 'defensive threshold' of R&D activity in every field where a competitive challenge might appear unexpectedly. This question can be put in another way: what is the risk to a firm or nation of giving up work in a whole field of fundamental knowledge or technique that might possibly become relevant to its commercial life?

A real neural net, in the brain or in a computer simulation, is usually remarkably resilient. The redundancy of connections allows the information flow to circumvent a hole or other local lesion, and to compensate effectively for it in its external behaviour.

According to this metaphor, therefore, the immediate commercial damage caused by a major breakthrough by a rival on an unguarded front might be very serious, but a flexible R&D system should be able to adjust its internal responses to this hole in its structure, and soon provide the necessary defensive material by indirect means. In other words, this risk is often exaggerated, and should not be allowed too much weight against the advantages of concentrating resources in fields that are already strong.

A very large cerebral lesion may, of course, be crippling. There can be no doubt, for example, of the effectiveness of the NATO 'Cocom' policy of denying the Warsaw Pact countries access to a wide range of advanced techniques and high-tech commodities. But note how very elaborate and extensive this embargo had to be. The target region of innovative Soviet weaponry could only be isolated by a massive surgical cut through innumerable connecting links to apparently irrelevant sectors of the western civil economy.

Conclusion

This paper is, in every way, a 'think-piece'. It relies on naive introspection to explore the images that we construct and manipulate when we hold forth, to ourselves as well as to others, on the general theme of technological innovation. It is not based on empirical research, nor is it grounded on an academic bedrock of citations. It also stumbles blindly into the deep scholarly waters of computer science and cognitive stumbles blindly into the deep scholarly waters of computer science and cognitive psychology.

Nevertheless, study of the social relations of science and technology is not well furnished with models, metaphors or analogies. We are asked to analyse policies and to devise strategies, yet we do not fully understand, intuitively, how and why things work as they do. A highly abstract, grossly simplified and crassly schematised model such as this can never be a reliable guide to practical decision-making, but it may provide some thematic insight to both decision-makers and policy analysts. All that can be claimed is that certain puzzling features of contemporary R&D institutions might be understood a little better from this point of view.

That is why I am very happy to offer this particular piece as a celebratory gift to my old friend Maurice Goldsmith. It may not conform to the conventional scholarly canons, but it might appeal to the companionable wit and enjoyment of wild ideas that enriches his rare breadth of vision in such matters. ◆

Visits to ICTP

Indian Ambassador

The new Indian Ambassador to and Member of the Board of Governors of IAEA (Vienna, Austria), Mr. K.N. Bakshi, visited the ICTP on 28th July, 1992. He is a professional diplomat and is interested in the development of science and technology.

He met Professor Abdus Salam and discussed the scientific activities of the ICTP, then he met some Indian scientists present at the Centre. He visited the ICTP Library.

Russian Academy of Sciences

Professor Ju.S. Osipov and Prof. A.A. Gontchar, President and Vice-President of the Russian Academy of Sciences, visited the Centre on 21 August 1992. Professor Abdus Salam, Director, International Centre for Theoretical Physics, and President, Third World Academy of Sciences, warmly received the delegation and briefed them on the scientific activities of the Centre, ICS
and TWAS. They discussed the further
and TWAS. They discussed the further co-operation of scientific activities with the Russian Academy of Sciences.

After the meeting with Professor Abdus Salam, the delegation met with the Deputy Director, Prof. L. Bertocchi, the Head of the Office of External Activities Prof. G. Denardo, and the Executive Secretary of TWAS Prof. M.H.A. Hassan, and discussed the activities of the Centre and TWAS.

The guests visited the Library of the International Centre for Theoretical Physics and the International Centre for Biotechnology and Genetic Engineering. ◆

1992 Dirac Medals of the ICTP

The 1992 Dirac Medals of the International Centre for Theoretical Physics (ICTP, Trieste, Italy) have been awarded to: Professor N. N. Bogolubov (posthumously) formerly of the Joint Institute for Nuclear Research, Moscow, Russia, and Professor Yakov G. Sinai, Landau Institute of Theoretical Physics, Moscow, Russia.

Professor Nikolai Nikolaevich Bogolubov is honoured posthumously *"in recognition of his many fundamental contributions in physics and mathematics. In statistical physics, his treatment of Bose-Einstein condensation in a non-ideal gas was a seminal work which laid the basis for a microscopic theory of superfluidity in Helium II. It stimulated many of the later developments using quasi-particle methods. He later generalised this method to fermions and applied it to the phenomenon of superconductivity providing a systematic microscopic theory. The famous Bogolubov transformation is now a cornerstone of modern physics. In elementary particle physics, Bogolubov was the first to give a rigorous proof, based on local quantum field theory, of fixed angle dispersion relations for pion-nucleon scattering. This emerged from his study of the axiomatic basis of relativistic quantum field theory and the structure of the S-matrix. Another important result was a systematic formulation of the*
renormalisation programme for
renormalisation programme for perturbative computations of the S-matrix. In mathematics, among his many important contributions we cite his work on non-linear mechanics and the general theory of dynamical systems".

Prof. Yakov G. Sinai is honoured *"for his outstanding contribution to Theoretical Physics and Mathematics through the development of Ergodic Theory and its applications to Dynamical Systems, in particular Billiards, Phase Transitions, Quantum Chaos and Hydrodynamics. Also cited is his work on the Spectral Analysis of Schrödinger Operators and Applications of Renormalization Group Theory"*.

The Dirac Medals of the International Centre for Theoretical Physics were instituted in 1985 in memory of Professor P.A.M. Dirac, an honoured guest and staunch friend of ICTP. They are awarded every year on Dirac's birthday — 8th August — for contributions to theoretical physics.

In 1985, the Dirac Medals were awarded to Prof. Yakov Zeldovich (Institute for Space Research, Moscow, Russia) and Prof. Edward Witten (Princeton University, USA) and in 1986 to Prof. Yoichiro Nambu (Enrico Fermi Institute for Nuclear Studies, Chicago University, USA) and Prof. Alexander Polyakov (Landau Institute for Theoretical Physics, Moscow, Russia). In 1987, they were awarded to Prof. Bryce DeWitt (University of Texas at Austin, USA) and Prof. Bruno Zumino (University of California at Berkeley, USA) and in 1988 to Prof. David J. Gross (Princeton University, New Jersey, USA) and to Prof. Efim Samoilovich Fradkin (Lebedev Physical Institute, Moscow, Russia). The 1989 Dirac Medals were awarded to Prof. Michael B. Green (Queen Mary College, University of London, UK) and Prof. John H. Schwarz (California Institute of Technology, USA). The 1990 Dirac Medals were awarded to Prof. Ludwig Dmitriyevich Faddeev (Steklov
Mathematical Institute, St. Petersburg.
Mathematical Institute, St. Petersburg, Russia) and Prof. Sidney Richard Coleman (Harvard University, Cambridge, Massachusetts, USA). The recipients of the 1991 Dirac Medals were Prof. Stanley Mandelstam (University of California, Berkeley, USA) and Prof. Jeffrey Goldstone (Massachusetts Institute of Technology, Cambridge, Ma., USA).

The Selection Committee includes Professors S. Lundqvist, R. Marshak, J. Schwinger, S. Weinberg, E. Witten and Abdus Salam. The Dirac Medals are not awarded to Nobel Laureates or Wolf Foundation Prize winners. ◆

Professor Abdus Salam in Dubna (Russia), where N.N. Bogolubov Worked

A.A. Bakasov
JINR (Dubna)/ICTP (Trieste)

Prof. Abdus Salam visited Dubna, Russia, where the Joint Institute for Nuclear Research (JINR), one of the biggest and most successful Russian physical institutes, is located.

This short visit (7-9 August, 1992) was connected with the occasion of the award (posthumously) of the Dirac Medal to the famous former director of JINR, one of the few truly leading physicists of Russia, Academician N.N. Bogolubov.

Academician N.N. Bogolubov, born in 1909 in Nizhny Novgorod (Gorky), spent almost the last forty years of his life in Dubna as Director of the Laboratory for Theoretical Physics of JINR (now Bogolubov Laboratory for Theoretical Physics), and later as Director of the whole JINR.

He has created there one of the leading Russian and international schools on theoretical physics; he involved quite a few outstanding experimentalists in high energy and nuclear physics in the work in JINR; he was responsible for the administration of JINR during the most difficult period of the economical decay of the USSR, using all his authority and influence in world science to provide physicists over all the Soviet Union with the maximum
possible help during those hard times....
possible help during those hard times.

