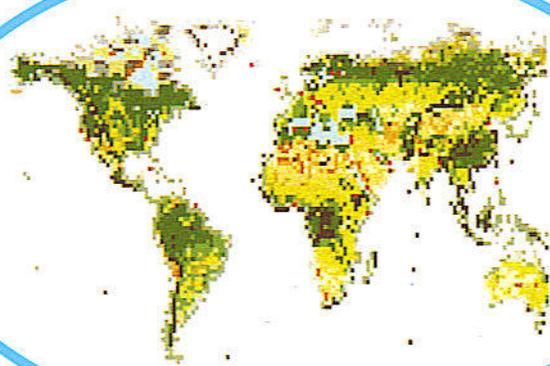


BIOLOGICAL EDUCATION

Challenges of the 21st Century



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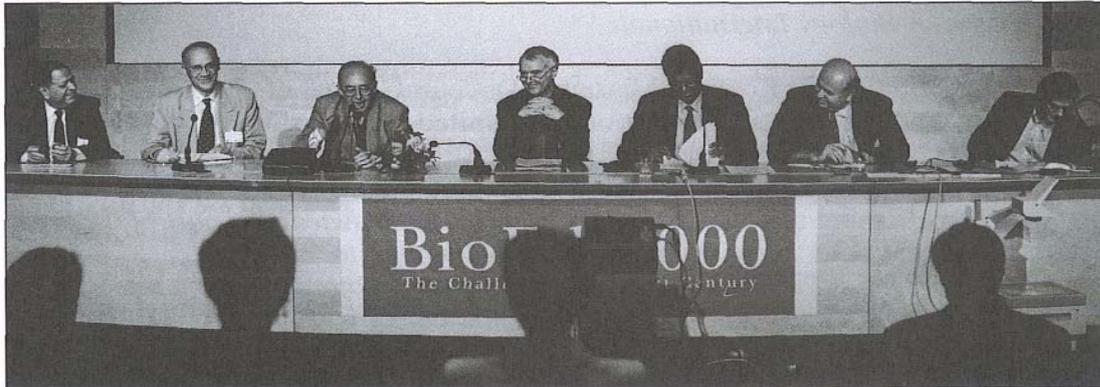
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Editorial

BIOED 2000 A Milestone for IUBS and UNESCO Collaboration in Biological Education



Closing session of "BioEd 2000." From left to right: Dr. Faquir Vohra, Prof. Jean-Claude Mounolou, Prof. Michel Thellier, Prof. Patrick Blandin, Dr. Armoogum Parsuramen, Dr. Talal Younès, Prof. André Giordan

The International Symposium "BioEd 2000: The Challenges of Biological Education for the 21st Century" was held on 15-18 May, 2000, in Paris, France. This meeting was organised by two international organisations: IUBS and UNESCO, in collaboration with two national institutions: the 'Muséum National d'Histoire Naturelle' (MNHN), France, and the 'Laboratoire de Didactique et Epistémologie des Sciences' (LDES) of the University of Geneva, Switzerland. Eighty-eight presentations were made, including reviews and research papers organized in three plenary sessions, twenty-six parallel sessions, four workshops and a poster session.

The reviews papers focused on new biological knowledge in such domains as biodiversity, ecology, genetics and molecular biology, and their impact on the lives of human societies in developed and developing countries. Research reports emphasized new education concepts, approaches and theories, as well as the new educational tools and technologies and the increasing role in biological education of such new partners as museums, botanical and zoological gardens, the media, and a large number of foundations and non-governmental organisations. Special workshops and sessions were also organized on bioethics, biotechnology, health and integrative biology education, and such societal issues as citizenship, sex education, sustainability, and environmental education...

In view of the magnitude and diversity of attendance, the high level of presentations and discussions, and the specific nature of the meeting place, BioEd 2000 was a great success. More than two hundred participants from Africa, Asia, Australia, Europe, North America and Latin America attended the meeting. Sessions took place in such

relevant settings as classrooms, laboratories or exhibition halls. And between the sessions, participants walked and talked among the fish, birds, mammals and butterflies of 'La Grande Galerie de l'Evolution' or along the flowering allées of the 'Jardin des Plantes.' In addition to the MNHN itself, educational material by UNESCO and the Lake Biwa Museum, Japan, were on exhibit, bringing in more experiences. To top them off, two theatre performances were offered: "Health fairy tales in preschool education," and "Shakespeare Gallery ou la pensée en formes," while the "Youth Forum on the Environment," organized on the day following the Symposium, provided a hands-on experience for out-of-school biological education!

In advance of the publication of the proceedings volume and the electronic format (www.iubs.org), we would like to provide highlights of this important event in the present issue of *Biology International*:

The address of Professor Koïchiro Matsuura, Director General of UNESCO, outlines the vision and policy of the principal United Nations' organisation with responsibility for both science and education. After reiterating the commitment of UNESCO to the Declaration of the World Conference on Science, 1999, in Budapest, proclaiming that the "*... access to scientific knowledge is part of the right to education and the right to information belonging to all people; ... science education is essential for human development and for creating endogenous scientific capacity, ...*" and stating that biology is at the core of new "contract" between science and society, the Director General says that he looks forward to strengthening cooperation with the IUBS, especially in "*... keeping this forum open and alive; producing guidelines for the development of education in such domains as biodiversity, biotechnology, natural resources conservation and management and bioethics; and assisting UNESCO Member States in the development of curricula, teacher training programmes, educational materials.*"

In the following paper, "Biological Education: Challenges of the 21st Century," I present the rationale and the objectives underlying the organization of BioEd 2000. On a more specific note, Professor Marvalee Wake explains how Integrative Biology can serve as a framework for education and training; Professors Mounolou and Giordan both address the relationships between biological education, ethics, and administrative decision-making processes, and Professors Ramakrishnan, Vijay and Blackmore review ecology teaching in developing countries, emphasizing the key role of traditional ecological knowledge in biodiversity conservation and management. Finally, Dr. Vohra reviews the major international programmes undertaken since the 1960's, describing the changing trends in biology education, from teaching separate scientific disciplines to interdisciplinary learning, and from isolated societal problems to a more integrated knowledge society.

Talal Younès
Executive Director, IUBS

The Address of UNESCO

by Koïchiro Matsuura
Director General
The United Nations Educational, Scientific and Cultural Organization

Delivered on his behalf at the Closing Session of the Symposium BioEd 2000:
The Challenge of the Next Century.

*Monsieur le Président de BioEd 2000,
Monsieur le Président et Monsieur le Directeur exécutif de l'Union internationale des sciences biologiques,
Monsieur le Directeur du Muséum national d'histoire naturelle, Mesdames et Messieurs les participants,
Mesdames et Messieurs,*

Je voudrais en tout premier lieu féliciter l'Union internationale des sciences biologiques d'avoir si bien préparé ce colloque international et proposé un programme remarquablement complet. L'UISB, partenaire de longue date de l'UNESCO, a réussi à réunir des experts de haut niveau représentant un large éventail de domaines connexes pour conduire le débat sur des questions dont l'importance est capitale pour le monde du 21ème siècle. L'UNESCO a eu l'honneur de parrainer BioEd 2000.

Les débats se sont déroulés dans un cadre exceptionnel, celui de la Grande galerie de l'évolution du Muséum national d'histoire naturelle que je remercie d'avoir accueilli cette manifestation.

I can assure you that UNESCO, in full partnership with the IUBS, will be active in following up recommendations made at this meeting for the improvement of biology education in its Member States.

As you undoubtedly know, at the World Education Forum in Dakar last month the international community renewed its commitment to basic education for all. Governments, intergovernmental organisations, NGOs and all other stakeholders reaffirmed the high priority that must be given to the provision of quality learning to all the world's children.

UNESCO is fully aware of its great responsibilities in playing an effective role in translating this commitment into a concrete reality. We are already preparing to give a new impulsion to our work in the field of education... And this effort to build up a world-wide momentum will be the business not only of UNESCO's Education Sector and Education Institutes, but of all its Sectors, not least of which will be the Science Sector.

For, in my view, basic education in the emerging knowledge society of the 21st century must be seen as part of a continuum that includes secondary, technical and higher education.

Why is this so important?

We live in a world where information has become the primary resource. There is a general consensus today that education is the key to development. But we are only beginning to realise just how essential it is for each and every country to have its own science and technology base. And the first step to building up this base is in the provision of science and technology education programmes.

Without this, countries cannot be active participants in the knowledge society. Without a basic science and technology education, people cannot participate fully in our fast-moving, interconnected and globalized world. We see every day the power of shared knowledge. But to share knowledge means sharing as active partners, not as passive recipients.

This is why science education was an important topic at the World Conference on Science in Budapest last June, organised jointly by UNESCO and ICSU, the International Council of Science, of which the IUBS is an active member.

The Declaration on Science and the Use of Scientific Knowledge, adopted in Budapest declared:

“... access to scientific knowledge is part of the right to education and the right to information belonging to all people; ... science education is essential for human development and for creating endogenous scientific capacity, ...”

As part of its follow-up to that Conference, UNESCO's Education and Natural Science Sectors are working together to prepare an integrated International Plan of Action for Science and Technology Education. Its main thrust will be to renew, diversify and expand science and technology education at all levels of learning, both in-school and out-of-school.

The promotion of biology teaching through science and technology education for girls and women and the development of gender sensitive approaches will be given a high priority.

Ladies and Gentlemen,

Biology is at the core of new “contract” between science and society to which the Budapest Conference sought to pave the way.

To summarise, the new contract involves renewed public support for science education and research on the one hand, and, on the other hand, the commitment of the scientific community to place science at the service of sustainable development and pressing human needs in such fields as health and nutrition.

Applications of biology today impact - or have the potential to impact - in the most far-reaching ways on our lives and environment. It is clear that the notion of a social contract for science, particularly its ethical dimension, has important implications for the framework within which biology is taught. And of course, the actual scientific developments which have given applied biology new life-changing powers have important implications for updating the biology curriculum.

So there is a major challenge for renewing the teaching of biology itself and another great challenge for teaching the issues linked to biology.

I said in my opening remarks that the biology-related issues you have been discussing are of pivotal importance to the modern world. It appears to me from the themes of this symposium's sessions over the past four days that you have been establishing a new social contract for science education!

You have balanced admirably the scientific aspects, and the social and ethical aspects of biology teaching. It makes me optimistic for the future of this highly influential discipline, which has extraordinary potential not only for producing scientists but also for producing generations of responsible citizens who match scientific, social and ethical awareness.

This is essential, as so many issues of major importance today - concerning human health, reproduction, food safety, intellectual property rights and so forth - require not only good analytical skills but a sound grounding in the science itself. In short: the level of biology literacy needed to be able to participate fully in many areas of public debate has risen dramatically in recent years.

As you know, UNESCO is actively engaged in encouraging broad debate on bioethical issues. The extensive world-wide discussions led by UNESCO's International Bioethics Committee, prior to the adoption by the United Nations of the Universal Declaration on the Human Genome and Human Rights, offer a model of participatory debate leading to collective decision-making.

UNESCO has also been at the forefront of international efforts to ensure that the DNA sequence data generated by human genome research remains within the public domain.

It is essential that such undertakings have strong public support, and that can only come from a clear understanding of the issues at stake. Here, biology education has a major role to play. Over half a century ago, UNESCO's founders called in its Constitution for - I quote - “... *the education of humanity for justice and liberty and peace.*” They wrote that at a time when molecular biology and biotechnology were as yet unknown, when issues such as biodiversity and bioethics had not emerged.

The Western world was shaking off the legacy of eugenics, but as yet knew nothing of the new pitfalls of genetic determinism or the commodification of nature. However, that insistence that education must be far more than technical instruction remains as valid as

ever. And the framework given by UNESCO's founders, when they insisted on the intellectual and moral solidarity of humankind, remains as valid as ever.

You have been very true to that framework in your efforts to establish ways of improving not only the contents of, but also access to, biology education. The biology teaching of the new century must aim at much more than scientific and technical competence. It must, at its basic level, offer everyone the opportunity of a learning experience that contributes to personal autonomy and responsible citizenship.

And for up-to-date, relevant biology education to be available to all, it must be given a new momentum - not only nationally but internationally. Renovated educational programmes, teacher-training, educational materials and delivery systems all need special attention.

Let me take the example of biodiversity education. A far greater effort in education in biological diversity is needed to create world-wide public awareness of the issues at stake. Only an educated, global constituency for biodiversity can build up the pressure to ensure that we take the path to a sustainable future. A new global initiative is being developed by UNESCO with other partners. The mandate for this initiative is provided by a decision of the last Conference of the Parties to the Convention on Biological Diversity, the CBD. It invited UNESCO "*to consider launching a global initiative of biological diversity education, training and public awareness.*" This UNESCO/CBD global initiative will not become a totally new programme of action. Rather, it proposes to link and support on-going processes and to develop a new dynamic in this way.

Developing this global initiative requires a committed team effort. In addition to the strong partnership between UNESCO and the CBD Secretariat, close cooperation will be needed with institutions of the UN family and non-governmental organisations as well as with teachers and schools world-wide.

UNESCO has convened a first meeting of key partner agencies at its headquarters here in Paris in July to set the initiative in motion. That gathering will pay particular attention to the results of this Symposium and will welcome any concrete suggestions you wish to make on action to be undertaken.

Ladies and Gentlemen,

BioEd 2000 has discussed new knowledge, new issues, new tools and new partners. It has examined the whole panorama of the biology revolution in order to better understand and define our approach to biology education. UNESCO is looking forward to strengthening cooperation with the IUBS in:

- keeping this forum open and alive, and developing and expanding biology education,

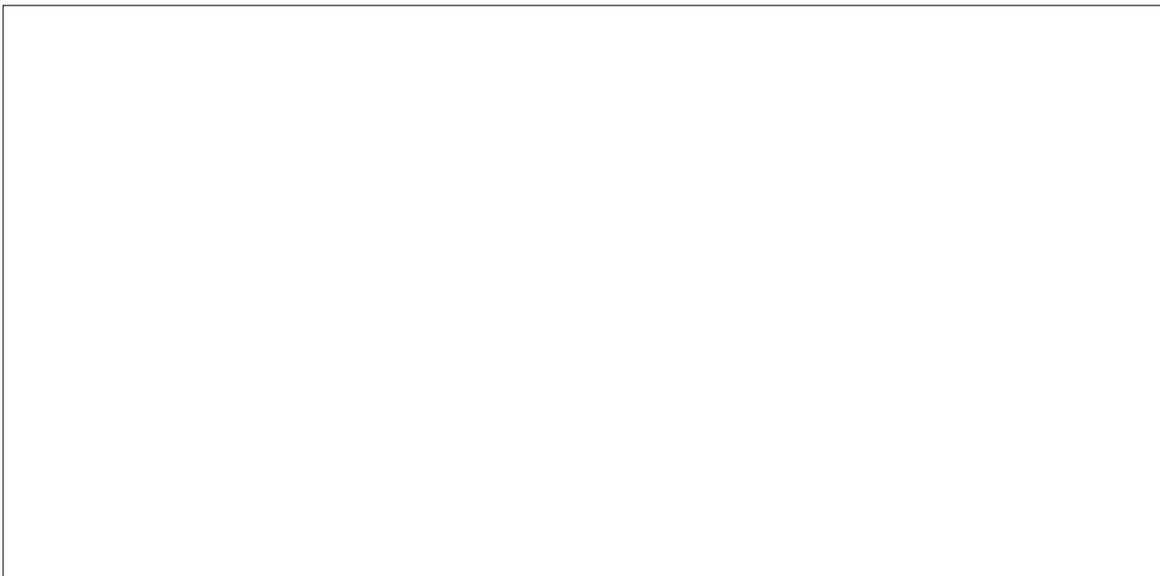
- producing guidelines for the development of education in such domains as biodiversity, biotechnology, natural resources conservation and management and bioethics;
- assisting Member States in the development of curricula, teacher training programmes, educational materials and
- working in close collaboration and partnership with the science education community, notably in the domain of biology education.

In conclusion, I would like to say something about the timing of this Symposium. I believe the time is ripe for biology education to take centre stage. It responds to the curiosity of children and young people about so many aspects of life and the world about them.

It offers them essential tools for tackling the issues which so many young people take to heart, such as protection of the environment and conservation of plant and animal life.

Public concern about issues like genetic engineering and the ethics of biomedical techniques suggests that there will be increasing demand for life-long access to biology education.

I am convinced that biology education in the 21st century will be central to efforts to reach social consensus on the use of many new technologies and on the management of natural resources. You have showed that you are prepared to respond to this challenge, and I congratulate you.



Biological Education: Challenges of the 21st Century

by Talal Younès
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Introduction

Generally speaking, education represents the domain through which humankind proceeds to transmit, consolidate and develop into human culture, the ensemble of knowledge systems, science, arts, values and religions.

In a report entitled "Learning - the Treasure Within," presented in 1996 to UNESCO, Jacques Delors, former President of the European Commission, and his colleagues recommended that education must be given top priority on the agenda of nations. Priority to the role of education in providing citizens with a 'passport to life' with which they learn to be, learn to know, learn to do and learn to live together. Educational activities now represent a major occupation of human societies. In-school education is a full-time occupation of a large part of the world's population (more than one billion students and 20 million teachers, in 1992), and occupies, on average, one quarter of every individual's life. Increasingly some form of out-of-school education is pursued throughout life. From an economic point of view, the world expenditure on formal education in 1996 totaled approximately 1,200 Billion US\$ (an average 5,1% of the world GNP). This budget represents the largest investment in the national accounts of many countries, yet it is still considered insufficient to cover actual needs.

