The International Geosphere–Biosphere Programme—A study of global change

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THERE is overwhelming evidence now that, consequent upon the industrial revolution of the nineteenth century, global trends have been set in motion that will cause increase of carbon dioxide in the atmosphere and of the global mean temperature. This is attributed primarily to increased fossil-fuel burning and industrialization. There is also ample evidence for anthropogenic increase in amounts of other trace gases in the atmosphere, like methane, nitrous oxide and chlorofluorocarbons (CFCs), which contribute to the greenhouse effect in a disproportionately large way (see Table).

Global circulation models (GCM) developed for climate studies under simplified assumptions and without taking into serious account the important role of the biosphere indicate that the accelerating technological advances, fossil-fuel burning and world population pressure would lead to a global warming of perhaps 3–5°C within the next century[2,3]. If this does happen, it is expected to trigger major changes in the patterns of climate in different parts of the world, a significant sea level rise, and a rapid increase in the frequency of occurrence of extreme natural disasters. The consequences of this for human life on earth, and particularly for the developing countries, can only be vaguely foreseen even by specialists. Furthermore, such a growing trend will compel all countries to spend increasing fractions of their national resources on environment-related programmes to safeguard their very survival. The associated national decisions and priorities will distort all existing situations, patterns and traditions.

Palaeoclimate studies going back to about 150,000 years have already established the intimate correlation between the level of greenhouse gases, global temperature and global climate[4–7]. The last major ice age, which saw glaciers in southern Britain about 15,000 years ago, was associated with a decrease of global temperature[8,9] by about 5°C. Although this field of study is still in its infancy, it is expected to yield valuable information in the future. It must be noted, however, that climate changes in the past were due to natural forces free of human intervention and extremely slow in growth. During the last 10,000 years the global temperature has remained steady, within about a degree Celsius of the mean. But what of the future?

In any analysis of global climate and climate trends, the extreme complexity of the Earth system and its fragile environment must be kept in mind. On the one hand we have an intimately interconnected feedback system of oceans, land, atmosphere and the complex hierarchy of life forms from plankton to man. Linking them are the numerous geobiochemical processes, whose nature, magnitude and working are still to be scientifically and quantitatively studied and understood. Behind these processes are the natural forces due to solar and orbital variations, and from deep in the solid earth, and anthropogenic factors like fossil-fuel burning, deforestation and industrialization. During the past few decades we have witnessed an increasing number of international programmes initiated by UN bodies and non-governmental agencies like the International Council of Scientific Unions (ICSU) to address the many topics of concern in environment and ecology (in the widest meaning of these terms). Nevertheless, many of the key geobiochemical interactions and the influence of human actions on environment still await serious quantitative studies owing to intrinsic difficulties and our past ignorance. Global climate models developed so far do not incorporate many of these important inputs. For this and other reasons (like the existence of positive and negative feedbacks) many scientists and others are of the view that the predictions of the existing GCMs cannot be relied upon and what we are witnessing are likely to be part of the climate fluctuations going on all the time. In view of such a situation, and the overriding consequences and implications to the well-being of life on Earth if the predictions are true, people in power and governments are in doubt over investing in projects that may have global change-related impact. Thus, both from a scientific viewpoint, and for developing and establishing credibility for long-term predictions of a new kind of geosphere–biosphere global model, there is a compelling and inescapable need to mount a new long-term, multidisciplinary, internationally co-ordinated project. This effort would require the development of our capability and expertise 'to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life,

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Greenhouse gases in the atmosphere

	CO_2	CH_4	N_2O	Ozone (O_3)	CFC-11	CFC-12
Concentration (ppm)	346	1.65	0.31	0.02	0.0002	0.00032
Residence time (year)	100	10	150	0.1	65	110
Concentration increase (per cent per year)	0.4	1.0	0.2–0.3	0.5	5	5
Radiative absorption potential relative to 1 mole of CO_2	1	32	150	2000	14000	17000
Present per cent contribution by anthropogenic trace gases	5	19	4	8	5	10

the changes that are occurring in this system, and the manner in which they are influenced by human actions' (IGBP plan of action). This is the genesis of the International Geosphere–Biosphere Programme (IGBP) initiated by ICSU.