He was truly a great man and a great scientist.

In recognition of his outstanding scientific and human merits and regretting that the award was posthumous*, Prof. Abdus Salam, Nobel Laureate, Director of the ICTP, President of the Third World Academy of Sciences, President of the Third World Network of Scientific Organizations and Foreign Member of the Russian Academy of Sciences, decided to go personally to Russia, to express his personal respect to the memory of N.N. Bogolubov.

On Dirac's birthday, 8th August 1992, in the largest conference hall of the JINR in the Bogolubov Laboratory for Theoretical Physics, Prof. Abdus Salam announced the award of the Dirac Medal to N.N. Bogolubov in front of a huge audience who had come to welcome the great modern physicist come to Dubna.

After the announcement, Prof. Abdus Salam delivered a one-hour lecture on "The role of chirality in the origin of life". The lecture was followed by a discussion containing miscellaneous questions and suggestions.

In particular, Prof. Ya.A. Smorodinskiy was curious about the crucial point of the theory suggested by Prof. A. Salam i.e., the mechanism of the enhancement at macroscopic level of the symmetry breaking of the potential at the level of elementary particles. Answering, Prof. Abdus Salam explained the quantum nature of the phase transition in the medium of proto-molecules which is like a Bose-condensation. He also argued why the different, non-equilibrium, theories, for instance, the theory developed by Academician V.I. Goldanskiy, are still failing to explain the phenomenon.

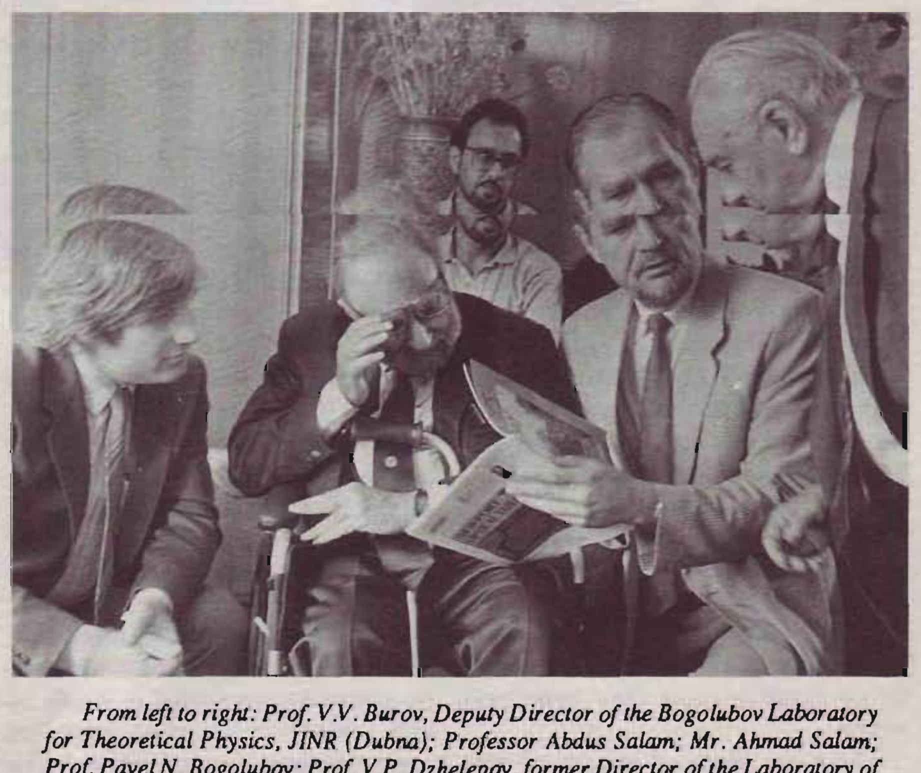
After the question of Prof. D. Kazakov about why chirality is thought by Prof. Abdus Salam to be responsible for the life reproduction process, Prof. Abdus Salam stressed once again that the coincidence of the chiral symmetry breaking and of the orientation of all molecules in aminoacids in Nature cannot be random following this statement with arguments from the equilibrium model he suggested several years ago.

The same day, Prof. Abdus Salam received some of those who were interested to speak to him. Some of them arrived especially from other cities of Russia just to see Prof. Abdus Salam.

There was also the first meeting of Prof. Abdus Salam with one of the sons of N.N. Bogolubov, Pavel, who is also a high-energy physicist and has worked for a long time at JINR (Dubna) and CERN (Geneva).

However, it was not the end of that day, at all.

It was amazing that Prof. Abdus Salam met in Dubna the father of the first



From left to right: Prof. V.V. Burov, Deputy Director of the Bogolubov Laboratory for Theoretical Physics, JINR (Dubna); Professor Abdus Salam; Mr. Ahmad Salam; Prof. Pavel N. Bogolubov; Prof. V.P. Dzhelepov, former Director of the Laboratory of Nuclear Problems, JINR (Dubna). (Photo N.M. Gorelov).

*Since Prof. Abdus Salam recommended that Academician N.N. Bogolubov be awarded the Dirac Medal before his death.

US H-bomb, Prof. E. Teller, one of the brightest US physicists from the Lawrence Livermore National Laboratory (USA). The two great men decided to have a dinner together. It was not a dinner, I can personally witness. It was really a long talk of two genii who were discussing the ways to save the Earth from military danger and world pollution.

Prof. Abdus Salam finished that day receiving people who were not lucky to see him during the morning reception.

On the next day, Prof. Abdus Salam started with a morning open reception. However, the two main points of the schedule of Prof. Abdus Salam for that day still laid ahead.

First, Prof. Abdus Salam attended the opening session of the International Conference on Global Monitoring and the first lecture, delivered by Prof. E. Teller. The audience in the conference hall met Prof. Abdus Salam with an applause. One of Dubna's weeklies, *Vesti Dubny*, said the next day: "It was an exceptionally high honour for the conference that a few of the greatest world scientists attended it. The participants were welcomed by Prof. world scientists attended it. The participants were welcomed by Prof. Abdus Salam, one of the true creators of contemporary theoretical physics, the author of the theory of electroweak interactions. Prof. Abdus Salam stressed both the importance and the complexity of the global monitoring of the Earth's ecological parameters. This was the reason why the chairman of the conference, Academician E.P. Velikhov, quoted a sentence by the outstanding economist Maynard Keynes from Prof. Abdus Salam's book which was presented to the conference: *"It is better to be roughly right than precisely wrong"*.

After the morning session of the conference, Prof. Abdus Salam left from Dubna for Moscow. His first destination was a visit to one of the most famous places in Moscow, the small Novodevichye cemetery where N.N. Bogolubov is buried along with other Russian famous people. There, Prof. Abdus Salam, together with N.N. Bogolubov's relatives, paid his respect to the grave of N.N. Bogolubov. He also visited the grave of L.D. Landau.

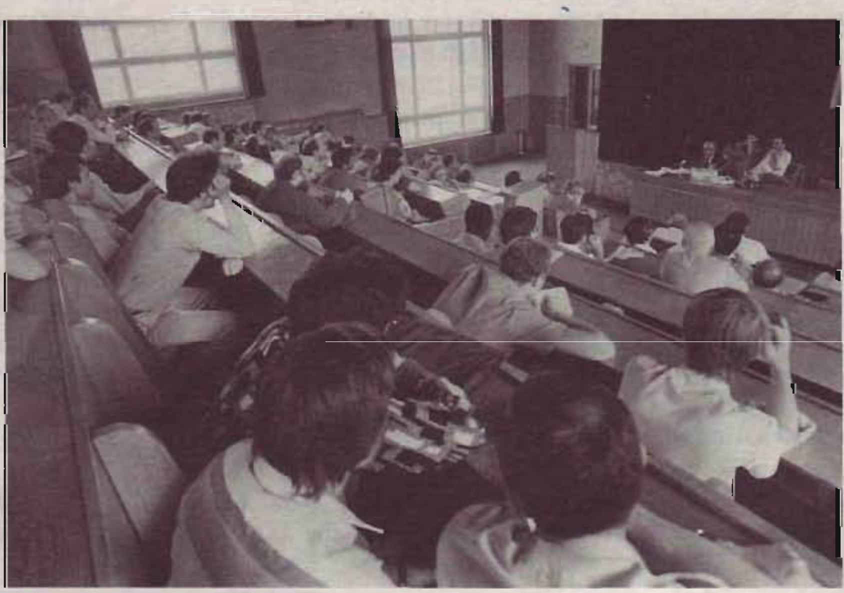
From the Novodevichye cemetery, Prof. Abdus Salam, the relatives of N.N. Bogolubov and friends of N.N. Bogolubov's family went to Vorobyovy Hills (Lenin's Hills), to the Moscow State University (MSU) where the wife of N.N. Bogolubov, Evgeniya Alexandrovna, lives.