During the 1990's, with their eyes fixed on the approaching year 2000, a large number of governments, national and international organizations and groups engaged in a trendy exercise. They participated at large scale conferences with the express aim to assess past achievements and failures, reap the lessons gained throughout the 20th century and identify the key challenges facing humankind at the beginning of the new Millennium. The first such event was the Earth Summit on Environment and Development held in 1992 in Rio-de-Janeiro, followed by the World Population Conference in 1994 in Cairo, the World Conference on Higher Education in 1998 in Paris, and the World Conference on Science in 1999, in Budapest, Hungary.

From these fora, there emerged a world consensus on the role of education, science and technology as the prime movers and most decisive factors of development. International programs and plans of action were launched: the Agenda 21, Education 2000+, Taxonomic Agenda 2000, Species 2000, and the Programs 'International Geosphere and Biosphere Program (IGBP), and the International Human Dimension of Global Change (IHDP), etc.

The recent history of human societies shows how scientific and technological progress have helped trigger economic, social and cultural development. In the 19th century, advances in physics, chemistry and engineering conducted to the industrial revolution. And in the 20th century, advances in agricultural sciences, physiology, genetics and breeding of plants and animals provided the basis for the agricultural (green) revolution; new knowledge in microbiology, immunology, medical and pharmacological sciences helped reduce the toll of diseases, and resulted in an increased life expectancy.

The discovery of the DNA structure and function ignited a biological revolution which will continue and expand during the 21st century. Deciphering the genetic code (alphabet) represents an essential step in the human endeavor to read the book of life, unravel the complexity of biological systems (molecules, cells, organisms and ecosystems), and perceive the unity of life through the diversity of living forms. Progress in the biological sciences is not only bringing about an understanding of the evolutionary processes and pathways which led to the present world, but also giving the humankind the power to modify drastically the course of biological evolution, including his own.

Like other scientific disciplines, biological sciences form a part of the overall human culture, which represents a specific evolutionary trait of *Homo sapiens* and marks the border line with other primate species. However, whereas biological traits are transmitted between generations through reproduction and modified through mutation processes, cultural traits (values and knowledge) are inherited and modified (scientific and technical innovations) through education, i.e., the ensemble of learning, training and research processes.

In all these processes, biological education, education about life, education through life and education for life, occupies the center stage.

New biological knowledge

During the second half of the 20th Century, impressive achievements and breakthroughs have been made in the fundamental and applied knowledge of the living world, with far reaching implications impacting almost every aspect of human life and society.

At the micro-level, the development and use of sophisticated molecular biology techniques have led to a revolution and the emergence of new disciplines, such as Molecular Biology, Molecular Genetics, Molecular Evolution and Genomics. Tremendous progress and breakthroughs have been achieved in our understanding of animal and plant reproduction and development, and more generally, our understanding of evolutionary processes. At the macro-level, the development of new concepts, new approaches and techniques, and the use of modeling, remote sensing and informatics are bringing about a revolution in the ecological sciences and the emergence of sub-ecological disciplines such as Functional Ecology, Landscape Ecology, Global (Biosphere) Ecology and Ecological Networks.

The biological sciences have seen the emergence of important interdisciplinary scientific domains, such as biodiversity, bio-complexity and integrative biology.

New Problematique

A new perception and formulation of the world problematique emerged at the Earth-Summit of 1992, in Rio-de-Janeiro, Brazil, replacing the traditional and fragmented vision of the problems facing human societies (individually and collectively). There is now a better understanding of the relationships and interconnections between the problems affecting human health, food and environment, problems related to agriculture and agro-industry, fisheries and aquaculture, pharmaceutical industry and biotechnologies, the problems of pollution (physical, chemical and biological), as well as problems related to the conservation and management of biological resources (deforestation, desertification, soil salinization and loss of biodiversity, etc.)

The new problematique that emerged at the Rio Summit is based upon a trilogy consisting of biodiversity, global change and sustainable development.

The awareness of biodiversity at the three levels of biological organization: the genetic, organismic and ecological levels (di Castri & Younès, 1996), highlighted the need to better understand such issues as the origins, maintenance and change of biodiversity over space and time scales, the ecosystem function of biodiversity and the many hidden ecological services it provides to humankind, the need to better conserve and manage the biodiversity of terrestrial, marine and inland-water systems, providing clues of how to restore degraded ecosystems. There is also a growing perception for the need to take into consideration the human dimension of biodiversity and, in particular, cultural diversity.

The second important issue, the global change and globalization phenomena, has been considered at the environmental, economic, and information/communication levels. Pollution problems do not recognize political boundaries between states, and global warming and ozone holes affect the whole biosphere. To face these problems, it is necessary to form a global coalition, with all nations working hand-in-hand, if we are to succeed.

The third and last “mot d'ordre” of the trilogy consists in sustainable development. This new concept, developed during the Earth Summit, aims at promoting a much needed solidarity over both space and time scales. On the geographical scale, this means a solidarity between North and South, between developed and well-off nations and the developing poor countries of the third world. And, over a time scale, it implies a solidarity with the future generations, taking into consideration the well-being of the generations to come, and leaving their options open.

Facing these challenges, research, training and education in science, particularly biology, are pre-requisites if we are to succeed in bringing about an economically efficient, socially equitable and environmentally sustainable development.

New Educational Concepts and Approaches

The goals, scope and content of biological education vary greatly with its target populations and the groups and parties involved in its implementation. Biological education means different things to different people. For biology researchers, education means the acquisition of the scientific knowledge, data and techniques that are necessary to perform research projects. For developers, professionals and engineers in a large variety of domains such as agriculture, health, industry, biotechnology and environment, education must provide the biological foundations underlying their respective domains of expertise. And for the general public, the principal aim of biological education, whether at schools (primary and secondary) or through the media, must be to develop citizens' biological literacy, i.e., provide them with the core biological knowledge, the ability to formulate questions, and an idea of how and where to look for answers, in order to help them to participate responsibly in the life of the society.

The diversity of the objectives assigned to biological education reflects its social function which is to re/produce knowledge, apply it and adapt to its impact on society. Therefore, addressing the challenges of biological education for the next century requires taking into consideration not only the new problematique and new scientific knowledge, but also to address the ethical dimension of biological sciences as well as the new findings of research on education processes and learning theory.

Biology, psychology and cognitive sciences are generating knowledge about how the human brain learns; and have shown us that we can use this knowledge to intervene effectively in the learning process of virtually any and all humans. In a comprehensive study of the theory of learning, Giordan, 1998, explains that learning is better achieved through a process of deconstruction. Concepts have evolved from the old passive process, whereby teachers passed or communicated their knowledge to students considered as empty containers; to the behaviorist and constructivist approach by which the teachers help the learners to construct knowledge, moving from the simple to the complex and from the specific to the general; and finally the development of a more active approach, whereby the re-construction of knowledge follows a necessary phase of deconstruction, i.e. a process by which the knowledge is generated (appropriated) by the learners themselves.

The adoption of this new learning concept has important consequences for the organization and functioning of educational institutions and curricula, the definition and practice of the respective roles of teachers versus learners, and the relationship between knowledge acquisition and learners' attitudes, behavior and ability to adapt to complex and ever-changing environments.

The development of the deconstructivist concept and the reconstructivist approach have led to more educational institutions adopting a new method of "learning science as scientists do." Students are invited to participate in research projects designed for them and the results of which are presented at major scientific congresses and published. At the AAAS Congress in 1999, held in Anaheim, USA, there were two major poster

sessions with hundreds of 'young' scientists (students at secondary schools) presenting their research results!

Another important consequence of adopting the re-constructivist approach consists in its great potential to reinforce the societal relevance of biological education, i.e., the link between science education and the needs of society, which, in turn, calls for the development of ethical dimensions of science education.

New Tools for Education

Today, the statement "*If only biologists knew what biology knows*" is more true than ever. The explosion of scientific knowledge and the rapid production and accumulation of staggering amounts of scientific data and information are creating the need for knowledge management, i.e., knowledge about knowledge. Actually, knowledge management is about learning. It is impossible for educational systems to cover all domains of knowledge, there is a need for school science curricula to provide citizens with basic scientific literacy, i.e., a common core of understanding, a knowledge basis and the intellectual ability to formulate questions and find answers.

At the same time, the explosion of scientific and technological knowledge is introducing new concepts and tools for distance learning, new access to the world storehouse of knowledge, and new interpersonal and group communication capabilities. Two subsequent approaches will also be needed: (1) to develop mechanisms for "learning on demand" within (2) a framework for continuous, life-long education. The success of such an endeavor will mark the passage to the education society, to a knowledge society. Biological training and education will be more and more about knowledge management than the simple traditional teaching of scientific data. Increasingly, modern Information and Communication Technology (ICT) is being developed and used for education in-school and out-of-school situations. In the developed countries, more and more ICT educational material, CD-ROMs and/or online education tools are becoming more available for learners. Modeling and simulation games are being developed. Benefits of introducing ICT are numerous, to mention but a few: increasing interactivity, availability of immediate links with almost an infinite world library, encouraging group work, and providing good tools for auto-evaluation.

However the development of ICT in education, and in particular in biological education still is in its infancy. There is here a large domain for development and research towards reconsidering the learners and teachers' functions and role and rethinking the structure of the school, college and university.

New Actors and Partners

Parallel to the explosion of scientific knowledge, the emergence of a new problematique, and the development of new concepts, approaches and tools, there also are a host of new parties with huge stakes and interest in biological education. Among these parties, there are natural partners wishing to strengthen their role in biological education, such as botanical gardens, national parks and nature reserves, and natural

history museums, and science centers. In addition, a large number of organizations, foundations, and agricultural and industrial corporations (pharmaceutical industries and biotechnology) are concerned with and, to a certain extent, involved in the development of biological education programs.

Prospects and Conclusions

Over the next three days of BioEd 2000, a large number of papers will be presented. The principal aim of the current organization into plenary, parallel or workshop sessions is provide the conditions for good presentations and discussions.

We hope that whenever possible, the discussions will focus on the main issues and problems and suggesting and recommending solutions. For BioEd 2000 to be more than a “happening”, a one-time event, every body’s contribution will be needed to help pave the way towards the future.

The success in meeting the education challenges will depend upon the dedication, commitment and efforts of all partners involved (scientists, teachers, students, politicians, decisions-makers and the public).

I would like to expand the parallel I mentioned earlier between education and biological reproduction. Because of the pain and high cost of having children and caring for them over a long period of time, the reproductive success of our species, *Homo sapiens*, would have been impossible without this extraordinary invention of life, that is love. This is also true for education, which is the key to the survival of human culture and civilization, love is needed for societies to provide for the high cost that education systems require.

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Integrative Biology as a Framework for Education and Training

by Marvalee H. Wake

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I introduce the concept of “integrative biology” and education by paraphrasing key statements in the preamble to the description of the IUBS “Towards an Integrative Biology” program (Anon., 1999). That is to say, “Integrative Biology” at this point in its conceptual development means different things to different people. To some, it emphasizes multidisciplinary (cross-disciplinary, transdisciplinary; including the incorporation of physics, chemistry, engineering, sociology, economics, etc., as appropriate) research, especially through the bringing together of scientists with different, but specific, areas of expertise to address particular questions. To others, it means using a diversity of techniques and approaches in one’s own research programme; and to yet others, the emphasis is on hierarchical approaches to questions and techniques. There are almost as many conceptions of “integrative biology” as there are people interested in the idea; this results in those people considering themselves to be “integrative biologists” without any clarification of or agreement upon the central themes of the concept.

What is “integrative biology?” Traditionally, biologists are trained, and departments and institutes organized, in a manner characterized by specific approaches, techniques, working at a specific level of organization in the biological hierarchy, and/or organisms, investigating on model organisms or on one or a very few species. Integrative biology is both an approach to and an attitude about the practice of science. It seeks both diversity and incorporation. It deals with integration across all levels of biological organization, from molecules to the biosphere, and diversity across taxa, from viruses to plants and animals. It provides both a philosophy and a mechanism for facilitating science at the interfaces of “horizontally” arrayed disciplines, in both research and training. Work at interfaces involves discussion of significant problems among scientists with diverse expertise and perspectives. It finds appropriate techniques, often from unanticipated sources, and it makes appropriate, often novel, choices of taxa for observation and experimentation (so that it is not taxon-bound). It particularly stresses an approach to problems and questions from diverse perspectives, so that the explication of the research protocol has the potential to be both innovative and integrative, as appropriate to the question being addressed. Many of the questions now being addressed by biologists require both reductionistic and incorporative elements, but in a framework that allows resolution of the sub-elements of the question to contribute to an answer to a larger problem. This lays the framework for new models of investigation and of education.

In the context of a synthetic approach to problems, some investigators have referred to “integrative” and “integrated” biology, often indistinguishably. In my opinion,

“integrative” and “integrated” are very different terms with reference to the concept. “Integrative” biology refers to the active development of integration through research and teaching across the hierarchy of biology and of science in general. “Integrative” biology is an on-going process, flexible and adaptive to the particular complex research issues being addressed; it emphasizes the training of students to be prepared to have that flexibility and adaptability, intellectually, philosophically, and technically. “Integrated” biology would be designed, or pre-designated -- it would have an output or product, rather than being open-ended and adaptive.

Many biologists are coming to the realization that our ability to deal with questions of biological complexity would benefit from a more integrative approach that spans the hierarchy of biological origin, and that includes techniques and theory from several subdisciplines, not just the biological. In my home department (which is called Integrative Biology) at the University of California at Berkeley, we are attempting to design a model for research and education in integrative biology; similarly, the IUBS is pioneering the presentation of integrative principles and practices in a diversity of ways.

I present as an exemplar a research- and education-based example of integrative biology as practiced in my department at Berkeley: the research and teaching of my colleague Bob Full and his associates, who study locomotion. They examine many animals--cockroaches, centipedes, crabs, salamanders, and other animals (e.g., Kram *et al.*, 1997; Martinez *et al.*, 1998; Queathem and Full, 1995). They have found that many animals (most animals that have limbs) use an alternating tripod gait, and they have analyzed its mechanical principles (Full and Koditschek, 1999). They have also examined the ways that gaits change, direction changes, and the differences in intermittent and sustained locomotion (e. g., Jindrich and Full, 1999; Kubow and Full, 1999). They study the cell, tissue, whole limb, and organismal bases of locomotion, and develop models that are testable in terms of principles. Understanding how animals locomote is allowing the development of muscle equivalents and of “walking” robots. They work on uneven substrates, including the bottoms of lakes and oceans. The tripod gait that characterizes most animal locomotion, and the “revelation” that animals don’t move in straight lines at constant speeds, but must adjust in order to compensate for both external and internal factors, are principles that are revolutionizing robotics. Further, the adjustment can be simply a physical property of the appendages of a crab or a robot -- neural feedback is not required. Little needs to be programmed into these robots. Big and small robots are being developed that can explore oceans, go into terrestrial areas where humans can’t or shouldn’t, and miniaturized robots are being developed that can potentially be employed in blood vessels -- but making them able to move is the key. The key point is that functional morphology and biomechanics are informing engineering, and engineering and physics are informing morphology. The instrumentation that functional morphologists now have available is expanding the scope of the science--much better cameras, computer-aided analysis, treadmills, running tracks, flumes, wind tunnels, and others all make innovative new research possible. Many functional morphologists are becoming highly integrative, as they look at the feedback from the skeleton to the nervous system, and muscle fiber dynamics, at one level of understanding locomotion, and the mechanical properties provided by the environment at another; this was

illustrated in a recent article in *Science* written by six of my colleagues who study animal locomotion from different but collaborative and complementary perspectives (Dickinson *et al.*, 2000).

New areas of biology are developing as a consequence of the kinds of questions and problems that require attention. The many manifestations of biocomplexity, from fundamental science to socioeconomic concerns, require approaches that transcend standard disciplinary lines in terms of research, funding, training, and dissemination. The problems now being addressed by many biologists require a diversity and range of expertise. It can be provided by bringing together experts in several areas, but may be better provided by biologists who are adaptable, flexible, and trained to address new questions that span levels of biological organization and extend to “non-biological” realms.

If, as I assert, integrative biology is more than the aggregation of workers with different expertise to consider complex problems, and new ways of approaching those problems are important, serious effort is needed to change the way that biologists, scientists in general, and even non-scientists, are educated and trained, as clearly delineated in the TAIB preamble (Anon., 1999). As stated there, the “separateness” of disciplines and sub-disciplines currently is structured by the identification of separate courses of instruction at all levels of the educational enterprise, and is reinforced at the university level by the discrete course offerings of departments of instruction and research. It is increasingly rare that a “department of biology” offers a full range of courses, from molecular biology to ecosystem biology, neontology and paleontology, and including members of all three domains of life, as well as the impact of non-biological domains of study. In fact, departments of biology are few, and their successors often focus rather narrowly, but with depth, on a small sub-set of biology. Even when taking courses in different sub-disciplines is encouraged, the course structure does not encourage an integration and synthesis of the information found in several such courses. This has several consequences: young biologists are well trained only in one sub-discipline; students who will become teachers in primary and secondary schools are not acquainted with the breadth of biology, let alone how to apply breadth to major questions; students who will enter other fields of endeavor, and become the educated public, and potentially policy makers, have only examples of parts of biology before them. Some institutions are attempting to develop cross-disciplinary programs, but they usually emphasize breadth of course work; the difficulty in effecting thinking synthetically is that most of the courses available to such programs are the traditionally structured ones.