Organization

After a two-year study by a group of experts constituted as an *ad hoc* committee, ICSU decided on establishing IGBP in 1985. A Special Committee was then constituted by ICSU in 1987 to be responsible for planning and implementation of IGBP. The period 1987–90 is the preparatory and programme formulation phase; the operational phase will begin by 1990–91 and will continue for ten years in the first instance. The Special Committee has started preparations through a series of scientific meetings, workshops and consultations to define and sharpen the core programmes. The findings of these meetings are brought out as IGBP reports. There is already evidence that with more studies and consultations the scientific programmes are getting better oriented and focused to fill existing gaps, to identify key links, and to strike working arrangements with other international programmes. In parallel, the national IGBP committees are formulating their own plans and projects to participate in core programmes and to complement them.

The Indian National Science Academy, which is the adhering body to ICSU, constituted a national committee for IGBP in 1987. This committee is currently in the process of identifying and formulating a national long-term scientific programme for IGBP. The work of the committee is actively supported by scientific departments and agencies of the Government of India.

The scientific action plan

Following what has been said so far one may say that the overall objective of IGBP is to develop, ultimately, a global predictive model tested and validated adequately to forecast with reliability future global changes over decades and centuries. It will also be necessary to have information on uncertainties in the predictive model in a quantitative way. How does IGBP hope to achieve this?

The underlying themes

It is clear that in order to realize the overall objective of IGBP, priority will have to be assigned to areas that deal with key interactions and significant changes on timescales of decades to centuries that are (a) likely to affect most life on this planet (biosphere), (b) likely to be most susceptible to human perturbations, and (c) most likely to lead to the needed predictive modelling capability. While it is true that there are numerous international programmes that deal primarily with single discipline-oriented studies, like the World Ocean Circulation Experiment, Man and Biosphere Programme, Global Atmospheric Research Programme and Global Energy and Water Cycle Experiment, there are not enough to cover the key interactions of multidisciplinary nature that fulfil the priorities described above. IGBP has in the first place tried to identify such themes. Four have been included so far. They are:

(i) *Documenting and predicting global change.* Any global predictive model of the kind we need must incorporate in itself the quantitative connections between the geobiochemical processes as well as the physical and climate systems. It must also contain current and anticipated anthropogenic impacts. For this purpose we will need long-term series of global data and monitoring networks to document small future changes. Further, palaeoclimatic and other data for the past 30,000 years could be used in a powerful way to test models free from anthropogenic factors. On the other hand, any small trends to be detected in the future can be used to test the combined effects of natural and human impacts in the models.

(ii) *Observing and improving our understanding of dominant forcing functions.* It is evident that global changes must come about because of certain driving forces. There are external forces such as solar and orbital changes, as well as solid earth processes like volcanic eruptions and marine vents. Then there are effects of human action, like the release of CO_2 and other trace gases into the atmosphere, changes in land and water use, and industrialization. These give rise to a wide spectrum of secondary and tertiary effects covering the geosphere and biosphere. There are positive and negative feedbacks, making the total Earth system a very complex one indeed. Unless we identify and study such important links and feedbacks quantitatively, the model will remain incomplete.

(iii) *Improving our understanding of interactive phenomena in the total Earth system.* Biological responses to physical and chemical changes in the environment are typically nonlinear. This becomes important when we consider that the anticipated global warming of the next half century could be of the same magnitude as experienced by the Earth's ecosystems since the glacial maximum about 18,000 years ago[8,9]. The climate conditions projected for the near future are beyond the range of experience of the living organisms that have survived and adapted to the temperate and subtropical latitudes successfully as the Earth has warmed and cooled.

(iv) *Assessing the effects of global change that would cause large-scale and important modifications that affect the availability of renewable and nonrenewable resources.* It is IGBP's concern that the predictive capability for global change must also contribute in assessing the availability of natural resources for future generations. It is the hope that the predicted global changes will also be interpreted at local and regional levels in the global backdrop of changing patterns of temperature, precipitation, wind, etc. to the advantage of nations and regions.

Research areas

IGBP has carefully analysed and examined the underlying themes to extract from them the research topics unique and essential for IGBP. Five such areas have already been identified and a Co-ordinating Panel (CP) already constituted for each. These are:

CP-1 Terrestrial biosphere–atmosphere chemistry interactions

CP-2 Marine biosphere–atmosphere interactions

CP-3 Biospheric effects of the hydrological cycle

CP-4 Effects of climate change on terrestrial ecosystems

CP-5 Global analysis, interpretation and modelling.

It is evident that all the above areas are highly interdisciplinary and hence will require special efforts in co-ordination in terms of organization, scientific expertise and implementation. Indeed, it will require a new breed of scientists in good numbers to be introduced to IGBP and trained in such challenging areas.