During the cordial, warm, meeting Alexandrovna, lives.

During the cordial, warm, meeting with Evgeniya Alexandrovna, a lot was told, a lot was remembered. The meeting in the MSU and the visit to Novodevichye cemetery was videotaped by Pavel Bogolubov.

At the end of the day, accompanying Prof. Abdus Salam to the Sheremetievo airport, Prof. Alexander Kurbatov said: "Professor Salam, you showed by your visit how a great man should behave!"

It was the highest honour for JINR's and other Russian physicists to see Prof. Abdus Salam in Dubna and in Moscow. He was really surrounded in Russia by truly cordial, careful, people who were expressing their respect for Prof. Abdus Salam at almost every step.



The Blokhintsev Main Conference Hall at the Laboratory for Theoretical Physics, JINR (Dubna). (Photo N.M. Gorelov).

"It is very rare and an almost unique occasion to have Prof. Abdus Salam here, in Dubna, with us!", said the Director of JINR, Prof. V.G. Kadyshevsky.

A lot of people were voluntarily involved in the organization of the visit. In particular, the contribution of Prof. V.V. Burov, the deputy for the Bogolubov Laboratory for Theoretical Physics in JINR, of Prof. G. Kozlov and Prof. A.T. Fillipov should be acknowledged among many, many others.

Completing his visit, Prof. Abdus Salam was invited to visit Dubna the forthcoming year.

The visit, it seems to me, was really fruitful in many aspects. Prof. Abdus Salam discussed with the heads of several Laboratories of the JINR and in Dubna the possible ways to enlarge the framework for mutual collaboration. Evidently, the main discussions regarded the administration of the Bogolubov Laboratory for Theoretical Physics which has research interests related to the ICTP.

However, I would like to note the following specific feature of the possible collaboration of the ICTP with leading following specific feature of the possible collaboration of the ICTP with leading Russian institutions like the JINR.

We know that for the moment ICTP has a few hundred federation agreements with plenty of institutes all over the Third World. The main term of these agreements is the *mutual* exchange of visitors.

However, it is not a top secret that the visitors who use these federation agreements generally go only in one direction — from a collaborating institute to the ICTP.

The reason for this is very simple - ICTP can provide a visitor from the collaborating institute with a relatively higher level of science and academic life than in that institute itself. This is also a reason why ICTP's resident scientific staff is not generally in a hurry to undertake an exchange visit in accordance with a federation agreement.

Thus, most of federation agreements serve *very formally*, I mean, as *unidirectional* agreements which provide one side with more possibilities than the other side.

Possible collaboration with Russian institutes like the JINR can provide the people from the ICTP with a *real* opportunity to have mutually beneficial exchange visit. Why? Very simply — leading Russian institutions still have the highest world research standards, being still (in spite of the daunting economical situation in the former SU) really competitive in world science.

As a confirmation of this assertion, I can mention two suggestions for fellowships for outstanding young scientists from Third World countries which came from the Director of the Frank Laboratory for Neutron Physics of JINR, Prof. V.L. Aksenov, and from the Director of the Institute for Studies on HTS, Prof. B.V. Vasiliev. Both these institutions are among a few Russian institutions which still maintain world standards in experimental studies. The fellowships suggested are thought to be directed from the ICTP but funded from Dubna. The first considerations show that living conditions can be provided for the fellows which are considerably higher than the typical living conditions of a Russian scientist (and of the average level in Russia) along with highest level working conditions.

I believe the ICTP should use the facilities and new opportunities given by leading Russian institutions on behalf of facilities and new opportunities given by leading Russian institutions on behalf of science and technology in the Third World countries.

It is a great pity that we no longer have with us N.N. Bogolubov who did all that possible to help scientists from all regions of the former SU. Most of these remote regions declared themselves as Third World countries, and the JINR was supporting the research in these regions during the whole of its existence — now this may become the support by JINR of Third World countries. Thus, ICTP should join this process in the former SU, being the main representative of Third World science. ♦

Dirac Medal Award Ceremony

On 28 July 1992, Professor Jeffrey Goldstone (Massachusetts Institute of Technology, Cambridge, Ma., USA) received the 1991 Dirac Medal which had been awarded to him last year. Two such medals are awarded every year on the birthday of Professor P.A.M. Dirac — 8th Agust.

The ceremony took place in the Main Lecture Hall of the ICTP, Trieste, Italy. Professor Abdus Salam, Director of the ICTP and President of TWAS, presented the Medal and a cheque of US$5,000 to Professor J. Goldstone.

Professor Jeffrey Goldstone is honoured *"for his fundamental clarification of the phenomenon of spontaneous symmetry violation in relativistic quantum field theory. This phenomenon has come to occupy a central role in our understanding of elementary particles, and Goldstone's work is now among the foundations of the standard model of fundamental interactions. The ensuing massless bosons, known as Goldstone bosons, have found crucial applications also in many spontaneous symmetry breaking processes in condensed matter physics."*

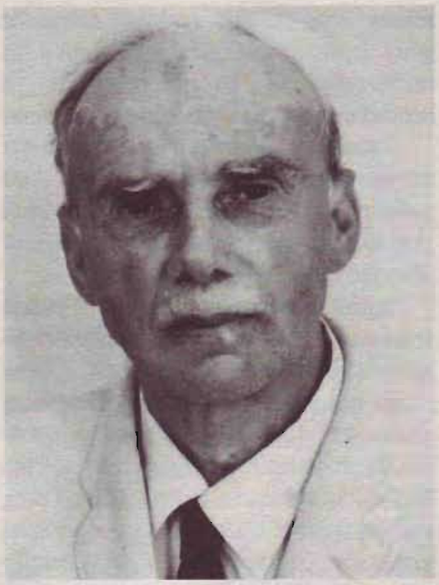
Prof. J. Goldstone was born in Manchester, England in 1933. He obtained his Ph.D. at Cambridge University (Trinity College) in 1958. He began his career as a Research Fellow at Trinity College, Cambridge University, (1956-60) where he was then appointed Staff Fellow (1962-82). Between 1961 and 1976 he was University Lecturer in the Department of Applied Mathematics and Theoretical Physics at Cambridge and in 1976 he became Reader in Mathematical Physics at the same University. In 1977 he joined the Massachusetts Institute of Technology as Professor of Physics, where he was then appointed as Director of the Center of Theoretical Physics (1983-89) and in 1983 Cecil and Ida Green Professor of Physics.

He held the position of Visiting Professor in many scientific Institutions in Europe and in the USA. He is Fellow of the Royal Society (1970), Fellow of the American Academy of Arts and Sciences (1977), and Fellow of the American Physical Society (1987). He received the Dannie Heinemann Prize of the American Physical Society (1981) and the Guthrie Medal of the Institute of Physics, London (1983). He is the author of many scientific publications. ♦

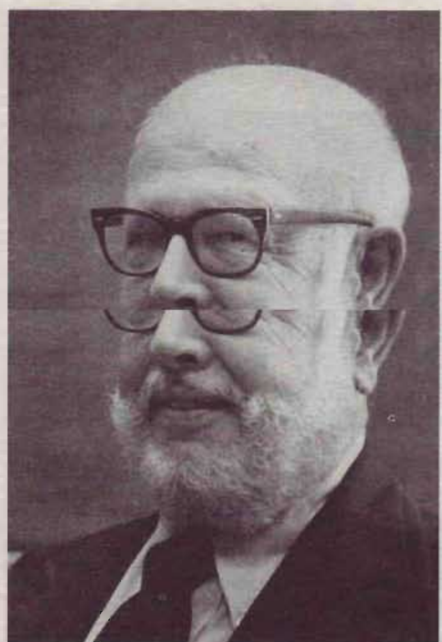
Professor Jeffrey Goldstone receiving the Dirac Medal of 1991 from Professor Abdus Salam, Director, International Centre for Theoretical Physics, and President, TWAS, on 28th July 1992, in the Main Lecture Hall of the ICTP.