How, then, can “integrative biologists” be educated? We are trying a new model in my department at Berkeley; it is only one possibility, and is imperfect at this time, but we are trying. We consider ourselves to represent several dimensions of the hierarchy of organization of biology, and we try to integrate those dimensions in various ways. We characterize the “old” model of education as the “tunnel” approach; a student learns a limited scope, but learns it well. The current model of teaching at many places is what we call the “funnel” approach; students are exposed to a greater range of subdisciplines, but with emphasis on a specific kind of problem, especially in graduate training (see Wake, 1998). We now, however, are trying for a mode of education that emphasizes

the cross-disciplinarity of both the entry-input and the output in terms of the student's facility with a broader scope of information and technique, in an integrative, problem-oriented framework.

How can this be achieved? We have all the constraints of the status quo that most institutions do. Curriculum is difficult to change. Clearly, the current course structure cannot be abandoned; it serves many purposes well. However, the content of such courses can be expanded to draw on a greater breadth of information, and new courses can be implemented, probably using information technology, especially Internet communication and computer simulations, that emphasize integration and synthesis, and these can be coupled with field work. It cannot be stressed strongly enough that integrative biology is not just assimilating and synthesizing ever more information, but, rather, a way of approaching questions and being equipped with the resources to think broadly about their solutions. Several approaches to developing the curricular and training structure that would implement integrative biology by adding a greater range of resources are possible, and immediately:

- 1) the meeting of scientists with diverse expertise, but an interest in complex questions, to discuss ways of integrating their approaches (this is occurring with increasing frequency with the goal of good science, but rarely with the goal of good education in addition, though this symposium is a notable exception);
- 2) the production of teaching materials as well as research publications by such aggregations of scientists;
- 3) greater breadth of examples in current courses, and especially a new emphasis in "traditional" courses of the relationship of course-specific material to other parts of biology and the current state of the world (this doesn't mean a separate, token lecture, but a common thread of interrelationship throughout the course);
- 4) the development of technical facilities (image analysis labs, gene sequencing labs, etc.) that are shared by people working on different kinds of biological questions, so that exchange of information, ideas, and questions is facilitated and common principles can be elucidated; and
- 5) at the level of graduate study, a real emphasis on transdisciplinary training in both theory and technique.

The process can be initiated by the development of new, non-traditional courses. My colleague Robert Full, whose research I discussed earlier, is not only a gifted researcher, but a gifted teacher. He was given an endowed professorship at Berkeley; there is one stipulation involved in the chair--the holder must design a new university course for non-biologists that meets the general education requirements in biological science. Full did this -- he designed a course on animal locomotion that integrates cellular, organismal, and robotic science. He gives a series of lectures (dynamic presentations using PowerPoint), and has laboratory/demonstration sections that work with models and computer simulations. He included one especially interesting aspect. Full wanted a logically consistent, adaptable course framework and design. Therefore, he structured his teaching plan so that his model would be applicable at different educational levels.

He first tested the model with the school class of his twelve-year-old daughter -- they loved it, and learned a great deal from it. He then added some slightly more sophisticated examples and simulations for his University students, but within the same pedagogic framework. The students loved it, and learned a great deal from it as did the younger students. This is an ingenious example of integrative biology in evolution that demonstrates that such an education is indeed possible, and useful.

Developing such courses as first steps would allow the “next generation” to implement education and training with new ideas and approaches to integration, synthesis, depth and breadth. It should be our charge and our mission to facilitate those developments in every way possible--and immediately. At the same time, it is essential that scientists interested in an integrative approach to research and education should be in extensive communication, so that a common philosophy of integrative biology guides our efforts, though their expression should be flexible and as varied as our backgrounds and the questions that we are investigating permit.

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Biology, Education and Ethics

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Since the 1st conference organized by the IUBS Commission for Biological Education (CBE) in 1975 in Upsala, Sweden, a lot of things have changed... During this last quarter century, the research in biology has led to an enormous expansion of our knowledge. For example, the ability to maintain cultures of totipotent human embryo cells points towards new directions in fundamental research. There is a great hope that, one day, we shall be able to use such cells to repair deficient tissues or even to replace whole organs.

Other potential forms of therapeutic utilisation would involve re-programming of differentiated somatic nuclei, either by introducing them into nucleus-free oocytes and to obtain new embryos and stem cells, or else by taking foetal blood cells from the umbilical cord; etc. Yet such striking scientific achievements also raise important ethical questions:

- Should we be producing such cells, since they come from human embryos, particularly as they derive from deliberately aborted fetuses?
- Should human embryos be the object of research at all?
- Do therapeutic ends justify cloning means?

What to do now ?

Questions about living organisms are never neutral, and there can be no single answer. The debate currently surrounding DNA epitomizes the issues involved. Isn't it absurd for biologists to want to patent it? Shouldn't it be pronounced the common property of humankind?

This is a hot topic, especially now that a race has escalated between private and public research institutions! The DNA molecule is the basis for countless techniques, which specialists call 'biotechnologies' or 'genetic engineering', but which the public is not afraid to brand as genetic 'manipulations'. As long as these are used for therapeutic purposes or as historical and legal tools, such modifications are well accepted by the public. In contrast, there are equally virulent opponents and supporters of Genetically Modified Organisms (GMOs) in the food business. Clearly, a number of technological blunders (AIDS-contaminated blood supplies, growth hormones, mad cow disease, etc.) have led the public to question deliberate risk-taking more actively than in the past.

What can be done? Who should decide? Should we let the market function on its own? Should there be a public referendum, a 'votation' like in Switzerland? Should we try consensus conferences or citizen councils? In all these cases, on what basis of knowledge should decisions to be taken? Which knowledge is a priority? Biological

knowledge has become fundamental to political/social responsibility. Without biological literacy, individuals are just as illiterate today as they were last century if they couldn't read.

Biological education and mediation

Schools do now provide more biological information, especially at the secondary level. Unfortunately, the absence of genuine reflection has made most biology curricula completely indigestible. They accumulate anecdotal, non-situated data. Receptors, G-proteins and kinases are mentioned, without being placed within the context of cell metabolism. Individual organisms, the knowledge of existing species, the organisation of life, and even evolution itself have virtually disappeared from the classroom.

At the university, teaching still adheres to historical subdivisions. Cell biology, biochemistry, immunology, molecular genetics are still taught separately, each according to its own internal code. Ecology, integrative biology, ethology and anthropology are given only a limited place. Practical exercises are often problematical, mere illustrative rituals which do not initiate students into a scientific approach.

Museums, science exhibits and the media are providing a growing platform for biological issues. However, such presentations frequently make use of outdated cultural references. Individuals are compared with machines, brains with computers, organisms with robots obeying microscopic commands, as though each act would be determined before birth.

Rarely is the possibility of questions taken into account: public worries or the loss of confidence in science are never discussed. Many people end up being confused and bored, as they were previously by physics. The image of Biology was clear; today it has grown murky.

What biologists do ?

Some biologists - still very few - are "coming out". They are initiating communications campaigns to renew the dialogue between science and the citizen. This can lead to even bigger problems, as the public is increasingly distrustful and wary of new dangers. Such scientists are aware of their ethical responsibilities but remain clumsy in the way they fulfil them. Most of them believe that they are contributing to the benefit of mankind, to the point where they often forget to question their own methods.

BioEd 2000 has been organized to find out what should be done. Should we question ourselves, and unravel the current links between biology, ethics, education and society, as directly and critically as possible? The answer is obviously yes, but we must go beyond this.

The solution is surely not additional classes, more concepts, or more public information regarding the contents and methods of research. What appears to be key in biological education is to trigger openness and alertness in the mind of each and every individual, and to foster curiosity for that which is not obvious, for problems. It is necessary to

provide food for thought, to use approaches that link technology, ethics and society, in order to assess the issues/stakes at hand, and to formulate the 'right' questions in need for expertise.

Out-of-school, we should take advantage of the current controversies surrounding dioxin, GMOs or mad cow disease, since they trigger a genuine desire for understanding in the population. They provide learning situations and public education opportunities, whereby newly available education resources and tools can be used. Given the difficulties of such a task, we need to construct knowledge networks, linking schools, the media and internet-like webs.

A clear project

But first, the biological community must itself have clear objectives and projects. And we must question - as some are already doing – the place that biology has/must have in society. One can criticise some biological practices, observe how certain biological approaches are becoming social challenges and consider the way in which the market, or policies determine research, without necessarily having an anti-scientific attitude. On the contrary, biologists must engage in such a questioning approach. If not, what would be the purpose of generating knowledge with no societal relevance?

Definitely, these are not internal questions of biologists to be dealt with behind closed doors. This is a public debate to be shared as broadly as possible.

Biosciences and Bioeducation in Administrative Decision-Making

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Introduction

Most administrative decision-makers have a confused perception that there is some kind of conflict between, on the one hand the social and economic goals to which they are committed and the policies to achieve them, and on the other the recurrent upsurge of unforeseen, contradictory biological events and social oppositions. In response, they look to biologists for help and are very often disappointed by the answers they receive. Similarly, biologists show some defiance, whether overtly or indirectly, towards decision-makers. They feel that public awareness of current biological problems is far from what it should be in a well-informed society and that the intellectual appreciation and social status of biology and biologists are not commensurate to the role actually played by the living world in economic development.

The poor reciprocal understanding and loose congruence between society and its biologists result in delays, costs and difficulties that have an increasingly adverse effect upon people and could be avoided. With the overall increase of biological knowledge in the second half of this century, tensions have been rapidly building up. These trends correlate with growing environmental concerns (pollution, degradation of ecosystems, loss of biodiversity, water shortages, climatic changes, biological epidemics...) due to increased global anthropic impacts, to developments of biotechnologies (gene therapy, genetically modified organisms), and the privatized appropriation and mastery of living resources (ecosystems, species and varieties, etc.) In general, the need for more dialogue and collaboration between decision-makers and biologists is mutually recognized. Changes are bound to occur, and the challenge facing societies for the next century is whether they will accord with the values of humanism, justice and democracy, or oppose them.

The reasons and forces underlying the present unsatisfactory situation are certainly many and complex. Not least among them, the inconsistent and, in effect, conflicting teachings imparted to administrative decision-makers and biologists. Administrators emerge from academic systems that prioritise economics, law, management, physical engineering... Their formal biological education dates back to primary and secondary school, and their information on more recent biological advances is mainly provided by the non-formal circuit (media, associations). Biologists, on the other hand, receive a thorough biological training, keep pace with the progress of science and participate in its development. However, for historical reasons, the social sciences, economics and the humanities have often been excluded from biology training programmes in the majority of countries. The trend towards

specialization has gone so far as to fragment the field of biology into particular areas (medicine, fundamental biology, pharmacology, agriculture...) and even narrower specific disciplines (physiology, ecology, genetics,...). In consequence, exceptions (individual personalities or circumstances of non-formal education) aside, most biologists do not share the vocabulary and the concerns of administrative decision-makers and are not fully aware of the true needs and expectations of their fellow citizens. This situation noticeably increases the difficulty of reciprocal understanding and reduces communication almost to the point of caricature, with decision-makers asking for advice and expecting an cut-and-dried answer, and biologists responding with uncertainties or seemingly narrow or irrelevant statements. No wonder that such scenarios create frustrations on both sides. Better education is a high hurdle in the way out of present difficulties. Initiatives could be devised to enhance the training and competency of both partners: biology education for administrative decision-makers, and social sciences and citizenship for biologists would be a first step.

The object of this contribution is to outline what is required now at a very general level. The idea is not to produce a specific curriculum or syllabus, but to identify topics of biological literacy that are directly relevant to the administrative decision-making process. Decision-making processes involving both the economy and the management of biosystems and bioproducts are generally related to food, health and industrial products derived from living organisms (wood, textile fibres, medicine, products of fermentation and biotechnologies,...). The question of how to deal with environmental problems (pollution, the degradation of ecosystems and landscapes...) also enters into this complex. Depending on the circumstances, the activities involved may have very different goals and scales, ranging from the daily survival of the individual in conditions of poverty to the profit-making strategies of nations or multinational companies. The decision-making processes and driving forces differ vastly from one case to the other; yet they all interact ultimately on local, regional, national and global levels. Everywhere, the language of management gives the same names to the elements involved in the decision-making process: biological resources, water and energy supplies, investments, cost of labour and techniques.

A biological education program for decision-makers should first explain that the concepts and methodologies applied to mineral or human resources cannot simply be transferred to biosystems, which exhibit their own set of specific properties. Foremost is the aptitude to reproduce true-to-type, which is not true for minerals, and at a pace that relates very directly to species. The second property is the capacity to generate heritable diversity at a low frequency in the course of generations (mutations). The third property is the potential for adaptation to changing environmental conditions. The fourth property is the ability to impact on the environment through biological activities and evolve in response to its changes.

Caught up in constant cyclic and renewal processes at the level of the biosphere, living organisms are not a stable resource that one can exploit by simple mining. This presents administrative decision-makers with a very demanding challenge. Beyond these biological problems lie key questions relating to Mankind's sense of

identity, place in these cycles, and perception of environmental and social relationships. Examples drawn from the management of biological resources and risk assessment in the case of GMOs and prions should help to clarify what biological knowledge may be of relevance for the choices facing society and the decisions administrators should be making.

Management of Biological Resources

Let us consider the example of an administrator responsible for the management of biological resources in any country today. His task consists mainly in placing and optimising his decisions within the constellation of three major driving factors: government, biology and economy (Figure 1). The government commissions him to implement a policy, as an expression of the needs (and hopefully the will) of the people. There is usually little biological information directly needed here (but this aspect will be dealt with later). Of course, since the managed objects are living resources, biology constitutes the second point of the triangle, and obviously biological information is required there (at all the various levels of organisation, from molecules to ecosystems, with emphasis on physiology, distribution, diversity and renewal potential of the resources involved). And finally, decisions must be made with a view toward economic benefit (whether a rapidly returning profit or a sustainable long-term gain).

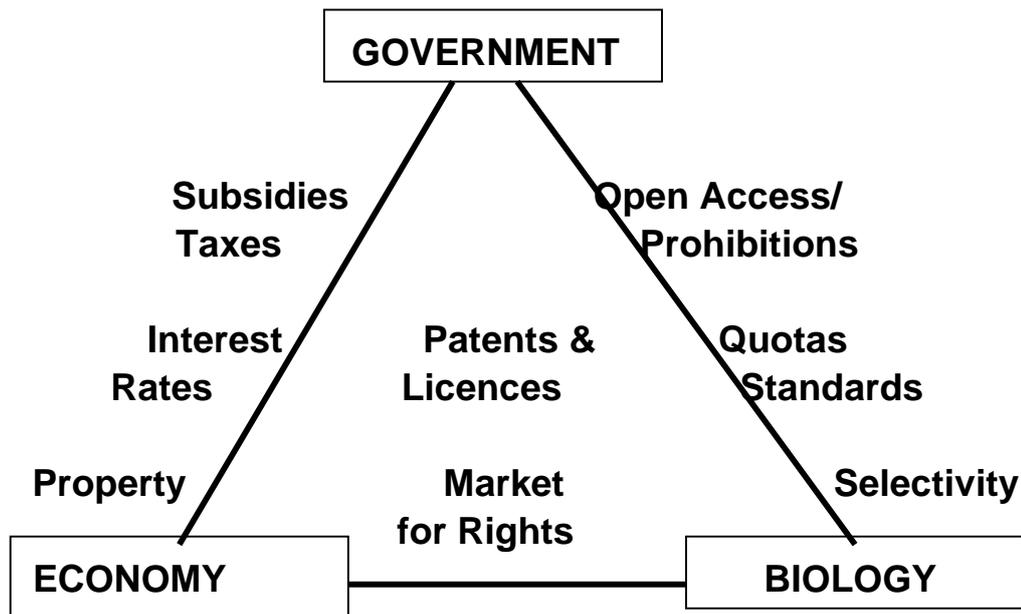


Figure 1: The formal environment of biological management

Thus, the basic terms of the decision-making process will be: property, interest rates, quotas and standards/norms. In the hands of a civil servant, some tools are more powerful than others: subsidies and/or taxes, controlled and/or selective access to the diversity of resources. In private enterprise, the same basic tools are used, but in a

different manner : since subsidies, taxes and rules of access are determined outside the company, they are less directly exploitable by the private decision-maker. On the other hand, he has more flexibility than the government to decide on investments and to exchange licences or rights rapidly via the market. In both cases, the selectivity of choices is the combined result of social, economic and biological inputs; yet without biology, there is no consistent future in the exercise.

The biology of living organisms (whether useful, such as cereals, or harmful, such as pathogenic viruses) is essential information. And decision-makers would obviously do better if they were fully aware of the nature and the dynamic properties of the objects they manage. This prompts a more thorough examination of the complexity of the relevant biological knowledge and its organisation (Figure 2).