The next step is to develop one or more core projects for each area, which, over a period of time, will generate data and information most relevant and needed for IGBP. A number of such projects have been identified and are being focused and structured for implementation. Others are still in the making. There are some ongoing international programmes that are close to the goals of IGBP. In these cases IGBP will attempt a joint partnership with them. The core projects will usually be organized and managed by IGBP.

Other scientific activities—the Working Groups

(i) *Data and information systems (WG-1).* International arrangements for the IGBP will have to be responsive to many challenges that transcend previous experience with collaborative scientific programmes. These challenges are presented by the range of disciplines involved, the need to blend new technology with traditional observational techniques on a world-wide scale, the need to plan and sustain a co-ordinated research and documentation effort over many decades, and the need to systematize and present in a timely manner both the conclusions and the basis for them on complex issues of substantial and growing public concern. Of particular importance are mechanisms relating to measurements and information systems.

An obvious high-priority need of IGBP is that of securing remotely sensed data for a critical suite of global parameters largely from spacecraft. These include physical and chemical properties of the land, ocean and ice cover, land-use changes, indices of primary biological production over land and oceans, tropospheric and stratospheric distributions of trace gases, and solar inputs to the Earth system. These and other ground-based data available and to be collected are to be deposited in a data bank. Methods and procedures for quick, easy and universal data dissemination will have to be worked out.

(ii) *Regional research centres (WG-2).* A network of IGBP (or global change) regional research centres will be designed to promote research on a regional basis. These centres will focus on interdisciplinary aspects of global change research. The number of RRCs is expected to be small (about 10) and to be located in different areas of the world on the basis of the scientific questions, geographic representativeness, existence of institutions of appropriate nature, and geopolitical considerations of national commitment, stability, etc. The RRCs should provide regional institutions with possibilities of expanding present interests towards global understanding and convenient access to global data sets. They would, especially, be involved in analysis, interpretation, synthesis and modelling of global change phenomena, and use this information for assessments and predictions at the regional level. Each RRC would develop differently according to site specificity, scientific questions and other considerations, but common to all the centres will be a minimum structure that assures that it can meet the general objectives.

(iii) *Global changes in the past.* Studies of the physical, chemical and biological parameters found in natural archives such as ice cores and tree rings, and in ocean, lake and terrestrial sediments have revealed a wealth of information on both the 'natural' and perturbed behaviour of the Earth system. Breakthroughs in this area, more than any other, have been responsible for the dawn of Earth system science. Quantitative information on global changes of the past can be used to put observed trends in contemporary data in broader context, to evaluate Earth system models, and to identify unknown and often important interconnections between physical, chemical and biological processes.

The national programmes

The national committees of IGBP have a wide choice of activities. They can participate in the core projects formulated by the Special Committee for IGBP; in this case they will have to work under the overall management system designed by them. They can design activities which directly contribute to core projects as in the case of large river basin modelling. And they can formulate programmes that are primarily of national relevance but also make useful inputs to IGBP.

India became a member of IGBP in 1988. The national committee constituted by the Indian National Science Academy is presently in the process of formulating a suitable long-term scientific programme. Under examination are activities like (a) geobiochemical dynamics of greenhouse gases and their sources and sinks, (b) estuarine ecosystems, with emphasis on the Bay of Bengal, (c) upwelling in the Arabian Sea and monsoon modelling, (d) Earth radiation budget and clouds, (e) palaeoclimate studies, and (f) modelling. These activities are being conducted with the participation and support of scientists, as well as the Indian National Science Academy, the Council of Scientific and Industrial Research, the University Grants Commission, and the Departments of Science and Technology, Environment, Ocean Development, Space and Atomic Energy. The operational phase for IGBP being 1990–91, the national committee hopes to be reasonably ready with its own programme of participation by then.

Other activities still under discussion

Human dimensions of IGBP

Environmental changes have powerful impact upon human beings and trigger reactions from attempts to cope with the impact. The new scale of interaction between environmental and social forces that has been gaining momentum over the last few decades is likely to increase more dramatically over the next century as industrial activity increases. The combined effects of population, energy and technology imply some colossal risk of disruption. Large-scale changes in temperature, precipitation, sea level, winds, etc. will affect resource availability, create new pressures and compulsions on individuals, communities and nations, and influence life-styles, values and altitudes, and, in general, human well-being. The repercussions and consequences will be varied and complex, and analysis will require the joint efforts of social scientists and natural scientists.