Pierre Gilles de Gennes (France), 1991
"for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers".
Dates of visits:
1968, June 9 – 13
1974, July 15 – 17
1976, June 6 – 8
1989, October 31 – November 3.

Thirty-five Nobel Laureates have visited the ICTP since 1964. The citations for the Prize and dates of their visits are given for five of them in this issue. More will be published in future ICTP newsletters.



Paul Adrien Maurice Dirac (UK), 1933
"for the discovery of new and productive forms of atomic theory".
Dates of visits:
1968, June 10 – 15
1969, August 24 – September 10
1970, July 25 – August 20
1971, July 4 – August 4
1972, September 5 – 26
1973, August 13 – September 16
1978, September 21 – October 8
1979, June 30 – July 13.



William Alfred Fowler (USA), 1983
"for his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe".
Date of visit:
1968, June 19 – 28.

Ilya Prigogine (Belgium), 1977
"for his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures".
Date of visit:
1968, June 25 – 29.

Tsung-dao Lee (USA), 1957
"for penetrating research on the laws of parity which has led to important discoveries regarding elementary particles".
Dates of visits:
1968, June 17 – 18
1974, September 11 – 14.

New Director for Mathematics

Professor James Eells is retiring from the University of Warwick and as ICTP's Director of Mathematics this Autumn. He has been associated with the Centre for the past 20 years, six of which were as Founding Director of Mathematics. He has directed the Mathematics Group of the ICTP since 1986 with great competence and efficiency.

The Director and the Staff of the ICTP express their appreciation and gratitude for all the outstanding services rendered to the Centre and, in particular, to the mathematicians from the developing countries. They wish him a pleasant retirement in Cambridge.

Professor M.S. Narasimhan (Tata Institute of Fundamental Research, Bombay, India), an Associate Staff Member at the International Centre for Theoretical Physics, has been appointed as new Director for Mathematics at ICTP.

He was born on June 7, 1932, in India. He joined the Tata Institute of Fundamental Research (TIFR) in 1953 as a research student and did his thesis under the supervision of Prof. K. Chendrasckharan. His post-doctoral work was carried out in Paris for a two-year period with Professor Laurent Schwartz. He has been associated with the Tata Institute in various capacities: Professor 1965-1975; Senior Professor 1975-1990; Professor of Eminence since 1990. He was also Chairman of the 1990. He was also Chairman of the National Board for Higher Mathematics, Government of India, from 1983 to 1987. He was a member of the Executive Committee of the International Mathematical Union (IMU) and is, at present, Chairman of the Commission for Development and Exchange (CDE) of IMU.

In 1987, he received the TWAS Mathematics Award *"for his fundamental contributions to mathematics in the areas of algebraic geometry, differential geometry, representation theory of semi-simple groups and partial differential equations"*. ♦

Activities at ICTP in July/August 1992

Title: SUMMER SCHOOL ON HIGH ENERGY PHYSICS AND COSMOLOGY, 15 June – 31 July.

Organizers: Professors E. Gava (University of Trieste, Italy), K.S. Narain (ICTP), S. Randjbar-Daemi (ICTP), E. Sezgin (Texas A&M University, College Station, USA) and Q. Shafi (University of Delaware, Newark, USA).

Lectures: Conformal field theories and quantum groups. The n-loop string amplitude: explicit formulas and treatment of the odd spin structures. Liouville theory and matrix models. BRST analysis of 2-gravity. 2-d gravity and 2-d string theory. Topological field theory. W-gravity and strings. Deformation of conformal field theories and integrable models. Topological field theories and integrable models. 1-d string via matrix models. Induced gauge theory at large N. Geometry of supersymmetric vacua. Integrable models and quantum groups. 2-d gravity and non-critical string theory. Mirror symmetries in string theory. Introduction to the electroweak model. Introduction to supersymmetry. Introduction to functional methods, gauge theories and quantization. Global symmetries, chiral Lagrangians and perturbation theory. Introduction to renormalization theory and QCD. Unified approach to Yang-Mills and Higgs fields. Quark mass hierarchies from a universal see-saw mechanism. Results from GALLEX. mechanism. Results from GALLEX. Grand unification: current status and future perspective. Precision tests of the electroweak model. Supersymmetric standard model; SUSY GUTS. Rare decays, mixing and CP violation. Non-perturbative electroweak theory. Neutrino physics. Baryon and lepton number violation in the electroweak model. Review of lattice theories. Seminar on LEP results. Foundation of the standard big bang model. Introduction to large scale structure (observations); dark matter. Inflationary scenario; motivation, implications. Microwave background isotropy; anisotropy calculations. Introduction to topological defects; monopoles, strings, textures. Large scale structure after COBE. Cosmic strings in cosmology. Observable consequences of cosmic strings.

Seminars: Heavy quark physics. Inflation generated gravitons. Microwave background anisotropy measurements. A predictive framework for fermion masses and mixings. Global symmetries and wormholes. Models for neutrino dark matter and the ionisation of hydrogen in the universe. From atmospheric to solar neutrino oscillations.

Workshop on superstrings and related topics, 2 – 3 July: Open string scattering. BRST cohomology ring in 2d gravity coupled to minimal models. Physical states in c<1 strings. Ground ring at different radii in c=1 string theory. Quantum Drinfeld-Sokolov — a reduction of the Knizhnik-Zamolodchikov equation. Black holes and solitons in string theory. Black holes in cosmological Einstein-Maxwell theory. Symmetries of string effective action. Exact solutions of four dim. black holes in string theory. KP-hierarchy and matrix models. Integrable models through quantum group truncation. Landau-Ginzburg vacua and mirror symmetry. Moduli dependence of couplings in string theory. Self-duality, supersymmetry and integrable systems. A geometrical construction of W-algebras. The spectrum of W-string theories. A new supersymmetric index. theories. A new supersymmetric index. From here to criticality. On amplitudes in non-critical N=2 strings. A class of finite 2-dim. sigma models and string vacua.

Report of the Directors (by E. Gava): The School was divided into two parts: the first part, from the beginning till July 3rd, was focused on more formal aspects of modern theoretical physics, basically related to string theory, quantum gravity and integrable systems. The last two days were devoted to a Workshop, open to contributions of participants.

The second part was devoted to phenomenological aspects of high energy physics and cosmology.

There were altogether 35 lecturers and 204 participants, almost equally distributed between the two parts (some of the selected participants were allowed, on the basis of their background and origin, to attend both parts). Concerning the spectrum of the participants, we had, together with the great majority coming from developing countries and supported by ICTP, a significant number of (cost-free) participants coming from developed countries (USA and Europe). I think this is something that we should try to guarantee even for the future (keeping the scientific level of the School on high standards), having a two-fold, positive meaning: first of all, it is an indication of the fact that the School made a good name for itself, as far as choice of topics and lecturers is concerned. Secondly, in addition to contributing to making the atmosphere of the School more lively, it gives the possibility of interactions among participants from advanced and developing countries, with obvious scientific benefit for the latter.

We had three lectures a day, of one hour and a quarter each, two in the morning, one in the afternoon. A discussion session was put at the end of each week.

Both the first and second parts had introductory lectures, with the purpose of providing to the audience some basic notions, useful for a better understanding of the subsequent, more advanced material: in the first part, Gava and Narain lectured on 2D gravity, Bonora (SISSA) on CFT and quantum groups. In the second one, we had lectures on QFT by Iengo (SISSA), on the standard model by Senjanovic (ICTP), on renormalization theory by Landshoff (Cambridge), on supersymmetry by

renormalization theory by Landshoff
(Cambridge), on supersymmetry by

Shamir (ICTP).

The main topics developed in the first part were 2D gravity and 2D string theory, by I. Klebanov (Princeton) and M. Bershadsky (Harvard), integrable systems by G. Mussardo (SISSA), N. Warner (S. Cruz), C. Vafa (Harvard), topological field theory by G. Thompson (Mainz), W-gravity by C. Hull (Imperial College), each of them giving from three to four lectures. We also had two lectures by V. Kazakov (ENS) on every new proposal (by him and A. Migdal) of an exactly solvable model of induced QCD (in 4-d), which has attracted a lot of interest since then.

As mentioned before, the first part of the School ended with a two-days Workshop, including 20 speakers, half of which were School participants selected by the Directors.