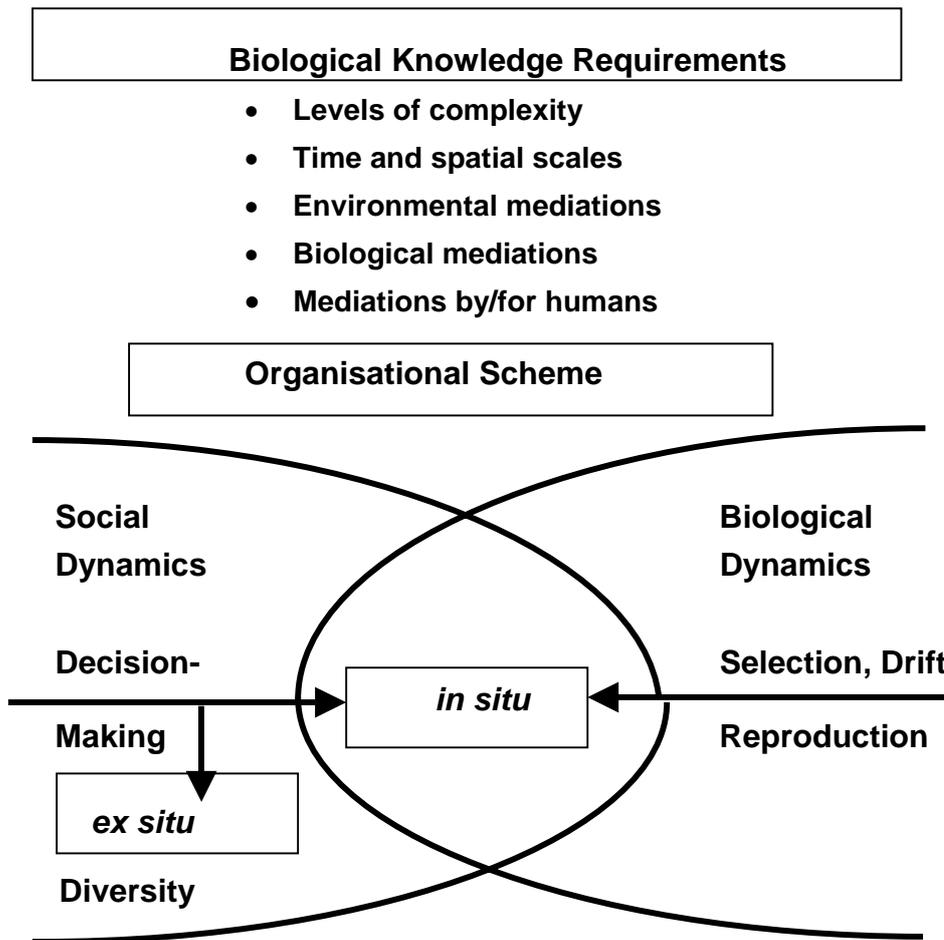


Figure 2: Management of biological resources

When considering the driving forces of biological dynamics, biologists emphasise the role selection and drift play on systems, depending upon their reproduction potential and their biological diversity. Their scientific input into the decision-making process will depend upon the context of the object of management: whether it is in the natural environment (*in situ* : fields, pastures, forests and conservation

areas) or in a man-operated artificial ecosystem (*ex situ* : cells, tissues, germplasm or DNA banks, collections of museums, arboreta, zoological and botanical repositories). Clearly, a key element is the balance of determinism and/or stochasticity in the functioning of the system. In the past, operators were more prone to elaborate procedures in cases where determinism was a prominent feature. By so doing, one has the means to optimise decisions and possibilities to evolve with the circumstances. In a system where stochasticity determines the dynamics, the techniques and types of decisions will be of a different nature, and concepts of probability, uncertainty and risk management will feature prominently in finalising the choices. In brief, an informed decision-maker needs a comprehensive knowledge of the complexity of biosystems. An Integrative Biology education may provide the solution, since it takes into consideration complexity levels, space and time scales, modulations of the system due to environmental factors, to external and internal biological interactions (impacts of hormones or pathogens for instance), and deliberate or unconscious human intervention.

The question of human-driven modulations may serve to introduce the second service which biology provides to decision-making. In Figure 3, the administrative operation is redescribed to focus attention on the values that legitimate decisions in terms of social goals in the perception of the operator and thus on the intended uses of biological resources. Perceptions and values, although not directly involved in the decision-making process, are the coordinates for the panel of socially acceptable choices, and in the long run, they evolve progressively, as does society. Understanding the importance and dynamics of values and perceptions is also necessary for the administrator. Access to such a knowledge is essentially provided by the social sciences. Moreover, developments in psychology (another discipline emanating from biology) and, however remotely, advances in brain and cognitive sciences should also be taken into account whenever management activities have to be implemented and accepted by the public.

Decisions related to biological resources management are obviously not the prerogative of the regions and people actively involved in the profit-making global economy of the World Trade Organisation. In many countries, government administrators deal with populations living in accordance with their traditional cultures and often struggling with poverty. In this situation, policies related to biological resources and community survival are closely intermeshed with land uses and appropriation regimes. In schematic terms, these people developed food production, indigenous knowledge and specific cultures on three basic activities : pastoralism, hunting, foraging and forest exploitation (Figure 4). Their enduring traditional structures and trade forms are now confronted to money-dependent economic systems (overall urban or peri-urban), where the rules of land management and the uses of domestic animals and cultivated plants are very different. The points of contact are brewing sites for biological and social conflicts, where, the responsibility of decision-makers is all the more difficult. Obviously, they not only need the confidence of their population, but have to develop an extremely refined and elaborate sense of balance and justice, using both social and biological sciences inputs. To confront the biological problems, they need pertinent

training, i.e. a strong background in ecology and some conception of the biological and historical processes that led to current situations.

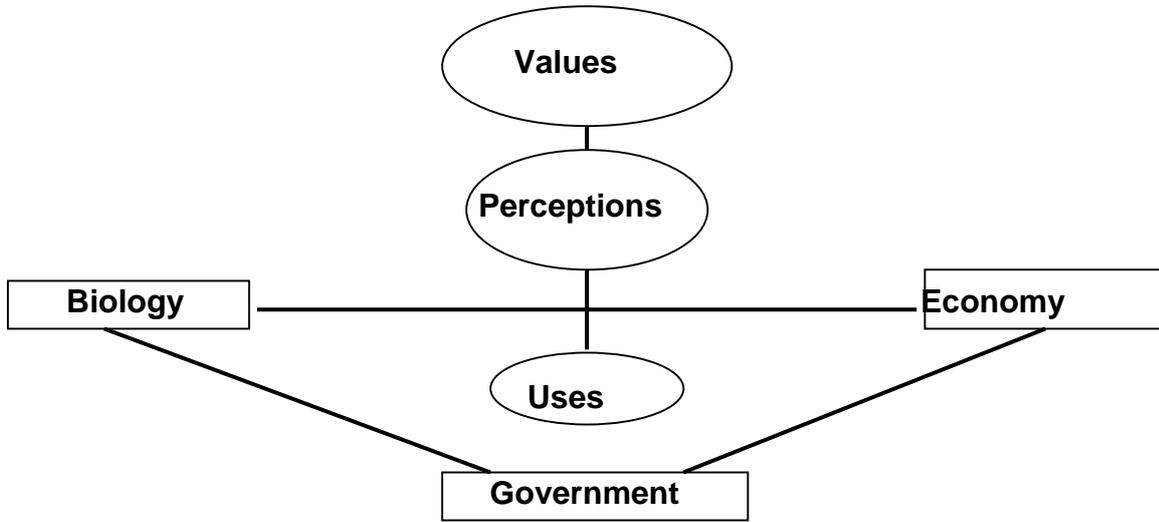


Figure 3: Values and perceptions in biological resources management

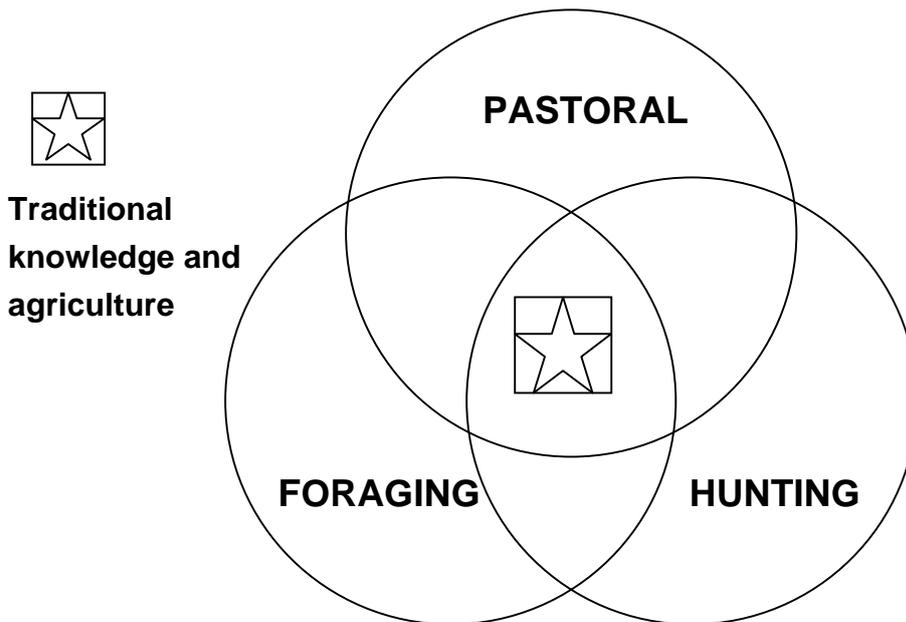


Figure 4: Interconnected traditional economic systems

Sources of biological information and education

As decision-makers have grown to recognise the pressing need for more accurate and up-to-date biological knowledge, they have begun to bring the same kind of capacity for communication and inquiry to bear upon biological systems that they habitually use for economic assessments. With the years, they have developed a

variety of approaches that all fit in the framework presented in figure 1: the first consists in negotiating and financing specific research projects with competitive expert laboratories. From such research operations, usually carried out over precisely limited periods of time, they acquire the information they need, plus relevant biological background and, sometimes, technical expertise for the future. The second approach is to seek direct recourse to specific education and training (short-term specialised, advanced training at non-formal institutions, or longer training courses, often developed by academic institutions). The third approach is to call upon outside help. This option applies the market technique of buying the services of specialised consulting agencies. It has the advantage of accessing biological information through financial exchange, but it does not usually increase the know-how in the administration. The fourth possibility is the most indirect one. It relies on social controls and market feed-back on previously implemented decisions. The arguments cited in favour of controls and feed-back often point out that alternatives to the debated decisions could have been envisaged at an earlier stage, if more thorough biological information had been considered. This is quite often the apparent reasoning behind the texts accompanying court rulings. Undoubtedly, such feedback is highly informative for administrators. However, the information comes very late and may follow in the wake of social difficulties that could have been avoided if a more accurate consideration of biological knowledge had been taken in the first place.

Recent developments concerning genetically modified organisms GMOs, human immunodeficiency viruses or prions provide ample illustration of the various possibilities which are available to administrators to increase their biological knowledge and optimise their decisions.

It should be emphasised at this point that these processes of learning are not of the traditional academic nature. In many universities and for many years, biology has, in general, been presented to students as a qualitative discipline and encyclopaedic endeavour. Even biochemistry, molecular biology and physiology courses were more prone to descriptions of mechanisms than to quantifications of their dynamics. On the other hand: population genetics, population biology, epidemiology and theoretical biology were, by their essence, obliged to teach mathematical concepts and techniques. Because of this tradition, the two complexes of biological training are segregated in different courses. Matters started to improve some 15-20 years ago, when advances in informatics provided biology with the tools to develop data banks and data bases as well as with modelling techniques and computing capacities. While modelling and bioinformatics have acquired some recognition in universities, they are still in their infancy, and their role and importance are bound to increase. The trend will be accelerated by the demands of society, especially that of administrative decision-makers. Indeed, in their profession, they need not only qualitative knowledge, but also testable scenarios of the costs and effects, as well as the indirect consequences of any possible decisions. Quantification, modelling and informatics are precisely the tools that administrative decision-makers use in normal practise. Since their accustomed entry is via these disciplines, it actually facilitates

their access to advanced biological information and education, if quantification methods are applied.

Risk perception and assessment

In the administrator's profession, decision-making is accompanied by risks. The examples cited above (GMOs, HIV, prions) well illustrate this situation, as do the examples of hormones, antibiotics or dioxin contents in food. Clearly, extensive biological knowledge is key to *a priori* or *a posteriori* risk and crisis management in any economic operation involving living organisms.

Let us first consider, in very broad terms, how administrators make their decisions with respect to risks. They look for an optimised position in a triangle of perceptions, the points of which are: political goals, public response, and judicial framework (Figure 5). They proceed by trying to mobilise biological knowledge in three steps. The first is the accurate definition of the pertinent biosystems (actors, hierarchies, time and spatial scales, human impacts...). In this phase, we again encounter the type of integrated biological knowledge previously called for (*cf.* Figure 2). The ultimate goal, here, is to be able to target the key elements of the productive biosystem in order to avoid unjustified costs and redundancies. The second step is to identify the risks, i.e. domains of uncertainties, chaotic or stochastic processes, and to correlate them with the concerns of society.

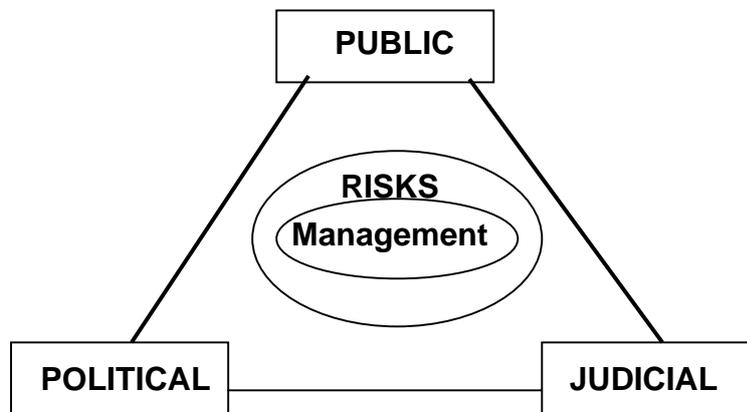


Figure 5: Perceptions, risks and management

A good example is the case of GMOs, where three major areas of risk are recognised : (1) the product itself (a living organism or the consequence of its activity); (2) the technologies (to develop, elaborate, produce and manage GMOs); (3) GMOs' environmental impact. The last step in the process is the assessment of probabilities, which is directly related to the quantitative disciplines of biology discussed above.

Once this path has been paved and walked, administrators make decisions on the management of the risks. In this operation, there are two guiding principles: the lowest ratio of risks /benefits, and the need for a continuous flow of innovations in order for society to survive and develop in a competitive world. This last part of the decision-making activity is not directly related to biological knowledge (except through the cognitive activities of the brain). However, recent developments in the judicial and political consequences of decisions involving biosystems have tended to cause more biological elements to be introduced into these decision-making operations. This brings us back to the earlier discussion about values and perceptions (Fig. 3). Approaching the end of this century, the control exerted by citizens on governments and policies has progressively led to a shift from prevention to precaution. In the name of the latter, the responsibilities and ultimately the culpability of decision-makers have been extended far beyond the actual object of the decisions, to encompass their general impact on society and the nature of their implementations (see the HIV and blood transfusion crisis in France and the recent problems of chemical and hormonal pollutants in food). Consequently, even in the process of risk assessment, administrators will be prone to found their positions on a more accurate biological understanding of risks. In the long run, proper biological education may prepare younger generations of decision-makers to face such tasks. But in the immediate future, there is a call for the services of experts in biology.

Obviously, biologists are willing to provide their expertise. However, the demands of today's society are not often in tune with the overall range of competencies and capabilities that biologists acquire through higher education and professional activities. In the scientific community, recognition is acquired through disciplinary specialisation and peer-review evaluation. Confronted by the same problem, different biologists may focus on different aspects and issue conflicting views, according to their specific knowledge. They may end up not rendering the service expected. Unfortunately, this academic habit of indulging in discussions among themselves has sometimes been misconstrued in court in order to deny any value to biological information and expertise... If society is has to succeed in building a community of true biological experts for the future, professional qualifications should be carefully debated and defined. Professionals should be trained in both biology and the social sciences and be made aware of their interconnection. Development of this corps will also require a definition of the social responsibilities of its members and as well as of their judicial protection. The question of whether experts are ordinary citizens is easily posed, but the answers are too many and are, at present, lacking a consensus in our societies.

To summarise: the future success of administrators and experts in the management of socio-agro-biosystems is highly dependent upon their biological and social knowledge and awareness. Possibilities to develop these skills and competencies are many and diverse. A fundamental, well integrated background in biology and social sciences is the common feature of these training concepts, within a framework that conjugates the consideration of facts, the reasoning of theories and the exercise of doubts.