Awareness creation and publicity

We are dealing here with a global problem of immense dimensions and consequence. National boundaries lose their meaning in such a context. People at all levels and everywhere are to be made aware of the magnitude and complexity of the scientific aspects and human dimensions. It has to be made into a very relevant and personal problem to every individual. This requires making use of every channel of communication and different kinds of talent to convey the content and consequences with realism, objectivity and without exaggeration. Much has to be done in this direction in the future.

Why India and other Third World countries must participate in IGBP

We have already seen that IGBP is the most extensive, relevant and ambitious international scientific programme so far. It is truly a global programme and it has to do with the Earth and its environment as a single total system, transcending national boundaries. All humankind is on equal standing here. Scientists from every country, including the Third World, have a right and a duty to participate in it, and share its excitement and benefits. Because it is also a nationally relevant programme for all countries, the Third World must seize this opportunity to strengthen its scientific base, build a self-reliant scientific leadership, and use them for national development.

It is estimated that Third World countries cover approximately three-fourths of the terrestrial world. Many of them are situated in the tropical region, whose study is a very crucial part of IGBP. Thus the Third World countries have the opportunity of participating and contributing in a significant manner to IGBP.

If the predictions of global changes are even approximately borne out, all countries will have to spend bigger fractions of their national resources on environment-related activities in the years to come. Furthermore, it is inferred from models that even with a relatively moderate sea level rise (in a matter of 10–20 years), the frequency of extreme events (like cyclonic sea surges and coastal inundations), which are now very infrequent, may increase[10]. The effects of such events on Third World countries can be cripling economically and in terms of human well-being. It will therefore be most crucial for every Third World country to have its own small team of scientists who can advise the government on the possibility of such occurrences and provide information on the level of reliability of the predictions, the options consistent with national relevance, and the precautionary steps to be taken.

Science and technology have become essential tools of development. Today's scientific research is tomorrow's technology. The scientific method and culture enable the people to develop the qualities of objectivity and rationality. It is therefore important for every Third World country to promote and support selected post-graduate teaching, training and research programmes that involve intellectual challenges and breed excellence and generate manpower in science and technology. IGBP involves all the ingredients of a national priority effort—challenges in basic science at the cutting edge; new and unexplored challenges in interdisciplinary sciences; opportunities of international and regional co-operation; special relevance to Third World countries on whom the impact of global change will be most acute; and immediate application potential in diverse fields of national relevance.

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Integrated entomology: Fact or fiction?

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Very few biological ideas have lent themselves to such incisive and intensive discussion as the species concept, which has occupied and continues to occupy a central place in biological thought. The modern synthesis of Huxley[1], involving the integration of Mendelian genetics into evolutionary theory, can be said to be a turning point, paving the way for a meaningful interpretation of the species. While classical biology has been essentially descriptive, the necessity to involve a functional component was considered obligatory to accommodate the emerging pluralistic views on selection levels, enabling a better appreciation of the several kinds of ecological interactions resulting in the recognition of population-dependent diversity. With increasing emphasis being laid on biological diversity, an understanding of the variations within and between individuals, populations, species and higher taxonomic groups, and of genetic diversity manifested in polymorphism and heterozygosity, has become obligatory. To be able to unravel possibly rare and unique genotypic and phenotypic traits, there is also a need for an assessment of how species respond to new environments—physical and chemical—and how evolution functions in species adapted to stresses. The numerical and species abundance of insects, which show large intraspecific diversity, and play a major role in agriculture, medicine and forestry, naturally demands a multidimensional approach to entomological problems.

The recognition of the dynamic, plurimodal configuration of species has made it obligatory to adopt this integrated approach. However, in spite of the consciousness it has generated, it has not really taken off in this country, as is evident from the small number of publications. Everything revolves around the species—whether it be taxonomy, biosystematics, ecology, genetics, molecular biology or biotechnology. Species being dynamic, plastic elements changing their genetic constitution under the influence of the physical factors of the environment, the relationship between genotype and phenotype, and reproductive fitness become essential aspects. Population studies directed at establishing variation patterns appear essential and basic to the proper definition of taxa, so that there is a shift from form to process and pattern. Studies[2–4] on patterns of intraspecific diversity and implications of polymorphism in mycophagous Tubulifera have highlighted the degree of 'expression and suppression' of characters of individuals at different levels in a population, making taxonomic studies 'a communicable generalization of patterns discernible in natural diversity'. While alary polymorphism tends to result in ovarian diversity, a combination of this feature with oedymery and