The second part was articulated along the following main themes: neutrino physics By P. Langacker (Phil.), precision tests of the Standard model by A. Ali (Desy), chiral perturbation theory by J. Gasser (Bern), baryon number violation in the EW theory through non-perturbative effects by L. McLerran (Minnesota) and V. Rubakov (Moscow), superunification by R. Arnowitt (AM) and J.C. Pati (Maryland). C. Rebbi (Boston U.) reported on the recent developments in numerical simulations of lattice gauge theories. The last week was devoted to cosmological-astrophysical aspects after COBE data, with R. Schaefer (Bartol RI), A. Stebbins (Fermilab). We also had experimental seminars by E. Bellotti on the very recent GALLEX (G. Sasso) data on solar neutrinos, R. Batley on LEP results and C. Lineweaver (Lawrence Berkeley L.) on microwave background anisotropy measurements, in addition to some seminars given by participants.

As a general remark about the School, it should be mentioned that, both in the first and in the second part, the attendance was always quite satisfactory, and actually, for the second one, better than in the past few years. The discussion sessions were also quite lively throughout all the School. Perhaps this indicates that the careful (and lucky) job done by the committee which selected the participants (Gava, F. Hussein, Narain and Randjbar-Daemi) paid off.

Title: RESEARCH WORKSHOP IN

Title: RESEARCH WORKSHOP IN CONDENSED MATTER, ATOMIC AND MOLECULAR PHYSICS, 22 June – 11 September.

Organizers: Professors G. Baskaran (Institute of Mathematical Sciences, Madras, India), E. Burstein (University of Pennsylvania, USA), P.N. Butcher (University of Warwick, UK), H. Cerdeira (Universidade Estadual de Campinas, UNICAMP, Campinas, Brazil, and ICTP), F. Garcia-Moliner (Instituto de Ciencias de Materiales, Madrid, Spain), I.M. Khalatnikov (Landau Institute for Theoretical Physics, Moscow, Russia, and Max-Planck Institut für Astrophysics, Garching, Germany), V. Kumar (Indira Gandhi Centre for Atomic Research, Kalpakkam, India, and ICTP), A. Levi (Università di Genova, Genoa, Italy), S. Lundqvist (Chalmers University of Technology, Göteborg, Sweden, and ICTP), Chi Wei Lung (Institute of Metal Research, Academia Sinica, Shenyang, P.R. China), N.H. March (University of Oxford, UK), A. Mookerjee (S.N. Nose National Centre for Basic Sciences, Calcutta, India), F.S. Persico (Università di Palermo, Italy), E. Tosatti (International School for Advanced Studies, SISSA, Trieste, Italy, and ICTP), M.P. Tosi (Scuola Normale Superiore, Pisa, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP).

In co-operation with the International Centre for Science and High Technology (ICS, Trieste, Italy).

Plenary Seminars: Kondo insulators. What we *do* and do not understand in heavy fermion physics. High-T_c transport properties: what is and what is not anomalous. Scaling in non-equilibrium nonlinear equilibrium nonlinear systems: where are the fractals? Dynamic roughening of surfaces and interfaces. Earthquakes as self-organized critical phenomena. Isoscalar surfaces in turbulence fractal? Collective phenomena. Vortices in layered superconductors. Uncertainty principle for non-Hermitian operators, Bose superfluidity and order parameter in Fractional Quantum Hall effect. Hall effect above T_c in superconductors. The micron superlattice of ferroelectrics. Work function and surface energy of metals. Density functional calculations of electron-phonons in High T_c superconductors. Quasicrystals.

of electron-phonons in High T_c
superconductors. Quasicrystals.

Rydberg atoms in temporally periodic fields. Evaporation-deposition processes: jamming and generalised quantum Heisenberg models. Chaotic systems: counting the number of periods. Hubbard model: an augmented space formalism. Theoretical description of dynamic charge transfer processes at surfaces.

Group Meetings: Classical and quantum liquids. Semiconductors. Atomic physics.

Working Group Activities:

Liquids - Electron Gas: Concentration fluctuations in liquid metal alloys. The concept of stabilized jellium and its application to planar and curved surfaces. Fluctuating - dipole interactions homogeneous electron gas. Gradient expansions for kinetic energy density functional in various dimensions. Plasmon damping in 3D jellium. Local field factor for 2D electrons from Quantum Monte Carlo. Computer simulation of critical phenomena in fluids. Charged hard spheres: story so far. Gradient expansions for kinetic energy density functional in various dimensions. Ab-initio MD study of Li_{12} Si_7 liquid alloy. Effective interactions between concentration fluctuations and charge transfer in chemically ordering liquid alloys.

Semiconductors: Acceptor related photoluminescence spectra of GaAs-(Ga,Al)As quantum wells and wires. Envelope function calculations for semiconductor superlattices. Electrical, thermal and thermoelectric transport in quantum point contacts. Electromagnetic absorption of finite systems and the crossover to the macroscopic behaviour. Phonon spectra in low dimensional semiconductor systems. Green's functions (Kjeldysh) in the study of resonant tunneling. On the magnetic-field dependence of the electronic charge density in semiconductor heterojunctions. Negative-donor centers (D^-) in two dimensions. Electronic states in GaAs/AlGaAs quantum wells with periodically structured interfaces. Confinement of acoustical modes due to electron-phonon interaction within 2D electron gas. Optical stark effect of the exciton in quantum wells. Exact solutions of the restricted Hartree-Fock equations for arbitrary p/q filling factors. Spin
arbitrary p/q filling factors. Spin
relaxation of 2D-electrons in semiconductors. Quantum-interference resonant photocurrent in semiconductors. Electronic structure of III-V semiconductor oxides. Rigorous approach to the construction of pseudopotential for molecular clusters. Electric-field effect on spatially dependent screening of impurity states in quantum wells.

Defects or Mechanical Properties: The defect studies in condensed matter physics. Dislocation contrast by transmission electron microscopy (T.E.M.) — Burgers vector characterization. Ar-ion plasma generation of point defects in Si. The preparation of nanocrystalline materials. The structure and properties of nanocrystalline materials. Ultradiffusion on the fractal branching Koch curves. Multi-range and multi-scaling fractals in fractures. High resolution electron microscopy studies on quasicrystals in quenched Fe-Nb alloy interfaces of semiconductor and electrolyte. Positron lifetime of defects in crystallization of $Fe_{78}Si_9B_{13}$ amorphous alloy.

Strongly Correlated Systems: Some remarks on fermion-based and boson-based anyons. Induced fractional vacuum charge and the Aharonov-Bohm effect. Analytical methods in the study of quasi-two dimensional quantum antiferromagnets.

General: Dynamical properties of quasicrystals. A two dimensional model of localized modes for (CH)x. Hall Anomaly: Does it provide any clue to the mechanism of high T_c superconductivity?

Working Party on "States of matter at high magnetic fields", 20 - 24 July:

Lectures: Current density functional theory I: formalism. Quantum melting in 2D electron gas and flux lattice melting. Superconductivity in high magnetic fields. Edge states in the quantum Hall effect. Current density functional theory II: Local density approximations. Vortices in superconductors. Quantum transport, defect waves and flux creep. Current density functional theory III: Applications. Re-entrant melting transition in 2D electron gas in strong magnetic field. Relativistic density functional theory: reduction of a many-body electron problem to a one-electron Dirac equation. Photoluminescence in
Dirac equation. Photoluminescence in
quantum Hall systems.

Seminars: Phonons in the 2D Wigner crystal from density functional theory. Effect of exchange and correlation on the Fermi momenta of a 3D electron gas in magnetic field. Anderson confinement of Edge states. Dielectric susceptibility of a two dimensional electron gas in magnetic fields beyond RPA.

Working Party on "Noises in mesoscopic systems", 27 July - 7 August:

Lectures: Main ideas of mesoscopic physics. Noises: main mechanisms. Superconductivity and Coulomb blockade. Tunneling junctions.

Seminars: Resonant magneto-tunneling in a double-barrier structure. Thermoelectricity and thermo-conductivity in quantum wires. A model study of disordered mesoscopic rings in magnetic field. Co-tunneling and noises in tunneling junction systems. Magnetoconductance fluctuation of mesoscopic rings by tight-binding approach. Resonant scattering by impurities with correlated electrons. The impurities in A^4 B^6 semiconductors.

Round Table Discussion: Noisy level of noises in mesoscopic systems.

Working Party on: "Disordered alloys", 24 August– 4 September:

Lectures: LMTO-CPA on random alloys. Magnetism and ordering in alloys KKR on random alloys. The Möbius transformation. The Bütticker-Landauer characteristic barrier interaction terms for 1-D random layered structures. Electronic structure of isolated defects on crystalline surfaces.