Suggestions for improved connections between biological knowledge and decisions-making processes

In order to promote a better reciprocal understanding between biologists and administrative decision-makers and prepare both groups to face adequately the changes of biotechnologies and bioevolutions of the next century, this summary and qualitative survey points to three basic needs: a need for accessible biological information, a need for more accurate and open education, and a need for more vigilant awareness and active citizenship on the part of individuals of the two communities. With a view towards the follow-up of the BioEd 2000 conference, one might conclude by formulating two clusters of suggestions relating to biology and decision-making:

1) New ways to teach and understand biology and society

Education should be concerned with biosystems and the integrative sciences necessary to analyse, formalise and manage their complexities. This will be achieved when syllabuses and curricula of Integrative Biology are developed. By nature, biosystems are diverse and tend to diversify. Social needs are likewise diverse and changing, driven by two different forces: the trend toward globalisation, and the trend towards development of cultural identities and the search for new spaces of freedom. In consequence, the idea of building up a unique and universally acceptable curriculum of Integrative Biology is not the answer to all the challenges. On the contrary, a plurality of non-centralized syllabi has to be elaborated through democratic processes and geared to respond to specific social expectations and biosystems properties. The integrative approaches will succeed in (and in return: benefit from) implementations attuned to local and national situations, structures and demands. These various endeavours share four basic principles:

- meshing biological and social approaches and disciplines;
- teaching intellectual doubt and developing capability for synthesis in conjunction with one field of specific expertise that will qualify the individual at the best possible level. In this respect, Integrative Biology is far removed from any brand of soothing, generalizing holism.
- providing various keys for decision-making and choosing among solution options;
- serving society's needs and future.

In theory, there is no obstacle to taking these principles into account in the remodelling of existing education structures,

- whether they are formal or non-formal,
- whether they address adults in their professional activities, children in elementary and secondary schools, or students of the higher education systems,
- whether they have short-term training goals (a few weeks to one year) or far-ranging objectives (engineering qualifications, Ph. D. diplomas...).
- whether they have already targeted very specific biosystems (specific seed production, for instance) or very large polymorphic ones (regional managements, peri-urban societies,...)

2) *The democratic prerequisites for success*

Although we cannot formally prove it, successful implementation of Integrative Biology concepts and a better reciprocal understanding between administrators and biologists depend on more dialogue and contractual practices (as opposed to rigid set-ups) at the three following levels : internal debate of individuals (doubts), community dialogues and negotiation processes; local national and international negotiations with a view towards enhancing democracy and justice.

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Ecology Teaching in India and in Developing Countries

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Introduction

Ecology teaching in biological sciences in our University system has to undergo very drastic changes, if it has to keep pace with developments in ecological paradigms in a biophysical sense, and emerging paradigms towards a holistic ecology that link-up ecological with social processes, an area which is relevant to India and the developing world. The beginning towards holism in Indian ecology was made in the early 1970s, with the work on shifting agriculture linked land use systems and their management in north-eastern hill regions of India (Ramakrishnan, 1992a).

Unfortunately, much of our curricula are driven by traditional ecological paradigms developed in the western world starting with the classical work of Clements (1916) and subsequently elaborated through temperate world natural ecosystem analysis (Odum, 1971). Biophysical ecology itself has undergone distinct shifts in paradigm, during the last few decades, from a predator/consumer controlled ecosystem dynamics to one where disturbance is a key element integrated into ecosystem functioning. With emerging interest in the human dimensions of ecology, it is important that we, in the developing world, capitalize upon the initial advantage that we have had in linking up natural with social sciences. This is critical for us, since our natural ecosystems have been largely degraded, and what we have been left with are confined largely to upland areas where highly traditional societies live. Much of what we have in the more populated fertile plains of a country like India are natural forest ecosystems degraded into poorly managed grasslands or vast landscapes of human-managed agroecosystems. It is in this context the following discussions become relevant.

Traditional rural societies as part of ecosystem functions

If we look at a country like India, only about 25% of the humans live in urban situations. The remaining 75% are 'traditional' agriculture driven rural communities in the plains or more 'traditional' upland societies practicing traditional multi-species complex agroecosystems closely linked with the forest resources on which they depend for a variety of their needs (Ramakrishnan, 1992a, 1994, 1999). It is important to realize that all traditional societies have some common characteristics: (i) ecosystem and social systems function as a unified whole, (ii) with a two-way interaction between these two, traditional societies emphasize upon ecological prudence to cope up with uncertainties in the environment, and (iii) therefore, the

emphasis is on diversification of their landscape rather than upon homogenization. One of the chief drivers of land use decisions for these rural societies often are a number of codified and not so often codified institutional arrangements, for sustainable use of their natural resources; biodiversity centred traditional ecological knowledge (TEK) often determine land use decisions. Therefore, socio-economic and socio-cultural dimensions have to be viewed as closely linked to ecological issues, institutions forming the connecting link.

Firstly, therefore, ecology teaching has to lay more emphasis on agroecosystem structure and functioning to illustrate many of the ecological principles; there are a few hundred typologies of traditional agroecosystems ranging between casually managed swidden agriculture on the one extreme, a variety of other agroforestry systems that are moderately managed, and the more intensely managed high energy input modern agriculture (Ramakrishnan, 1992a; Ramakrishnan *et. al.*, 1998, 2000). Secondly, natural forest ecosystem analysis in our teaching curricula should emphasize upon our own forest ecosystems linked to a variety of agroecosystem types, as part of mountain landscape analysis (Ramakrishnan, 1992a,b; Ramakrishnan *et. al.*, 1996a,b).

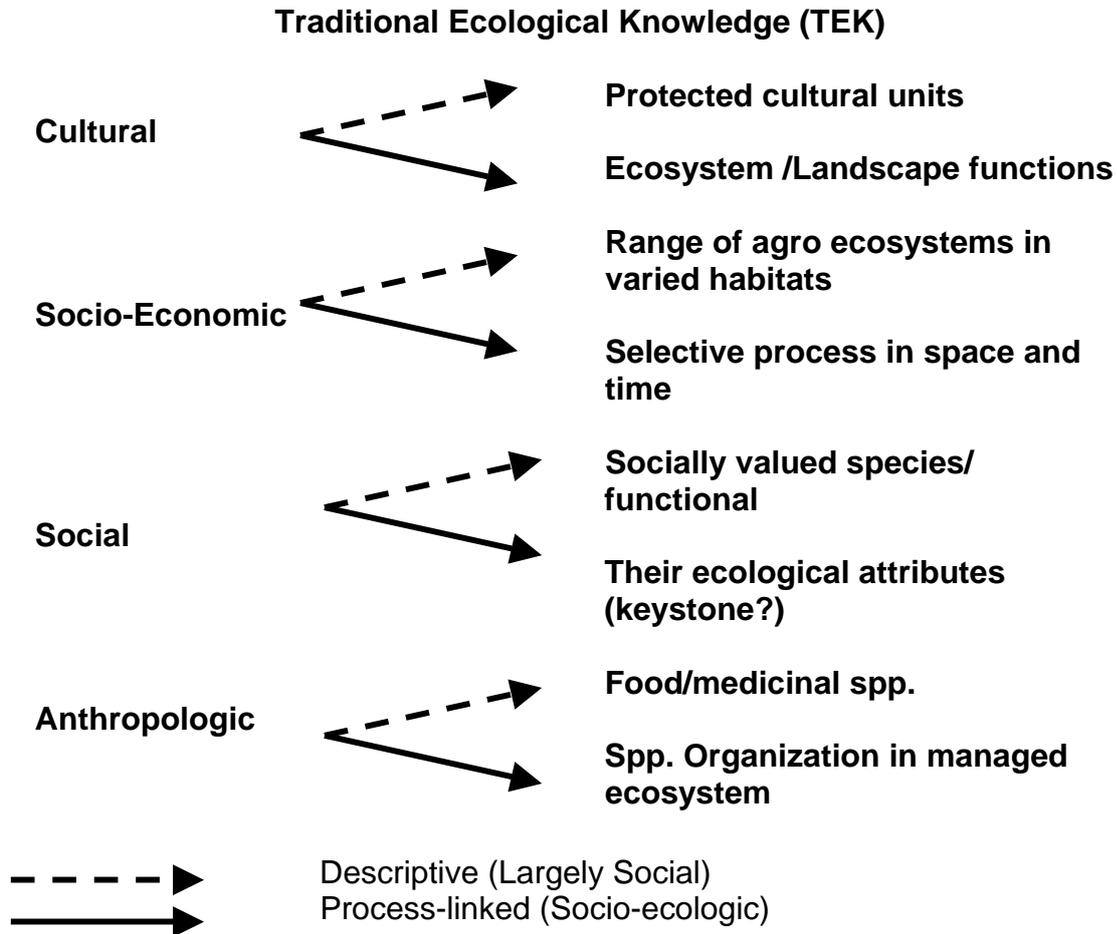
Linking ecological with social processes through TEK

*Ethnobiology started off being descriptive, as an appendage to classical taxonomy and systematic biology essentially listing species collected from the wild and used by traditional societies. It is only in recent times that the scientists interested in ethnobiology have started looking at the dynamics of the relationships existing between individual species and populations, ecosystems and landscapes (Fig. 1). Further, it is only recently that the interest in TEK has moved in the direction of understanding the interconnections that often exist between ecological and social processes, determining the functional attributes of ecosystems/ landscapes. The way in which traditional societies, (a) perceive and manipulate biodiversity around them in the landscape, both in space and time, to ensure ecosystem stability and resilience, and (b) have evolved sound eco-technologies to deal with land use management issues such as soil fertility and soil water regimes, to cite two examples, are now being seen as critical for managing natural resources sustainably, with peoples' participation, more importantly in the context of 'global change' (Ramakrishnan *et. al.*, 1996a, b). Many of these ecological knowledge of traditional societies is often embedded in their belief system (Ramakrishnan *et. al.*, 1998). At the rate at which 'global change' is occurring, a major proportion of all species on earth will be lost over the next century, and yet it is those species that we need to build a secure future. Therefore, the renewed interest in ethnobiology in its broadest sense. There is also an increasing realization that in many ecological/social situations, TDK should be an integral part of a holistic and cost-effective approach to sustainable development.*

The important point in all this effort is to build up linkages between system level research with process level understanding, with a view to evolve strategies for better management of natural resources. The schematic diagram (Fig. 2) developed for soil fertility management through internal strengthening of soil biological processes, rather than depending upon external energy subsidies alone, as part of the Tropical Soil Biology and Fertility programme (TSBF) is an effective approach to teach

ecology, with adequate concerns for the human dimensions of the subject. Whilst doing this, it is equally important to look at the interconnections that exist between ecological and social systems, using traditional ecological knowledge (TEK) as the connecting link for sustainable management of natural resources with livelihood concerns of societies involved (Fig. 3).

Fig. 1. Ethnobiological approaches towards descriptive (dotted arrows) and process (solid arrows) level analysis of ecosystem/social system complexities



Landscape ecology: the appropriate basis for linking ecological with social processes

A landscape unit in the a developing country context such as India has two important components - (a) human-managed agroecosystems, plantation forests, etc. and (b) natural ecosystems, such as forests, mangroves, water bodies, etc. If sustainable livelihood/development of the predominantly rural societies in a developing country context is to be the basis for teaching ecology, as it should be, then, a set of interconnected ecosystem types in a landscape has to be the basic unit for any meaningful ecological or socio-economic analysis and evaluation.

Fig. 2. Building interconnections between systems and process level analysis in understanding soil biological processes and sustainable soil fertility (from Ramakrishnan *et. al.*, 1993)

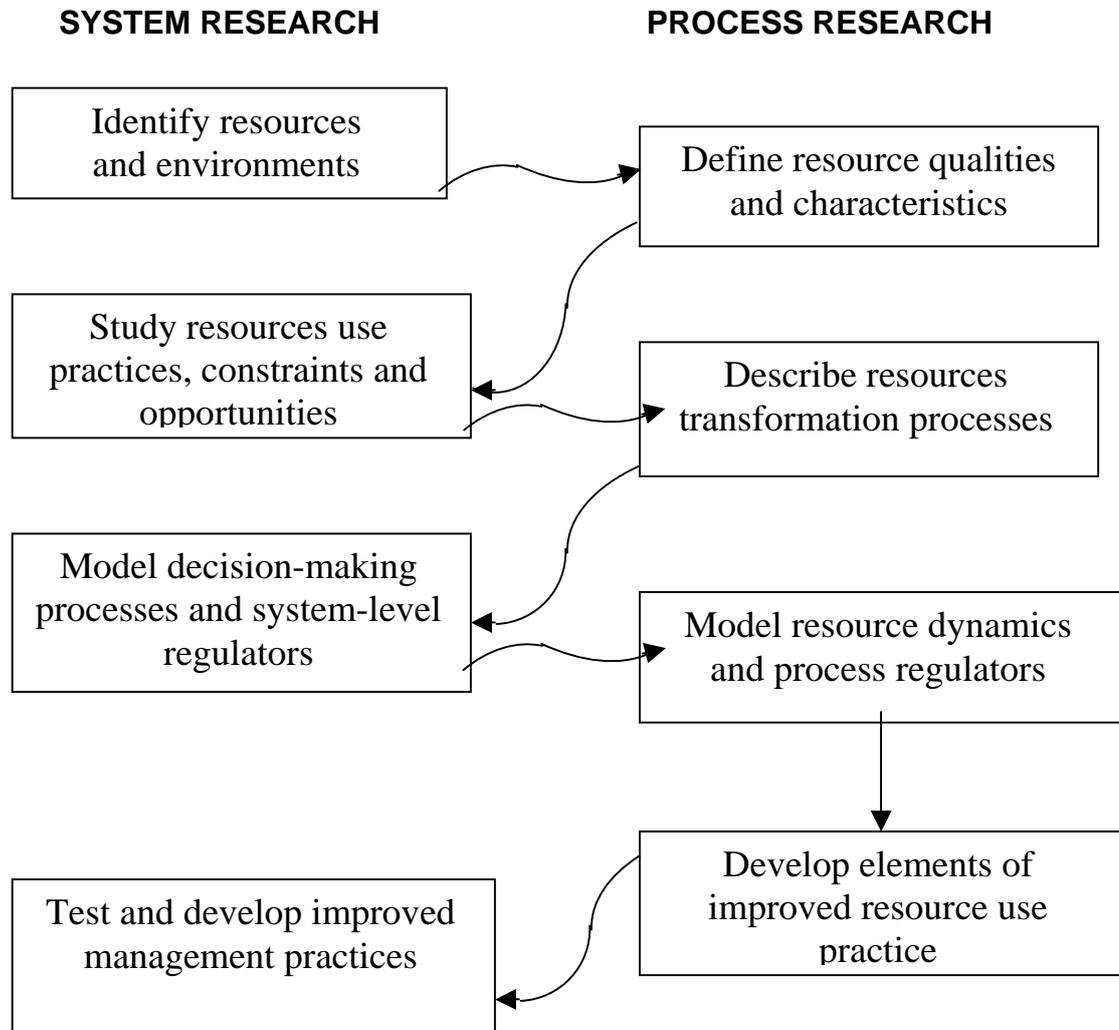
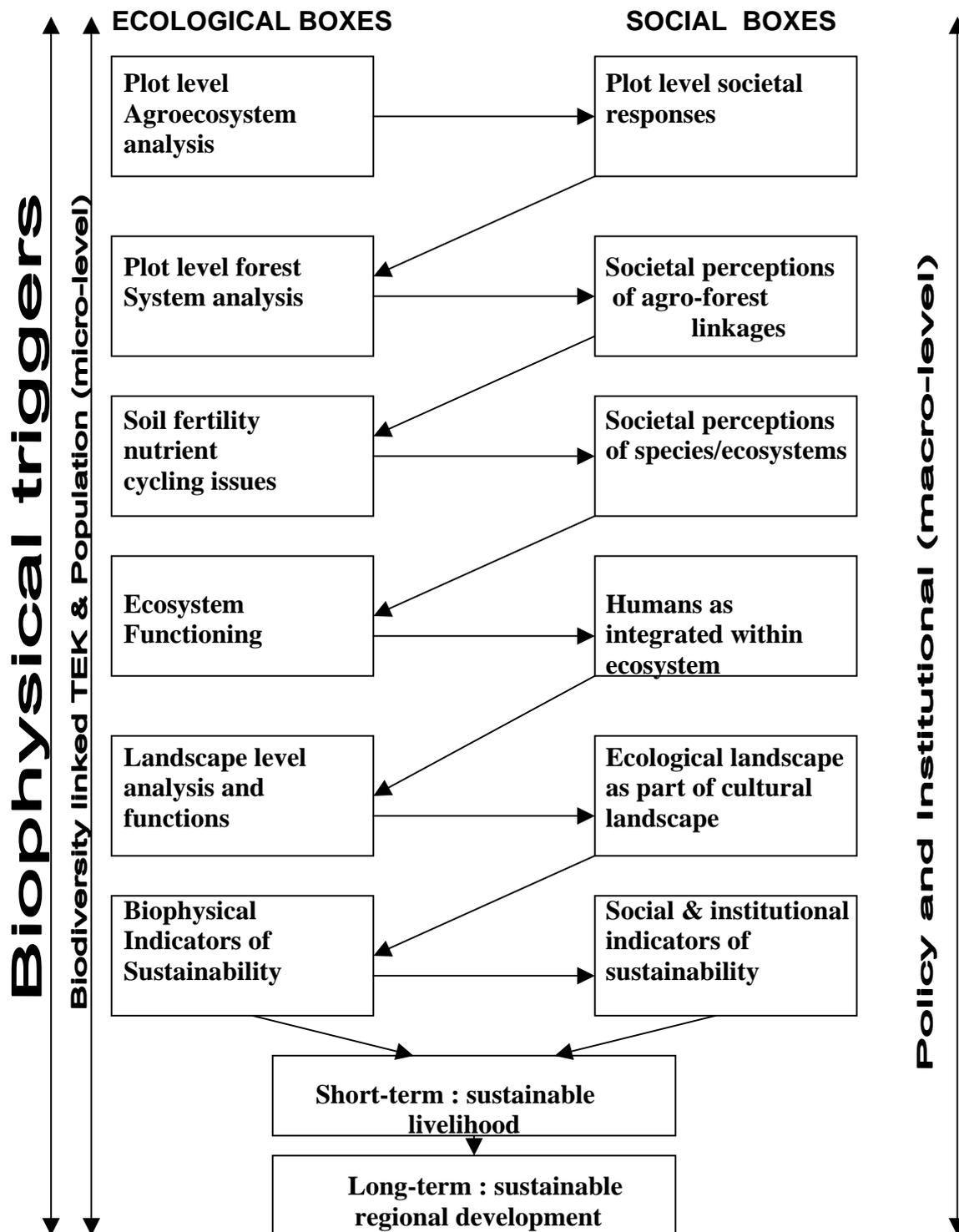


Fig. 3. Integrating elements involved in linking up ecological and social systems, with sustainable livelihood/development concerns of traditional societies



Agroecosystems

Agriculture, forestry and fisheries are traditional activities in the rural environment of the Asian tropics. Forest conversion has been accelerated by activities associated with rapid industrialization. Much conversion is due primarily to the extraction of timber for industrial uses, and some to meet the needs of the rural poor, for food, fodder, and firewood. The result is extensive degraded systems (Ramakrishnan *et.al.*, 1994b), which now represents over 1/3rd of the irrigated agricultural land, about 1/2 of the rain-fed agricultural land, and almost 3/4 of the pastoral land.

In spite of this scenario, agriculture is an important economic activity for a large population of the developing tropics. However, a large proportion of the farming community still operate at low levels of productivity and management. Even where 'green revolution' has contributed towards increased food production and has led to national level self-sufficiency as in India, it still is confined to a small section of the society (Ramakrishnan, 1993; Ramakrishnan, 1999) and has had its negative environmental impacts as well. These negative impacts are both biophysical, such as organic carbon depletion, increased soil salinity, drastic changes in soil water regimes, chemical pollution due to fertilizer and pesticidal applications, and social disruptions leading to marginalization of a large segment of the farming communities due to limited access to energy inputs that sustain modern agriculture.

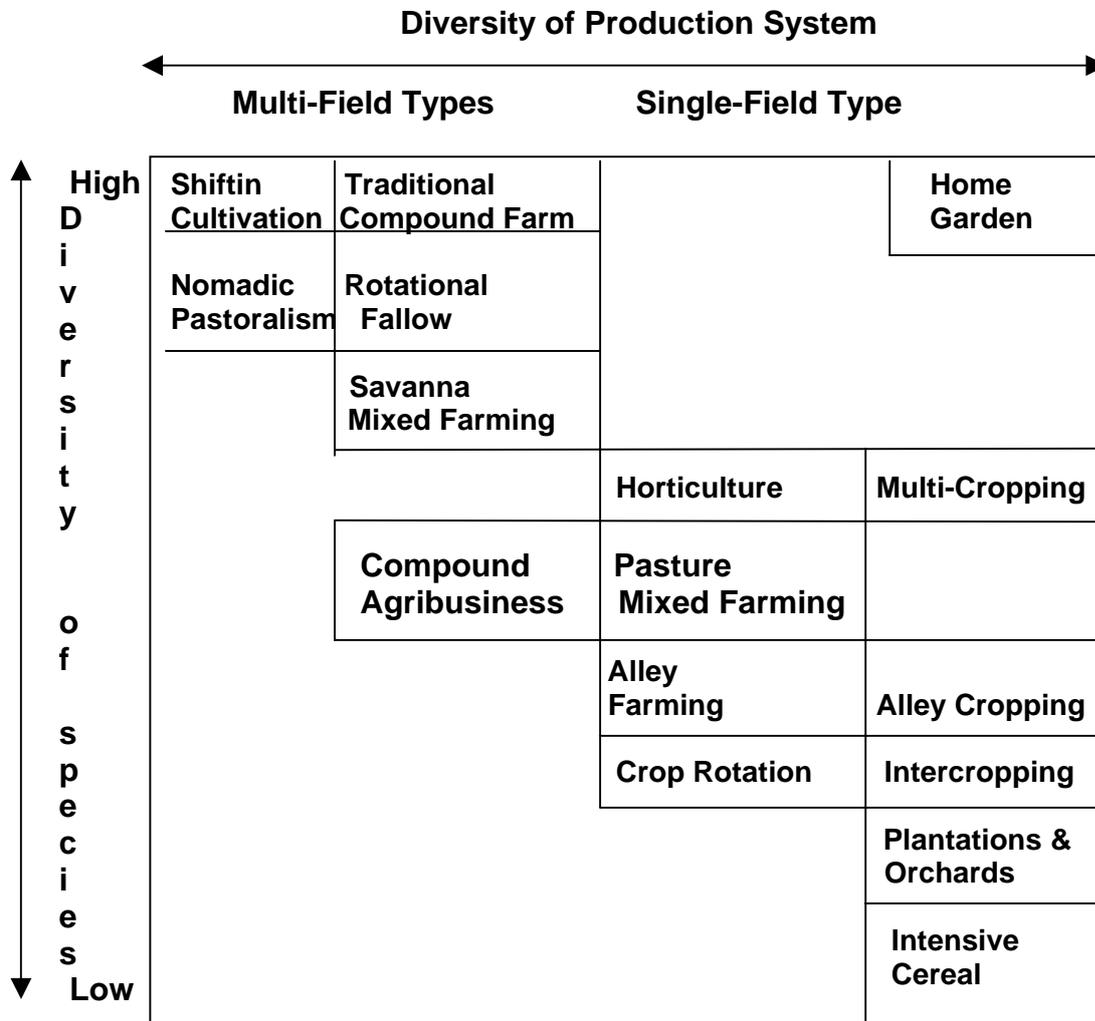
Thus, on the one hand we have a monoculture production system, that is market driven, using genetically engineered uniformity in organisms of a few crop species that could be manipulated under ecological conditions that maximizes output. On the other hand, are over 1.4 billion people (Wolf, 1986) in the developing world are involved in a whole variety of low input multi-species complex agroecosystems, operating under difficult ecological and/or socio-economic circumstances (Fig. 4). Essentially based on traditional technologies developed on the basis of empirical knowledge accumulated over a long period of time, the traditional societies involved have learnt to use crop and associated biodiversity in a variety of ways to strengthen the internal processes that determine stability and resilience of these systems. The emphasis here is not so much on high production but more towards coping with uncertainties in the environment (system resilience), under not so favourable ecological situations in which they operate.

With 'global change', such as large-scale deforestation for meeting industrial needs, over-exploitation of land for agriculture by ever increasing population, the associated decline in biodiversity, soil erosion and nutrient losses, and site desertification on a scale that is unprecedented, impacting upon these systems in a variety of different ways affecting ecosystem complexity (Sala *et. al.*, 1999), two questions become critical. How do we reconcile the productivity concerns with agricultural system resilience? How do we handle our concern for sustainable agriculture in the context of 'global change' (climate change, biodiversity depletion, biological invasion by exotic species, land degradation and desertification)? These are the kind of concerns with which we in India are trying to grapple, on the basis of many initiatives (Ramakrishnan *et. al.*, 1996b).

Forest ecosystems

Tropical forests, an important natural resource used traditionally on a sustainable basis by the local communities, are currently under serious threat due to over-exploitation. Ironically, deforestation carried out in the name of 'development' has led to a steady erosion of the very life support base of the vast majority of the people in the tropics, causing social disruption. Conservation and management represent two sides of the same coin and need to be tackled through a broadly-based interdisciplinary approach with interacting components; silvicultural, ecological, social and economic (Ramakrishnan, 1992b). Only such a strategy would ensure people's participation and ecologically sustainable management of this valuable resource.

Fig. 4. Traditional multi-species agroecosystem complexity linking biodiversity with productivity (from Swift and Ingram, 1996)



Ecological inputs are important for determining management decisions. Knowledge from areas such as tree biology and architecture, patch dynamics, ecophysiology of developing forest communities, reproductive biology and nutrient cycling processes could all be integrated into the current management process and future management options. In such an integrated approach to management, the socio-economic and socio-cultural issues and TEK coming from the local communities need to be reconciled. This is seen from our north-east Indian case study, where the sustainability criterion was the touchstone for designing management strategies (Ramakrishnan, 1992a). Mobilizing the local community in model studies on forest restoration and catchment protection, rainwater harvesting and its distribution, and in a variety of related eco-developmental work arising out of watershed management (e.g. agriculture, agroforestry, horticulture, animal husbandry, bamboo plantation and bamboo-based artisanal activities) have been done in the Himalayan and sub-Himalayan tracts of India by the present author and his colleagues. Local involvement was made possible on the basis of a value system that they understand and appreciate, through direct interaction with villagers, through NGOs or through organized village-level societies.

Landscape Mosaic

Realizing that biodiversity does contribute in a variety of ways to ecosystem functions (Gliessman, 1990; Ramakrishnan, 1992a) and that agroecosystems do harbour a great deal of biodiversity valuable for human welfare (Pimental *et. al.*, 1992), it is reasonable that we go in for a mosaic of natural ecosystems coexisting with a wide variety of agroecosystem models derived through all the three pathways. Such a highly diversified landscape unit is likely to have a wide range of ecological niches conducive to enhancing biodiversity and at the same time ensure sustainability of the managed landscape itself; what we have now represents the other extreme with miles and miles of ecologically non-sustainable human-altered agricultural mono-cropping systems.

Traditionally, many societies have viewed their land use activity in a given landscape as part of an integrated land use management, wherein human managed ecosystems are closely linked to a variety of natural systems (Ramakrishnan, 1992a; Ramakrishnan *et. al.*, 1998, 2000). The diversity of cropping and resource systems that form part of the landscape serves not only as a major means of protecting ecological integrity at the landscape level, but also acts as the knowledge and resource base that makes adaptivity possible; traditional societies adapt their land use practices both in space and time to cope up with uncertainties in the environment and/or to capture market opportunities (Ramakrishnan, 1992a, 1999; Brookfield and Padoch, 1994). Such an adaptability is feasible from the already conserved diversity readily available at the landscape level.

The concept of 'sacred groves' (patches of forests strictly protected and conserved for religious or cultural reasons), as typical examples of protected ecosystems were often part of each village unit (Ramakrishnan, 1992a; Ramakrishnan *et. al.*, 1998), though this value system has been on the decline under the onslaught from the so called 'modernisation' phenomena. Indeed, many traditional societies even had large sacred landscape units: eg., the sacred Ganga river mega-watershed in northern India or the

'Demajong' landscape covering many altitudinal zones ranging from the alpine to the sub-tropical rain forest zone in eastern Himalayan Sikkim, and many sacred mountains in the tropical world (Messerli and Ives, 1997). In these landscape systems, traditional societies had their own way of making subtle distinctions between permissible small-scale perturbations and the tabooed large-scale perturbations, about which modern ecologists have started paying attention only during the last few decades (Ramakrishnan *et. al.* 1998). Indeed, the more recently evolved 'biosphere reserve' concept of UNESCO, is indeed a rediscovery of the 'sacred landscape' concept of many traditional societies dating back to antiquity, is an attempt towards an integrated management strategy to conserve natural resources for sustainable use, with inter-generational equity concerns.

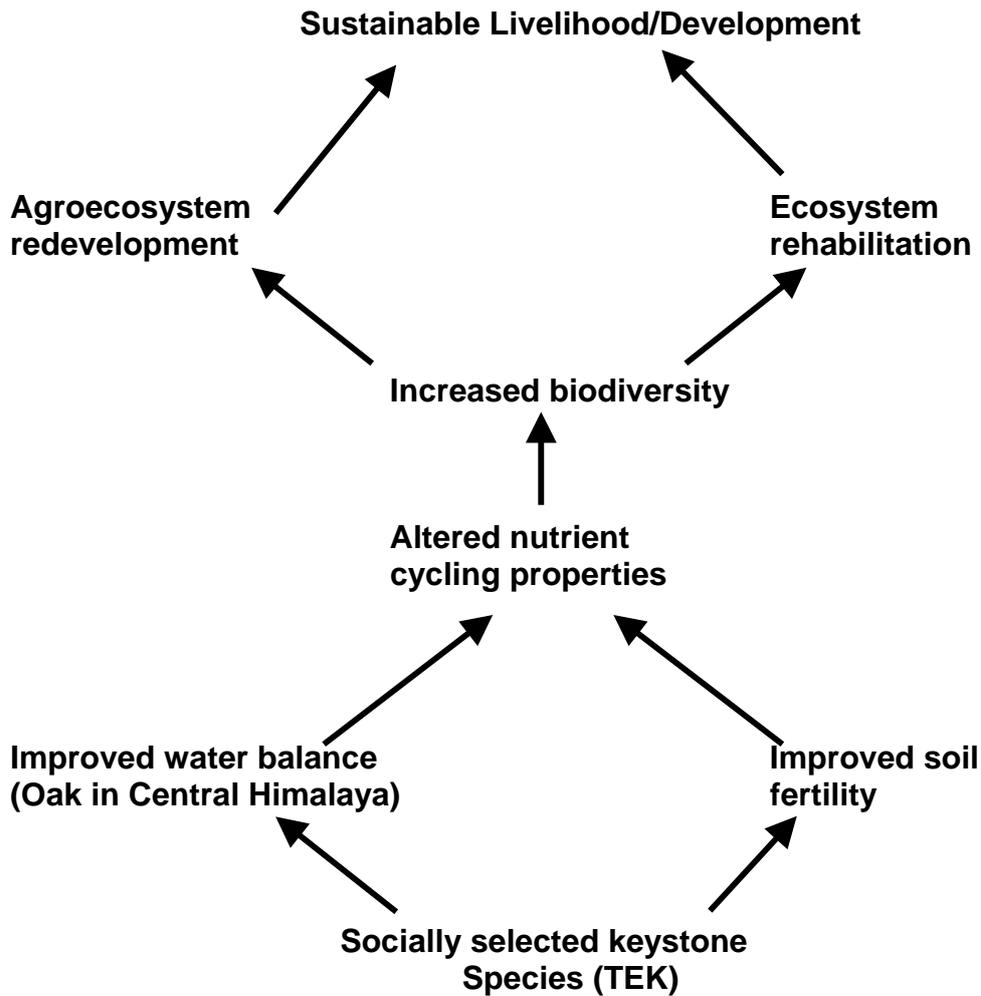
Landscape management demands a variety of responses that are location-specific, in terms of land use activities linked with natural resource management such as, hydrology regime, sustainable soil fertility, biodiversity and biomass production. Whilst dealing with sustainable rural development in the Asian tropics under monsoonic climate, we have shown that water could be a powerful triggering agent for sustainable land use development (Ramakrishnan *et. al.*, 1994a,b). Linking up traditional ecological knowledge and technologies in rain water harvesting and adapting them to meet with contemporary needs is an approach that was taken in the arid regions of Rajasthan in India, by an NGO organization 'Tarun Bharat Sangh', for reviving half a dozen of the already dried up rivers and thus developing the water resource base of this arid zone, through a revival of traditional dug out water harvesting tanks locally called 'Johads' (Singh, 1999). Through a series of over 2500 tanks and small engineering structures erected for soil conservation and increasing rain water seepage into the soil, this NGO organization has been able to regenerate a few thousand square kilometers of land area with good forest cover, increase agricultural production through redeveloped agroecosystems, improve wildlife, and provide a better quality of life to hundreds of villages. The basic tenet which was the driving force in this effort was small-scale operations that are location-specific, through community participation ensured through a variety of institutional arrangements arrived through a participatory mode. In this situation and in all other similar landscape situations, maintenance of the overall sustainability of the systems demand a loosely coupled management (Ehrenfeld, 1991), specifically designed to accommodate large variability in ecosystem complexity within a landscape mosaic.

How do we connect biodiversity, TEK and landscape dynamics with sustainable development?

I shall illustrate the interconnections using just one example. In the Central Himalayan region, are a set of culturally valued *Quercus* species, around which the local communities have many, folk stories, dance, music and poetry, since antiquity. This set of socially selected species are shown to be ecologically significant keystone species, which trigger a whole variety of soil biological processes, which in turn contribute to a rich associated biodiversity in the ecosystem (Fig. 5). Further, the organic litter from them and the associated biodiversity that they support is the key for sustainable mountain agriculture,

also acting as a trigger for ecosystem rehabilitation with community participation. We have also shown that water, through cheap rain water harvesting tanks, acts as a trigger for the regeneration of this species (Ramakrishnan, 1992a; Ramakrishnan *et al.*, 2000), and these species in turn themselves contribute towards improved soil water balance!

Fig. 5. Traditional ecological knowledge, as a trigger for redeveloping ecosystem complexity, with concerns for sustainable livelihood/development of traditional mountain societies



In the ultimate analysis, social processes involved in developing TDK at all scalar dimensions, both in space and time should be reconciled with adaptation of traditional eco-technologies such as water harvesting, show an interesting interconnection between biodiversity, land use dynamics and sustainable natural resource management with concerns for societal welfare.