Informatics Laboratory: Working with computer codes.

Technical Sessions: Recursion. Augmented space.

Working Party on: "Energy transfer in interactions with surfaces and adsorbates", 31 August – 11 September:

Lectures: Phonons at surfaces and their excitation by external probes. Electronic response of surfaces and adsorbates. Inelastic effects in the electronic spectra of adsorbates. Quantum versus semiclassical regimes of sticking. Vibrational lineshapes of adsorbates. HREELS and ARUPS from physisorbed molecules. The role of adsorbate degrees of freedom in sticking.
adsorbate degrees of freedom in sticking.
Inelastic effects in ESD and PSD from surfaces. Rhodium structure and phonon spectra. Charge exchange in particle scattering from surfaces. Light ion scattering from surfaces. Surface plasmons and electron microscopy. Inelastic effects in EELS of metal surfaces. Bortolani-Mills paradox in helium atom scattering. Inelastic He atom scattering (HAS) from surfaces. Anharmonic effects in surface phonons. Debye-Waller factor in atom-surface scattering. Multiphonon excitations in HAS from surfaces.

The Workshop was attended by 357 lecturers and participants (235 from developing countries).

Title: MINIWORKSHOP ON NON-LINEARITY: DYNAMICS AND SURFACES IN NONLINEAR PHYSICS, 13 – 24 July.

Organizing Committee: Professors S. Lundqvist (Chairperson; Chalmers University of Technology, Göteborg, Sweden, and ICTP), H. Cerdeira (Co-chairperson; Universidade Estadual de Campinas, UNICAMP, Campinas, Brazil, and ICTP), E. Tosatti (International School for Advanced Studies, SISSA, Trieste, Italy, and ICTP), M. Tosi (University of Trieste and Scuola Normale Superiore, Pisa, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP).

Course Directors: Professors T. Bohr (University of Copenhagen, Denmark), H.A. Cerdeira (UNICAMP, Brazil, and ICTP), M.H. Jensen (Nordisk Institut for Teoretisk Atomfysik, NORDITA, Copenhagen, Denmark) and I. Procaccia (The Weizmann Institute of Sciences, Rehovot, Israel).

In co-sponsorship with NORDITA and NORFA (Nordic Academy for Training of Researchers, Oslo, Norway).

Lectures: Various aspects of experiments in thermal turbulence. The wrinkled geometry of turbulence. Dynamic scaling of growing surfaces and interfaces: comparison with experiments. Theoretical aspects of interface growth problem. Role of wrinkled surfaces on quantum gravity. Surfaces in turbulence. Static wrinkling.

From 21 to 24 July, the participants in the Miniworkshop attended the lectures of the Adriatico Research Conference on wrinkling of surfaces in nonlinear systems.

The Miniworkshop was attended bv

The Miniworkshop was attended by 42 lecturers and participants (20 from developing countries).

Title: ADRIATICO RESEARCH CONFERENCE ON WRINKLING OF SURFACES IN NONLINEAR SYSTEMS, 21 – 24 July.

Organizing Committee: Professors S. Lundqvist (Chairperson; Chalmers University of Technology, Göteborg, Sweden, and ICTP), H. Cerdeira (Co-chairperson; Universidade Estadual de Campinas, UNICAMP, Campinas, Brazil, and ICTP), E. Tosatti (International School for Advanced Studies, SISSA, Trieste, Italy, and ICTP), M. Tosi (University of Trieste and Scuola Normale Superiore, Pisa, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP).

Course Directors: Professors T. Bohr (University of Copenhagen, Denmark), H.A. Cerdeira (UNICAMP, Brazil, and ICTP), M.H. Jensen (Nordisk Institut for Teoretisk Atomfysik, NORDITA, Copenhagen, Denmark) and I. Procaccia (The Weizmann Institute of Sciences, Rehovot, Israel).

In co-sponsorship with NORDITA, NORFA (Nordic Academy for Training of Researchers, Oslo, Norway) and SISSA.

Lectures: Experiments in 2-d turbulence. Scalar interfaces and scalar dissipation in turbulent jets. Time series, wrinkled surfaces and singularities in turbulent flows. Geometric statistics and turbulence. Scaling behaviour of one- and two-dimensional measurements of turbulence. Convective patterns on liquid-liquid interface in a binary mixture. Wrinkling transition in polymerized membranes. The growth of rough surfaces in the presence of quenched multiplicative noise. Statistical mechanics of randomly charged polymers. Interface dynamics in imbibition. Scale invariant fluctuations and the maximum complexity principle. The butterfly effect and predictability in turbulence. Intermittency in Fourier-Weierstrass analysis of high Re turbulence. An analytic solution to intermittency corrections in the shell model. Understanding glassy directed polymers through stochastic surface dynamics. Fluid displacement in porous media. Surface roughening in flame propagation and crystal growth: KPZ and KS models in d-dimensions. Radial growth and the tip-splitting instability. KS models in d-dimensions. Radial growth and the tip-splitting instability. Electrochemical growth. Phase transitions of interfaces in driven diffusive systems.

The Conference was attended by 59 lecturers and participants (25 from developing countries).

Title: ADRIATICO RESEARCH CONFERENCE ON SYNERGETICS IN CONDENSED MATTER, 4 – 7 August.

Organizing Committee: Professors S. Lundqvist (Chairperson; Chalmers University of Technology, Göteborg, Sweden, and ICTP), H. Cerdeira (Co-chairperson; Universidade Estadual de Campinas, UNICAMP, Campinas, Brazil, and ICTP), E. Tosatti (International School for Advanced Studies, SISSA, Trieste, Italy, and ICTP), M. Tosi (University of Trieste and Scuola Normale Superiore, Pisa, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP).

Course Directors: Professors G. Denardo (ICTP), H.P.J. Haken (Universität Stuttgart, Germany) and S.O. Lundqvist (Chalmers University of Technology, Göteborg, Sweden, and ICTP).

In co-sponsorship with the Commission of the European Communities, Fondazione IBM Italia and SISSA.

Lectures: Non-equilibrium phase transition in semiconductors. Self-organized spatio-temporal pattern formation in semiconductors. Dissipative structure formation in the electric breakdown of solids. Synergetics: from pattern formation to pattern recognition. Pattern formation and routes to chaos in the Taylor-Couette experiment. Hydrodynamic instabilities in rotating systems. Interaction of perturbations and patterns in convectively unstable pattern forming systems. Two-dimensional models for three-dimensional convection instability. Spatio-temporal patterns in reaction-diffusion systems. Solitary waves and solitons in non-equilibrium media. Some aspects of the transition to space-time chaos and turbulence in convection. Pattern formation in rotating Benard convection. Stochastic resonance: energy transfer from microscopic freedom to a coherent macroscopic freedom. Unbiased estimation of forces causing observed macroscopic freedom. Unbiased estimation of forces causing observed processes. Time-dependent Hamiltonian dynamics into the maximum entropy principle context. Hamiltonian dynamics in planetary-type fluid flows.

The Conference was attended by 27 lecturers and participants (11 from developing countries).

Title: MINIWORKSHOP ON METHODS OF ELECTRONIC STRUCTURE CALCULATIONS, 10 – 21 August.

Organizers: Professors O.K. Andersen (Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany) and V. Kumar (Indira Gandhi Centre for Atomic Research, Kalpakkam, India, and ICTP), with the co-sponsorship of the International Centre for Science and High Technology (ICS, Trieste, Italy).

Lectures: Density functional theory. Linear combination of muffin-tin orbitals (LMTO) and the periodic table. Solving electronic structure problems with the recursion method. Tight binding LMTO. Pseudopotentials. Augmented space formalism for disordered systems. First principles investigation of epitaxial interfaces using LMTO-supercell approach. Density functional theory beyond LDA. Density functional molecular dynamics. Interatomic interactions in the effective medium theory. PAW: an all-electron technique for first principles molecular dynamics. Band structure calculations for incommensurate spiral magnetic structures. Towards very large scale electronic structure calculations. Energies of oxygen vacancies in MgO. Car-Parrinello molecular dynamics with the Vanderbilt pseudopotentials. First principles calculations of self-diffusion constants in silicon. Density functional perturbation theory. Atomic and electronic structure of clusters from Car-Parrinello method. Calculated phonon dispersions of Nb using linear response method.

Computer exercises: Computer codes.