How do we operationalize ecological holism in teaching ?

Linkages between natural sciences and social sciences is a process of constant interaction, and involves moving back and forth between the ecological and social boxes (Fig. 4). One could move from a plot level analysis of natural and human-managed ecosystems, through a ecosystem level analysis of the ecological and social processes involved, moving on to an understanding of the sustainability considerations at the landscape level. Such a linkage analysis between natural and social sciences alone will be meaningful towards designing short-term strategies for sustainable livelihood of rural communities of the developing world, and for making long-term plans for sustainable regional development.

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Endangered Resources: Biodiversity and Cultural Knowledge.

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A fundamental distinction is often made between the science of the natural world and traditional or ethnobiological systems of knowledge. We question the validity of this distinction. Both systems share a common origin and arise from our innate human behaviour of exploring, characterising and communicating about the world around us. Both have equal validity. However, even when the importance of traditional knowledge is explicitly recognised, as it is in Article 8 of the Convention on Biological Diversity, it is rarely given the attention it deserves and must always defer to science. One of the most important advantages of taxonomy, the scientific system of naming and classifying biological diversity, is that it aims to provide a unique, distinctive name for each species. It has long been recognised that the “international language” of taxonomy enables scientists around the world to communicate and share information about species. Nevertheless, the common language of taxonomic names has generally been seen as superior to, or more correct than, traditional names. This attitude tends to marginalize traditional knowledge and misses the point that it is only through taxonomic nomenclature that we connect together all that we have learnt about biodiversity.

The dazzling diversity of species found on Earth is the result of millions of years of evolution. This biological diversity underpins the economic wealth of our planet providing all of our food, many medicines and numerous other materials. The range of species used by people continues to increase as our exploration of biodiversity progresses. Not only is biodiversity a repository for genetic information gained through the long and incompletely understood processes of biological evolution, it provides vital ecological services and it enriches the aesthetics of our environment.

Culture and language are also repositories for information gained through social development and diversification in ways that are broadly analogous to biological evolution. Like biological diversity, linguistic and cultural diversity have incalculable value to present and future generations. Just as human lives are impoverished by the loss of species, so too are they diminished by the erosion and loss of culture and language. This loss depletes the store of information as surely as the loss of biological diversity. And just as biodiversity research can lead to the identification of useful, species, genes or compounds, so can local knowledge about tropical forest plants or crop varieties. Human cultures and languages are disappearing rapidly, and this loss is as grave as the loss of biological diversity it parallels. Frequently, both losses are inter-related, especially when habitat conversion impacts both on landscape and indigenous peoples.

The Convention on Biological Diversity embodies a world wide consensus on the need to respond to the loss of biological diversity. The corresponding challenge of conserving cultural and linguistic diversity has yet to be adequately addressed and neither have the links to biodiversity been fully appreciated. Although indigenous people, their advocates, and social scientists are acutely aware of the losses, there is as yet no political consensus on how to address this problem or how to conserve cultural knowledge. The dynamics of political and social systems make it far more difficult to design programmes of cultural conservation than it is to establish protected areas or to achieve *ex situ* conservation in botanical gardens, zoos or seed banks. Cultural knowledge cannot adequately be conserved by setting it aside in a museum or by recording it, whether on a paper or electronically. Like biological diversity, traditional, ethnobiological knowledge can only be conserved by keeping it alive and in use.

Traditional knowledge of biodiversity concerns plants and animals and their uses as perceived by the local and or indigenous people of a given area. Having evolved over the millennia it encapsulates accumulated experience, abstracted in the form of appropriate systems of local names and folklore. Such indigenous systems include the botanical or pharmaceutical lexicons of peasants and tribal people, the farmer's knowledge of soils, the hunter's knowledge of animals, the baker's knowledge of yeast and dough and the shaman's ability to read oracle bones. Two definitions of indigenous knowledge have been proposed by Brush (1996): (i) Broadly defined, indigenous knowledge is the systematic information that remains in the diverse social structures. It is usually unwritten and preserved only through oral tradition; (ii) Narrowly defined, it refers to the knowledge system of indigenous people and minority cultures.

Some ancient records concerning knowledge of biological diversity have been preserved, for example, the Indian Vedas, the ancient Chinese herbal *Pen ts'ao kang m*, and Egyptian scrolls concerning medicinal and other plant uses (Schultes and von Reis, 1995). In one sense this is hardly surprising, the oldest and fundamental knowledge for human survival concerns the characteristics and properties of organisms. Knowing which species are beneficial and which are harmful is now, and always has been, a matter of life and death. These ancient insights into medical knowledge are carefully studied by the ethnobiologist. The pre-requisite of all these studies is diligent gathering and pooling of knowledge existing with indigenous folks and traditional groups of people. Important written sources include works of sacred scriptures (eg., Vedic texts and Ayurvedic treatises) and other indigenous medical systems. But much such knowledge is not written down and survives only in the oral culture of local people. Even in ancient times, sages, including Charak and Susruta, mentioned that medical herbs and plants should be recognised and identified with the help of cowherds, hermits, huntsmen, forest dwellers and those who cull the fruits and edible roots of the forest.

Botany, the scientific study of plants, has been approached from two divergent viewpoints; the philosophical and the utilitarian. From the first point of view, botany stands on its own merit as an integral branch of natural philosophy, but when regarded from the second it is the source of origin for medicine, agriculture and industry. It is possible to trace the development of these two lines of enquiry from classical times and

to see how one or the other has predominated and that although they have converged they have often, to their detriment, followed unconnected routes (Arber, 1986).

To the ancient Greek authors Dioscorides, Theophrastus and Aristotle each plant had a soul or psyche, an idea which later European thinking inherited. The science of ethnobotany developed by Western scientists built on these classical Greek writings on the therapeutic efficacy of plants. Indeed, formal systems such as Linnean binomial nomenclature and western pharmacology originated in the indigenous knowledge system (Atran, 1987).

Other cultures have developed ethnobotanical knowledge by different routes. The discovery, enumeration, and evaluations of uses of plants in primitive societies has been described by Shultes and Von Reis (1995). Anthropologists and linguists have documented the breadth, complexity, regularities, and usefulness of indigenous knowledge (Berlin, 1992). Although different concepts are often employed, indigenous knowledge shares these attributes with formal scientific knowledge systems. The Mayan folk classification of plants, for example, is no less systematic than the latest scientific classifications based largely on analyses of DNA sequences. Typically, however, indigenous knowledge is more accessible and freely shared within local communities (Berlin, Raven, and Breedlove, 1974), providing that their cultural traditions persist..

Unfortunately, there remains little interaction between the scientific classification of biodiversity and traditional cultural knowledge. Taxonomy has now provided names for about 1.7 million species out of an estimated total that might be as many as 13 million species. No doubt there are many species recognised and named in traditional systems of classification that have not yet been described by science. In many cases even when a species has been formally described under the internationally agreed rules of scientific nomenclature, science knows nothing more about it than the time and place where it was collected.

We see the opportunity, created by the Convention on Biological Diversity, for a new and vital rapprochement and synthesis between scientific classification and traditional knowledge of plants and animals as captured in myriads of cultural practices, folklore, and indigenous language systems. There is a direct relationship between knowledge and classification based on folklore and taxonomy. Bulmer (1969) pointed out that, "If folk taxonomy bore no relation to scientific taxonomy, but was entirely based on biologically arbitrary but culturally relevant discrimination, there would be no point in obtaining biological identification for the creatures and plants concerned, no way of relating biological information about them to ethnographic information about the uses to which they were put or the manner in which men conceptualised them". Berlin(1992) has indicated a strong need for linking the scientific and folk systems of classification. Example of such links have been quoted by Berlin(1992) who has looked at the relationship between folk names and scientific names. Thus in this relationship Berlin has observed that *Lantana*, a genus in Verbenaceae can be identified by local Tzeltal Maya people, but the local name given 'ch'ilwet' actually is for five different species of

Lantana. Similar studies made by Kapoor(1978) and Pratap and Kapoor(1985) on *Chenopodium* species in India have shown that several species of *Chenopodium* including *C. album* and *C. murale* are known as bithu or bathu by the local rural communities in northern India especially North West Himalayas. Himalayan cultivated forms of *C. album* are referred to by hilly communities called kauna. Interestingly this name is closer to *C. quinoa* a native food crop in Latin American countries Mexico, Bolivia, Peru etc.

The opportunity exists for connecting up all human experiences and knowledge of the diversity of the natural world through the medium of scientific names for species. This is particularly timely given the increasing use of computerised information systems as a means of accessing information about species. In many cases it would not be possible to provide a direct one to one correspondence between culturally important organisms and scientific names. The units recognised in cultural classifications do necessarily correspond to a particular species, or to units, such as genera or families in the higher classification. In fact, scientific concepts of what constitutes a species are not precisely fixed. In practise many species have been given more than one scientific (synonyms) and rules of nomenclature exist to establish which should be correctly applied. Furthermore, scientists differ in their circumscription of genera, families and more inclusive groups. These complexities requires computerised information systems to accommodate different systems of classification and to provide links between the known synonyms of species. Thus, establishing the correspondences between cultural information about species and their scientific names merely extends an existing challenge for such systems. Given the recently announced intention of the OECD nations to create a Global Biodiversity Information Facility, it is important that emphasis be placed on the inclusion of traditional names in this system. In the long run this will contribute to the empowerment of all people to access scientific information about species via whatever names they are familiar with. Furthermore, it will be one contribution to the *ex situ* preservation of endangered cultural knowledge. By including such information the Global Biodiversity Information Facility, and related projects, can be important components in achieving the kind of benefit sharing envisaged under the Convention on Biological Diversity.

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Changing Trends in Biology Education: An International Perspective

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Introduction

Biology as the study of animals and plants has been an integral component of all cultures and religions. The folklore is rich in stories of animals conveying distinct messages of accepted ethics and morals. There is a wealth of traditional knowledge of living things amongst people of all continents. Knowledge relating specifically to healing and harmful properties of local fauna and flora has been passed from generation to generation as part of our heritage through non-formal education and training for life in the community. With modernization has come specialization whereby people are trained to do different jobs in the community. Thus education, once the responsibility of the community, came to be regarded as a special purview of teachers to be had only in schools. As a consequence, biological knowledge as part of the cultural heritage for survival lost much of its significance.

In many countries of Africa, the Arab States, Asia and Latin America, there is usually a single centralized curriculum designed for urban and rural children alike with a view to avoid discrimination and provide equality of opportunity. Within this curriculum, biology is rarely taught as a distinct subject at the primary and lower secondary levels. Instead, it is usually offered as a part of environmental or nature study at the former and as general or integrated science at the latter stage. It is only at the secondary stage that we find biology as a well-established school curricular discipline in most educational systems with public and institutional support. Science as part of general education has always been viewed as a subject of life-long utility in school curricula. Biology, by virtue of its usefulness in everyday life and in sociocultural change, forms an integral component of almost all school science courses. Recently, the trend in many countries has been to switch to environmental studies with curricular content based mainly on three clusters: living things, matter and energy, and earth and universe.

Traditional Setting

In the traditional setting, the scope of school biology education was rather limited. As an elitist subject, it catered to select students who were intending to become either research scientists or medical practitioners. Accordingly, school biology courses concentrated on describing the structure and function of selected types of organisms representing various levels of biological organisation. Biology was taught as an experimental science with emphasis on biological principles to bring out similarities between organisms. In the 1960s, following the lead of the NSF supported Biological Sciences Curricular Study (BSCS) in the United States and the Nuffield Science Programme in the United Kingdom, many countries reoriented their biology education in terms of what biologists actually do. Methods of developing and testing knowledge, concepts, and theories that are central to the discipline of biology were highlighted in the school biology curricula. In order to help its developing Member States, UNESCO, in collaboration with the International Union of Biological Sciences' Commission on Biology Education (IUBS-CBE), initiated the Biology Pilot Project in Africa as part of its Programme

and Budget for the biennium 1967-1968. The course content was organised around important unifying concepts revealed through the process of investigation. New teaching-learning materials were designed to give students the opportunity to learn by doing. The Project was complemented by launching a series of publications under the heading of "New Trends In Biology Teaching."

Science and Society Axis

In the Seventies, a significant drive for the socio-economic applications of science to a vast range of changing human needs gathered momentum. With increasing implications of developments in biological sciences to society, a social approach to biology education was promoted. This initiated a movement to change the orientation of biology discipline as a curricular subject to functionality of biology for the majority of students who would not enter the university. A Preparatory Group Meeting, convened by UNESCO (1975), suggested that school biology education content, while consistent with the new knowledge, should be relevant to the real life and work experience of the learner. Thus, to support the national efforts in adapting biology education to the sociocultural context, UNESCO, in collaboration with IUBS-CBE, produced biology teaching materials relating to some aspects of human biology, such as nutrition, human reproduction, and disease. In particular, IUBS-CBE cooperated with UNESCO in organizing the International Conference on Biology Education in Sweden in 1975 with a view to determine the major problems and trends in biology education. Based on its findings, published as Volume IV of "New Trends in Biology Teaching", a long-term Program of Action for UNESCO was prepared. It emphasized the change from the closely directed learning of facts to conceptual understanding, application of acquired knowledge and skills to solve emerging life's problems, and linking biology education to socioeconomic needs, productive work, and development. Accordingly, UNESCO, in cooperation with IUBS-CBE, promoted innovations to increase the relevance of biology teaching to the various needs and socioeconomic priorities of its Member States.

Thus, trends such as "science in society" and "science, technology and society" placed biology teaching in the context of social needs of everyday life. This shifted the focus of biology education from, "what to know?" to "what to do?" Accordingly, efforts were made to reorient the biology teacher education and training programmes to suit the changing goals of biology education. The 1980's marked the surge of a new wave demanding science and technology to be an integral component of general education in schools with a view to turn out future citizens as responsible productive persons in the society. With this, the purpose of biology education and teacher training shifted towards social action, marking a change from "what to do?" to "what to become?"

With sociocultural and economic changes occurring as a consequence of scientific and technological developments, it became clear that biology education should aim at preparing people to face new situations and changing social patterns in such a way as to satisfy both the individual needs of learners and the collective requirements of the society. The Association for Science Education (ASE) in the United Kingdom (1979) suggested introduction of some aspects of the world of work into the school science curriculum. In order to improve children's appreciation of the world of industry and work, biology education undertook the task to encourage public awareness of the inter-relationship between science, technology, and society as well as to stimulate attitudes that would prove conducive for their preparation for the world of work. Accordingly, IUBS-CBE devoted two of its annual meetings (1978 London, UK and 1979 Kiel, Germany) to the topic of "Biological Education for Community Development." This was followed by the publication, "Teaching Science Out-of-School with Special Reference to

Biology” (Meyer and Rao, eds., 1984), based on the proceedings of the IUBS-CBE meeting held in Singapore in 1981. In addition, the Commission produced a series of documents published by UNESCO in its Science and Technology Education Document Series (STEDS). These included: Genetically-Based Biological Technologies (1984); Biological Systems, Energy Sources and Biology Teaching (1984); Ecology, Ecosystem Management and Biology Teaching (1984); Agriculture and Biology Teaching (1984); Human Development and Evolution and Biology Teaching (1985); Field Work in Ecology for Secondary Schools in Tropical Countries (1988); Repair and Maintenance of Biology Laboratory Equipment (1989); and Teaching Biotechnology in Schools (1990).

Science and Development

Following the United Nations Conference on Science and Technology for Development (UNCSTD), 1979, the concern for modernization through science and technology in many developing countries gathered momentum. Science and technology education became increasingly acknowledged as an essential contributor to national development. The International Congress on Science and Technology Education and National Development (UNESCO, 1981) bears ample testimony to this effect. The Bangalore Conference, sponsored by ICSU, UNESCO and ICASE (1985), encouraged science education reform in terms of future human needs and various quality issues such as ethics, social responsibility, agriculture, industry, technology, health, food, energy, environment; land, mineral, and water resources; and information transfer. In line with this, IUBS-CBE developed such documents as “Biological Education and Community Development” in 1980, containing a collection of reports and papers presented during its annual meetings of 1978 and 1979 and edited by Kelly and Schaefer; followed by “Health Education and Biology Teaching” in 1984; “Leisure, Values and Biology Teaching” in 1987; “Biology and Human Welfare: Case Studies in Teaching Applied Biology” in 1988; “System Thinking in Biology Education” in 1989; and a book on “Basic Human Needs: An Interdisciplinary and International View” by Schaefer, (1992).

This ushered a shift in emphasis towards social action, extending the slogan, “Science, Technology and Society (STS)” to “Science, Technology, Society and Personal Development (STSP).” The personal development aspect, as described in the UNESCO Regional Workshop on Science and Technology Education at Lower Secondary Level (1991) recognized the possibilities within the science curriculum to enhance students’ personal skills in logical thinking, expression, personal management, self-directed learning, co-operation and responsible action. This approach demanded more attention to teaching children how to learn, manage their own learning, analyze problems, as well as design and implement solutions.