Informal discussions: Pseudopotentials. Car-Parrinello method. Large scale electronic structure calculations. Density functional theory.

The Miniworkshop was attended by 69 lecturers and participants (43 from developing countries).
69 lecturers and participants (43 from developing countries).

Report of the Directors: The Miniworkshop focussed on some of the important developments in the area of the electronic structure calculations in condensed matter. These included the density functional theory, linear combination of muffin tin orbitals (LMTO), effective medium theory, recursion method, pseudopotentials and the ab-initio molecular dynamics techniques and their application to some physical problems. As it is now becoming possible to perform some of the above mentioned state-of-the-art calculations even on personal computers, which are becoming increasingly accessible to scientists in developing countries, this Miniworkshop provided them an opportunity to not only learn the development but also to get a hand-on experience on some of the best computer codes. We installed LMTO (Skriver), tight binding LMTO (Andersen), recursion library (Haydock) and LMTO-recursion (Vargas-Mokerjee) programmes on ICTP computers. Participants could carry home these programmes and a few even used the programmes to work on their own problems. This aspect was appreciated very much by the participants and it is suggested that a library of these programmes be maintained for future use by the ICTP visitors. A demonstration of molecular dynamics using the effective medium theory was also made by Professor Jacobsen.

Seventy-one participants from 30 countries specifically participated in this activity. Ten participants were cost-free and most of the participants from East European countries came with their own travel grant. Some participants continued their stay to attend the Working Party on disordered alloys.

Some participants complained about the computer facilities at the ICTP as computer power even comparable to CONVEX is now becoming available on workstations. An upgrading of these facilities is strongly recommended.

In summary, this Miniworkshop has been very successful and it would be useful to organize a follow-up activity in this field for 1994.

Title: WORKSHOP ON TROPICAL CLIMATE VARIABILITY AND REGIONAL IMPACTS, 17 – 21 August.
CLIMATE VARIABILITY AND REGIONAL IMPACTS, 17 – 21 August.

Organizers: Professors G. Furlan (University of Trieste and ICTP), V. Krishnamurthy (International Institute for Earth, Environmental and Marine Sciences and Technologies, IIEM, Trieste, Italy), R. Legnani (Istituto per lo studio delle metodologie geofisiche ambientali-CNR, Modena, Italy), A.D. Moura (Instituto de Pesquisas Espaciais, INPe, São José dos Campos, Brazil, and National Oceanic and Atmospheric Administration, Silver Spring, USA) and J. Shukla (University of Maryland, College Park, USA).

Lectures: Climate and global change research at IIEM. International Research Institute for Climate Prediction. Climate prediction and economical development in tropical countries. Australian operational seasonal forecasting services and supporting research. Changing climate and global change: United States and international perspectives. Effects of 30/60 day oscillation over tropical South America. Tropical forests and climate. Interannual variability of rainfall in the South American Altiplano and associated mechanisms. Climate monitoring in Northeast Brazil. Variability and long-range forecasting of Indian summer monsoon rainfall. Changing predictability of Indian monsoon rainfall anomalies. Seasonal predictability experiments with the ECMWF model. Predictability of seasonal averages. Causes, mechanisms and predictability of seasonal rainfall variability in sub-Saharan North Africa. Modelling of long-term climate variability. Mechanisms of variability and predictability of the tropical ocean-atmosphere system. Is tropical climate more predictable? Tropical-extratropical interactions and their relevance for tropical predictability. East Asian monsoon variability and relationships with tropical sea surface temperature. GCM simulated sensitivity of Indian summer monsoon to Eurasian snow cover. Principal modes of atmospheric circulation anomalies associated with global angular momentum fluctuations. Sensitivity of numerical predictions in subtropical South America to initial conditions and model resolution.The influence on cloud cover on tropical Atlantic sea surface temperature simulations. Seasonal and interannual signals of SST and thermal profiles in the tropical Atlantic given by an OGCM.
signals of SST and thermal profiles in the tropical Atlantic given by an OGCM.
Monsoon and the ENSO.

Round-table Discussion on ENSO application centers.

The was attended by 37 lecturers and participants (20 from developing countries).

Title: ADRIATICO RESEARCH CONFERENCE ON HYDROGEN ATOMS IN INTENSE ELECTROMAGNETIC FIELDS, 18 – 21 August.

Organizing Committee: Professors S. Lundqvist (Chairperson; Chalmers University of Technology, Göteborg, Sweden, and ICTP), H. Cerdeira (Co-chairperson; Universidade Estadual de

Workshop on tropical climate variability and regional impacts, 17 – 21 August.

Campinas, UNICAMP, Campinas, Brazil, and ICTP), E. Tosatti (International School for Advanced Studies, SISSA, Trieste, Italy, and ICTP), M. Tosi (University of Trieste and Scuola Normale Superiore, Pisa, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP).

Course Directors: Professors L. Armstrong Jr. (Johns Hopkins University, Baltimore, USA) and N.K. Rahman (International Centre for Pure and Applied Chemistry, IIC, Trieste. Rahman (International Centre for Pure and Applied Chemistry, IIC, Trieste, Italy).

In co-sponsorship with Fondazione IBM Italia and SISSA.

Lectures: Atoms and electrons in strong laser fields: what have we learned since 1980? Atomic and molecular stabilization in intense laser fields. Radiate (QED) processes for hydrogen atoms in intense electromagnetic fields. Strong-field ionization, stabilization and atomic-state effects. Keldysh-like approximations for multiphoton ionization: when are they valid? Interference stabilization of population at Rydberg levels of the hydrogen atom in a strong ionizing laser field. Classical scaling of nonclassical stability in microwave ionization of hydrogen atoms and its destruction by additive noise. Stability and chaos for Rydberg atoms in strong electromagnetic fields. Classical and quantal effects of high-frequency fields on excited hydrogen. The trapping of population in Rydberg atom wavepackets. Classical theory of intense field stabilization. Dissociation dynamics of hydrogen molecule. Adiabatic stabilization. Role of classical structures in intense-field stabilization. Calculation of the photoelectron energy structures in intense-field stabilization. Calculation of the photoelectron energy spectrum for multiphoton ionization of hydrogen. Stabilization of atoms in ultraintense laser pulses: a classical approach. Decay and formation of hydrogen atom in intense laser fields. An approach to above-threshold ionization in two electromagnetic fields. Comparisons of multiphoton ionization by circularly polarized light in the non-relativistic and relativistic regimes. Target dressing and polarization effects in laser assisted X-ray photoionization. Photoionization of hydrogen using the strong field approximation: calculation of ion yield for a time dependent laser pulse. Transient stabilization: creation of an antiwave packet. The role of Rydberg states as resonant intermediates in sub-picosecond MPI. Hydrogen atoms in intense short laser pulses. Bichromatic photoionization in intense fields.

Round Tables: H^-. Stabilization.

The Conference was attended by 53 lecturers and participants (25 from developing countries).

Title: SUMMER COURSE ON LOW-DIMENSIONAL QUANTUM FIELD THEORY FOR CONDENSED MATTER PHYSICISTS, 24 DIMENSIONAL QUANTUM FIELD THEORY FOR CONDENSED MATTER PHYSICISTS, 24 August – 4 September.

Organizers: Professors S. Lundqvist (Chalmers University of Technology, Göteborg, Sweden, and ICTP), G. Morandi (University of Bologna, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP).

In co-operation with the International Centre for Science and High Technology (ICS, Trieste, Italy).

Lectures: Some geometry and topology. Exactly soluble models. Field theory methods in condensed matter: fermions; bosons; fermions meet bosons; application to pure Ising models; random Ising model. Chern-Simons field theory and the QHE. Gauge symmetries, topology and quantization. Anyons and anyon superconductivity: introduction to anyons; RPA for anyons; self-consistent Hartree approximation for anyons; self-consistent Hartree-Fock approximation for anyons. Methods of conformal field theory in condensed matter physics. Gauge field approach to magnetism and superconductivity. Fermion field theory approach to the FQHE.

The Course was attended by 132 lecturers and participants (76 from developing countries).

Title: ADVANCED WORKSHOP ON ARITHMETIC ALGEBRAIC GEOMETRY, 31 August – 11 September.

Organizers: Professors A.H. Assadi (University of Wisconsin, USA) U. Jannsen (Universität zu Köln, Germany) and N. Schappacher (Université Louis Pasteur, Strasbourg, France).

Lectures: Arakelov theory — the basic ideas. Algebraic geometry. Complex geometry. Algebraic number theory. Schemes and sheaves: review of the first AG-courses. Topological theory of characteristic classes; an alternative approach to the one used in the TDG course. Riemann surfaces; complex (and complex algebraic) geometry in dimension 1. Cohomology theories. Topology and differential geometry. Examples of explicit calculations in algebraic number theory. Kähler manifolds; complex geometry, Hodge theory, and metrics. Intersection theory on algebraic surfaces. Chern-Weil theory. Algebraic surfaces and Mordell's conjecture over function fields. Algebraic curves and their Jacobians. Classical algebraic number theory. Arithmetic of elliptic curves. Derived categories. Arakelov theory and applications. Rank of elliptic curves, Néron height and intersection number, with computer applications. Elliptic complexes and differential operators. Green's functions. Counting points on elliptic curves over finite fields. Grothendieck-Riemann-Roch. Geometric invariant theory (G.I.T.). Fibred surfaces. Abelian varieties. Abel-Jacobi theorem. Abelian varieties over C and theta-divisors. Green's functions via theta-functions. Arithmetic curves; algebraic number theory interpreted in Arakelov's way. Jacobian and Picard variety. Applications of G.I.T. to curves and Abelian varieties. Arakelov theory and applications (2): ampleness. Analytic theory of Teichmüller space. Vector bundles on curves (d'après Faltings). Periods of algebraic curves, the arithmetic-geometric mean, and generalizations.

Round Table: Mathematics in the Third World.

The Workshop was attended by 134 lecturers and participants (82 from developing countries).

Title: COLLEGE ON MEDICAL PHYSICS: IMAGING AND RADIATION PROTECTION, 31 August – 18 September.

Organizers: Professors A.M. Benini (International Atomic Energy Agency, IAEA, Vienna, Austria), R. Cesareo (Università "La Sapienza", Rome, Italy), J. Chela-Flores (ICTP), H.A. Farach (University of South Carolina, Columbia, USA) and S. Mascarenhas (Universidade de São Paulo, São Carlos, Brazil).

Lectures: The programme of the

Advanced Workshop on arithmetic algebraic geometry, 31 August – 11 September.

Commission of the European Communities (CEC). The IAEA programme. The approach of CEC to radiation protection and image quality in diagnostic radiology. Radiation detectors and electronics. Radiation protection principles and practice (with video presentation). Interaction of radiation with matter. Principles of ESR. Physics of radiological imaging. Principles of X-ray tomography. Fundamentals of radiation dosimetry. Dosimetric techniques and instrumentation. Medical radiation exposure. Uses and applications of X-ray tubes. Dosimetric instrumentation and TLDS. Radiation detectors and related electronics. Personnel dosimetry. Minitomographic unit. Quantitative analysis of diagnostic imaging. Quality control measurements in diagnostic radiology. Tests on radiological equipment; LEEDS Test, grid characteristics. Minimum requirements of quality control programmes in developing countries. ESR dosimetry. Quality control measurements in CT units. Physical principles of ultrasound diagnostic equipment. Quality control of ultrasound equipment. Introduction to NMR spectroscopy. Low exposure risk or not. Principles of reconstruction methods. Principles of NMR. Clinical results of NMR. Physical principles of biomagnetism. Radiation protection and quality assurance in diagnostic radiology. Maintenance problems in X-ray diagnostic equipment. Introduction to patient dose reduction in diagnostic radiology. Overview of radiological accidents. Planning of radiological departments. Organization of radiation protection in hospitals. The application of the Monte Carlo method in medicine. Screen characteristics in diagnostic radiology. Nuclear medicine equipment. Radiation protection and quality assurance in nuclear medicine. Occupational exposure. The programme of WHO. Adequate radiological equipment for developing countries. Quality control in mammography. Image quality criteria status of the CEC project. New ICRPs recommendations. The International Chernobyl Project.

Practical Sessions: Radiation detectors and related electronics. Minitomographic unit. Uses and applications of X-ray tubes. Dosimetric instrumentation and TLDS. NMR spectrometry. Software for image reconstruction. Use of Matrox Card. Radiation protection and quality control of X-ray equipment. Testing of ultrasound equipment and visit to the Hospital.

Projection of films on radiation protection with discussion.

Round Table Discussion: The situation of medical physics in developing countries and presentations by participants.

Working Sessions: Image quality criteria. Patient dose reduction.

The College was attended by 84 lecturers and participants (60 from developing countries). ♦

College on medical physics: imaging and radiation protection, 31 August – 18 September.

Calendar of Activities at ICTP

1992

Workshop on commutative algebra .... 14 – 25 September

Fourth International Conference on applications of physics in medicine and biology: advanced detectors for medical imaging .... 21 – 25 September

WMO Workshop on limited area modelling .... 28 September – 2 October

College on methods and experimental techniques in biophysics .... 28 September – 23 October

Second College on microprocessor-based real-time control — Principles and applications in physics .... 5 – 30 October

Second Trieste Conference on recent developments in the phenomenology of particle physics .... 19 – 23 October

Conference on chemical evolution and the origin of life .... 26 – 30 October

School on physical methods for the study of the upper and lower atmosphere system .... 26 October – 6 November

Second Autumn Workshop on mathematical ecology .... 2 – 20 November

Workshop on three-dimensional modelling of seismic waves generation, propagation and their inversion .... 30 November – 11 December

1993

Sixth International Workshop on computational condensed matter physics .... 11 – 13 January

Experimental Workshop on high temperature superconductors and related materials (advanced activities), San Carlos de Bariloche, Argentina .... 11 – 29 January

Fourth Training College on physics and technology of lasers and optical fibres .... 18 January – 5 February

Second Workshop on functional-analytic methods in complex analysis and applications to partial differential equations .... 25 – 29 January

Third ICTP-URSI College on theoretical and experimental radiopropagation physics .... 1 – 26 February

Third ICTP-URSI College on theoretical and experimental radiopropagation physics .... 1 – 26 February

Winter college on optics .... 8 – 26 February

Workshop on scientific aspects of the rural communications in developing countries .... 1 – 5 March

Adriatico Research Conference on quantum interferometry .... 2 – 5 March

Conference on "Highlights of particle and condensed matter physics" .... 8 – 12 March

Workshop on representation theory of Lie groups .... 15 March – 2 April

Spring School and Workshop on superstrings .... 19 – 30 April

Meeting on "Intracellular channels, organelles and cell function" .... 21 – 23 April

Sixth Workshop on perspectives in nuclear physics at intermediate energies .... 3 – 7 May

Workshop on qualitative aspects and applications of nonlinear evolution equations .... 3 – 14 May

School on ocean-atmosphere interactions in the Tropics .... 10 – 28 May

College on computational physics .... 17 May – 11 June

Spring College on plasma physics	**17 May – 11 June**
Summer School in high energy physics	**14 June – 13 August**
including	
Third School on non-accelerator particle astrophysics	**28 June – 10 July**
Miniworkshop on strongly correlated electron systems	**21 June – 9 July**
Research Workshop in condensed matter, atomic and molecular physics	**21 June – 3 September**
Adriatico Research Conference on scattering from surfaces	**6 – 9 July**
Miniworkshop on the liquid state of matter: opportunities from new radiation sources	**19 – 30 July**
Miniworkshop on non-linearity: chaos in mesoscopic systems	**26 July – 6 August**
Adriatico Research Conference on mesoscopic systems and chaos, a novel approach	**3 – 6 August**
Conference on variational problems in differential geometry and partial differential equations	**16 – 20 August**
Adriatico Research Conference on vortex fluctuations in high T_c superconductors	**17 – 20 August**
Working Party on mechanical properties of interfaces	**23 August – 3 September**
Workshop on materials science and physics of non-conventional energy sources	**30 August – 17 September**
Course on geometric phases	**6 – 17 September**
College on soil physics	**6 – 24 September**
Second Workshop on composite media and homogenization	**20 September – 1 October**
Workshop on telematics	**27 September – 22 October**
Workshop on radioecology: mechanisms of transfer of radionuclides to the environment	**11 – 29 October**
Conference on the origin of life	**25 – 29 October**
Second School on the use of synchrotron radiation in science and technology: "John Fuggle Memorial"	**25 October – 19 November**
Trieste Conference in high energy physics	**8 – 12 November**
Second Workshop on non-linear dynamics and earthquake prediction	**8 – 26 November**
Workshop on VLSI technology	**22 November – 3 December**

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

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