Science for All

It was recognized that science and technology cannot contribute successfully towards national development in the absence of a broad base of scientifically literate populace (Yager, 1989; Bowyer, 1990). Consequently, the goal of an “appropriate science education for all” started assuming greater prominence. The Science Council of Canada (1984) commissioned a study entitled “Science for Every Student.” It pointed out that Canada needed science education that could: develop citizens able to participate fully in the political and social choices facing a technological society; train those with special interest in science and technology fields for further study; provide an appropriate preparation for the modern work world; and stimulate intellectual and moral growth to help students develop into rational autonomous individuals. Similarly, the “Science for All Americans” Project, launched in 1985, presented what all USA

students should know and be able to do in science, mathematics and technology by the time they graduate from the high school. It also emphasized “understanding of the world through the eyes of science.” Another effort for “Science for All” can be cited from Asia and the Pacific (UNESCO, 1983). In this context, science referred to all those aspects of knowledge that result from the application of the scientific method for investigating real life situations relating to natural phenomena, the material world, and the immediate environment, including scientific concepts, processes and attitudes. Its purpose was to enable the whole population to participate in the responsible use of science and technology for development. The 1990 World Declaration of Education for All and the 1992 Rio Declaration on Environment and Development provided the driving force for the Project 2000+ Declaration. It urged NGOs, INGOs and governments to work together to enhance scientific and technological literacy for all within the Project 2000+.

International Commission on Education

A significant event of the 1990s, with consequences for the future of biology education, was the establishment of the International Commission on Education for the 21st Century by UNESCO in 1993. Based on a worldwide process of consultation and analysis, the Commission highlighted the role of education in personal and social development. It also predicted that the coming century, dominated by globalization, will face some serious tensions between: the global and the local; the universal and the individual; tradition and modernity; long-term and short-term considerations; the need for competition and the concern for equality of opportunity; the extraordinary expansion of knowledge and human capacity to assimilate it; the spiritual and the material. Irrespective of diversity of cultures and systems of social organization, the Commission believed that education could serve as one of the means to foster more harmonious human development to overcome the said tensions and maintain social cohesion. Accordingly, the Commission proposed and described four pillars as the foundations of education: learning to know, learning to do, learning to be, and learning to live together. In order to deal with the fast change of traditional patterns of life and to meet new situations arising in our personal lives and working conditions, the Commission put greater emphasis on the last pillar, learning to live together. Furthermore, to keep abreast and live in harmony with the ever changing world, the Commission supported learning throughout life and pointed out that the only way to satisfy this is for each individual “to learn how to learn” (UNESCO, 1996).

Future Outlook

The Twentieth Century is often called the century of Physics and Information Technologies. During our own lifetime we have seen the development of television, computers, satellites and the Internet. These technologies will continue to affect our lives and our social, cultural, economic and educational systems. Recently, however, Biological Sciences have been making tremendous strides. As we stand at the threshold of the 21st Century, we see the beginning of another scientific revolution that is likely to dominate the new century, sparked, in particular, by research in biotechnology and the success of the Human Genome Project. In the next couple of years, people will be able to assess their own genetic susceptibilities to various diseases and hence be able to make their necessary lifestyle adjustments in a way that has never happened before. Gene therapy may replace some of the current medical practices for the treatment of certain forms of disease. Extending already to other species of microbes, plants and animals, genetic manipulation is expected to take us into a brave new world with greater societal impact than that of the technological revolution of the 20th Century. Influencing almost all our activities, from inception to the grave, this revolution will require profound decisions with respect to the ethical, legal, social, cultural, educational, and development issues that are sure to

arise, affecting our personal lives and society in ways that we have never experienced before. In order to be prepared for this, it is imperative that biologists, media, educational planners and biology educators work together to ensure that future citizens who are in school today and the public at large are thoroughly educated and made aware of the basic and relevant knowledge of biology and biotechnology, so as to enable them to make informed decisions to meet any emerging situation.

Learning Society

The exponential growth of biological knowledge and development of new information and communication technologies along with the concept of learning throughout life lead us straight to what we may call the “learning society.” Such a society is based on the acquisition, renewal, and use of knowledge. The hallmark of this learning society will be the provision of many and varied opportunities of learning both at school and at work in social, cultural, and economic life to fulfill one’s potential. This requires two important actions: firstly, to make new knowledge more accessible in more ways to more people; and secondly, to make more knowledge more useful to learners. It will also require greater co-operation and new partnerships involving family, industry, business, voluntary associations, and individuals active in new information and communication technologies. Many institutions have already started pooling their resources to create new educational courses using computers and Internet as educational tools for distance learning. Libraries with their vast holdings can work with educators to provide educational content to meet the changing needs of school biology curricula. With similar collaboration, television and satellite can also be exploited for the same purpose.

Humans, Environment, and Sustainable Society

With ever new knowledge and tools of science and technology developing during the last few decades, humans magnified their role as a dominant force in nature, modifying its physical, chemical and biological systems at rates and scales larger than ever. The growing human population has caused, among other things the following major changes: altering and/or depleting major natural resource systems; altering biogeochemical cycles of carbon, nitrogen, water, synthetic chemicals, etc.; disturbing ecological balance; transforming land, sea, and air; depletion of the ozone layer; producing genetically manipulated species and/or populations; loss of biological diversity; depletion of forests and fisheries; and environmental degradation and pollution.

These changes are direct or indirect consequences of our thinking, values, and practices in social, economic, and political affairs. If not checked, many of our current actions will soon put at risk the future we wish for human society. The need is now evident to ensure a society that is more sustainable. In fact, while accentuating the global environmental challenges, the United Nations Conference on Environment and Development, held in Rio in 1992, expressed the urgency of sustainable development for the world community. To achieve this, it is essential that we get our thinking right and new values sorted out. The most critical challenges facing such a society include conservation, restoration, and rational management of world’s natural resources.

Humans and their socio-economic systems are intimately dependent upon ecological systems, as these provide a broad range of essential goods and services to humanity. In fact, they form the life-support systems of all life on the planet. Ecological goods and services provide a key link to understanding how changes in diversity, climate, stratospheric ozone, as well as land and sea

transformations and cycles of water and nitrogen have immediate and long-term consequences for humanity. Ecosystem services include purification of our air and water; mitigation of floods and droughts; detoxification and decomposition of waste; generation and renewal of soil and soil fertility; pollination of crops and natural vegetation; control of agricultural pests; dispersal of seeds and translocation of nutrients; and maintenance of biodiversity. Hence, biology education as part of general education, emphasizing these and other relevant topics, offers one of the most effective means of confronting the challenges of the future. Its goal should be to make people more knowledgeable, better informed, ethical, responsible, critical, and capable of continuous learning and exercising rational choice of options based on proper knowledge and information. In the light of biological revolution, the discipline of biology should be woven with the social, cultural, economic, and political issues. Thus treated, biology education can easily help to sensitize people to create a sustainable society. This question was discussed in more detail in the IUBS-CBE meeting held in Moscow in 1997.

Biology Education Agenda

In the fast changing world of tomorrow, there will be far less stability, and as a consequence, people may have to change directions in their careers and lifestyles. With the inventions of new technologies to take up the routine or dangerous tasks, there will also be an increasing amount of leisure. Of all the ills that presently beset us, none is more pernicious than the fragmentation of knowledge into arts and science and their corresponding disciplines. Life and its problems do not fit into such neat compartments. These divisions are only for convenience and do not accord with the nature of our experience of reality. With recent advances in scientific knowledge and their applications in solving emerging global problems, the traditional subject boundaries in science are fast fading, giving greater significance and vitality to bridging sciences of biochemistry, biophysics, and material sciences. To be realistic, biology education must interact with other school disciplines, particularly with social sciences and humanities, to be of use to society in solving its current problems.

Biology education, over the years, has undergone significant changes in its perception. It is increasingly recognized as an essential background for socio-economic growth and stability. As such, it should be seen in a broader perspective, i.e. as catering to prepare biologically literate populace capable of contributing towards sustainable development. It can also help to improve the quality of human situation through informed decision-making based on judicious understanding and rational utilisation of biological knowledge and biological technology in such areas as agricultural production, nutrition, health, population control, natural resource management, and environmental improvement. The new biology education content must accommodate these issues in meeting the challenges of the environmentally and socially sustainable development. Information and communication technologies have, indeed, created great educational possibilities, but to succeed, political will, proper planning and concerted actions are equally necessary.

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International Association of Sexual Plant Reproduction Research (IASPRR) Conference

Banff , Alberta, Canada, April 1-5, 2000

The 16th international congress on sexual plant reproduction was held at The Banff Centre in Banff, Alberta, Canada April 1-5, 2000. The congress was organized by David Cass (University of Alberta, Alberta, Canada), Art Davis and Vipen Sawhney (University of Saskatchewan, Saskatchewan, Canada), and Yvonne Dixon (The Banff Centre, Alberta, Canada). There were about 160 delegates from 23 countries. The congress consisted of 2 special lectures, 6 symposia (38 individual talks) over 4 days, and nearly 90 poster presentations. One of the special lectures was the keynote address entitled "Sexual Plant Reproduction: past, present, and future," given by Joseph Mascarenhas (State University of New York at Albany, U.S.A.). The other special lecture, "Conifer reproduction: diversity in a small but ancient group," was given by John Owens (University of Victoria, Canada). Symposium topics were: experimental embryogenesis; flowering and flower development; environmental stress and reproduction; apomixis; pollen tube growth; male sterility and hybrid seed production. In addition to symposium talks and special lectures, there were approximately 90 poster presentations, which delegates could view at their convenience. A general meeting of the IASPRR was held after the apomixis symposium on Monday, April 3. A banquet was held in the evening of Tuesday, April 4 at the conclusion of which special recognition was given to Ms. Yvonne Dixon, Conference Services Manager of The Banff Centre, for her inspired assistance in putting this conference together, and to Dr. Michiel Willemse, Wageningen University, Wageningen, The Netherlands, for his lifetime contributions to the IASPRR. At the closing ceremonies on Wednesday, April 5, awards were made to Kristen A. Lennon, University of California, Riverside, California, U.S.A., for her poster on pollen tube structure of *Arabidopsis*, to Jeffrey D. Pylatiuk, University of Saskatchewan, Saskatoon, Canada for his poster on hybrid seed production in *Brassica napus*, and to M. Sofia Cordeiro, University of Lisbon, Lisbon, Portugal, for her symposium talk on chloride and potassium fluxes during pollen tube growth in *Lilium*. The conference ended with lunch on Wednesday, April 5.

Our conference was an interesting blend of both basic and applied science. The basic parts included new information on the genetics of floral development, electrophysiology of pollen tube growth, stylar extracellular matrix structure as it relates to pollen tube growth, genes controlling apomixis, experiments with living flowering plant embryos, the effects of environmental stress on plant reproduction, and male sterility and hybrid seed production. Many of these topics have important applications to crop production. For example, the group from Hamburg, Germany has developed a method for introducing a novel gene into sperm cells of maize. Zygotes resulting from in vitro fusion of eggs with transgenic sperms express the novel gene. This result is important to researchers interested in developing different approaches for the introduction of new genetic material into plants at very early stages. Researchers at Pioneer Hi-Bred have developed a line of maize which is male sterile unless the tassels are sprayed with biotin. Their result means that male fertility can be "switched on" when pollination is required. If the biotin spray is not used, the plants remain male sterile.

Sponsors for IASPRR 2000 were: Ag-West Biotech, Inc., Saskatoon, Saskatchewan, Canada; Aventis CropScience, Brussels, Belgium and Saskatoon, Saskatchewan, Canada; Novartis, Basel, Switzerland; Pioneer Hi-Bred International, Inc., Johnston, Iowa, U.S.A.; Plant Biotechnology Institute, Saskatoon, Saskatchewan, Canada; University of Alberta, Edmonton, Alberta, Canada; University of Saskatchewan, Saskatoon, Saskatchewan, Canada; Zeneca Agrochemicals Ltd., Jealott's Hill, U.K. The organizers of IASPRR 2000 wish to express their gratitude for the generous support received from these sponsors.

PUBLICATIONS REVIEW

ALTERNATIVE REPRODUCTION STRATEGIES

Edited by Motonori Hoshi & Midori Matsumoto, 2000. Published in *The Journal of Reproduction and Development* (Vol. 46, Supplement March, 2000, (88 pages).

This Supplement Issue is a collection of the extended abstracts of the presentations at the IUBS-TAIB Symposium on "Alternative Reproductive Strategies." The meeting was held on 25-28 Nov., 1999, in Hayama, Japan to discuss the problem of alternative strategies with a very broad view from theoretical to experimental, from molecular biology to natural history, and from bacteria to mammals.

BALANCED THINKING An Educational Perspective for 2000+ on the Basis of a Cross- cultural German/Japanese Study

By Gerhard Schaefer and Ryoei Yoshioka. Published by Peter Lang GMBH, Frankfurt/M., Germany, 2000, (206 pages)

This book, initiated by a comparative empirical study on ways of thinking of populations of German and Japanese students, picks up on the old question of the decision-making process between contradicting needs. Stimulated by striking differences found in the way the two populations dealt with the contradiction problem, the study addresses the general problem of contradiction against the background of a "polarity approach" to life.

BIOTECHNOLOGY AND BIOSAFETY

Edited by Ismail Serageldin and Wanda Collins. Published by the IBRD/World Bank, 1999, (214 pages).

These are the proceedings of the meeting on "Biotechnology and Biosafety," an associated event of the fifth annual World Bank Conference on Environmentally

Sustainable Development. Focusing on how the promises of biotechnology can be realized for the benefit of the world's poor, the environment, and the safe management of biotechnology products and processes, this volume summarizes the wide-ranging, stimulating and provocative presentations and discussions that took place during the meeting.

GLOBAL CHANGE STUDIES Scientific Results From ISRO Geosphere Biosphere Programme

Edited by BH Subbaraya, DP Rao, PS Desai, B Manikiman, P Rajaratnam. Send your order to: San Subscription Agency, 104, Sector 28, Faridabad -121 008 (Haryana-India) Tel: 5278504 E.mail: sansub@ndf.vsnl.net.in

The book Global Change Studies contains about 20 scientific articles based on actual work done and results obtained by ISRO-GBP scientists during the period 1994 to 1997. The papers address a wide range of topics from atmospheric chemistry and radiation (trace gases and aerosols) atmospheric/climate modelling, boundary layer research, agriculture and forestry biodiversity and ecosystem studies, oceanography and paleoclimate studies.

LIMNOLOGY IN DEVELOPING COUNTRIES

Edited by Robert G. Wetzel and Brij Gopal, Published by SIL and International Scientific Publications New Delhi, India, 1999 (330 pages)

Freshwater resources are becoming more crucial than ever for the sustenance of life on the earth. The ever increasing human demands for water and rapid deterioration of water quality threaten freshwater biodiversity. Understanding of the functioning of inland water ecosystems and their interactions with their respective drainage basins is critical to their sustainable management. The principal aim of the "Limnology in Developing Countries" series, which is published by the International Association for

Theoretical and Applied Limnology (SIL), is to review the status of conservation and management of inland water resources, and to encourage limnological research and training in developing countries. This 2nd volume of the series includes reviews of limnological research and training for five countries: Costa Rica, Uruguay, Ethiopia, Indonesia and Morocco. Reviews for three of the largest developing countries, Brazil, China and India, are in advanced stages of preparation.

MOUNTAIN BIODIVERSITY, LAND USE DYNAMICS, AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Edited P.S. Ramakrishnan, U.M. Chandrashekhara, C. Elouard, C.Z. Guilmo, R.K. Maikhuri, K.S. Rao, S. Sankar & K.G. Saxena. Published by UNESCO MAB and Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India, 2000 (353 pages).

This book presents the results of a 3-year research initiative funded by UNESCO and the MacArthur Foundation and comprising three case studies in India, namely: the Kodagu District, Karnataka State; the Chinnar Wildlife Sanctuary in the Kerala State; and the buffer zone of the Nanda Devi Biosphere Reserve, in the Uttar Pradesh. This comparative study programme looked at the dynamics involved in natural resource management, both in space and time, linking them wherever appropriate with traditional ecological knowledge.

A whole gamut of interconnections ranging from sub-specific, species, ecosystem, leading up to landscape levels were used to arrive at conclusions relevant to natural resource management with concern for the livelihood/development of the communities and regions under consideration.

OUR COMMON JOURNEY A Transition Toward Sustainability

By the Board on Sustainable Development, Policy Division, National Research Council. Published by National Academy Press, 1999, (363 pages).

With the world human population expected to reach upwards of 9 billion by 2050, two key questions arise: How can the transition to a stabilizing population also be a transition to sustainability? And how can science and technology help ensure that human needs are met while the planet's environment is nurtured and restored?

Examining these questions, this book draws strategic connections between scientific research, technological development, and societies' efforts to achieve environmentally sustainable improvements in human well-being. Arguing that societies should approach sustainable development not as a destination but as an on-going, adaptive learning process, the book proposes a strategy for using scientific and technical knowledge to inform future action in the areas of fertility reduction, urban systems, agricultural production, energy and materials use, ecosystem restoration and biodiversity conservation, and suggests an approach for building a new research agenda for sustainability science.

THE VENICE LAGOON ECOSYSTEM Inputs and Interactions Between Land and Sea

Edited by P. Lasserre & A. Marzollo, 2000. Published by UNESCO MAB & The Parthenon Publishing Group (508 pages).

The scientific results of the Venice Lagoon Ecosystem Project, which are reported in this volume, represent a distinctive contribution to the understanding of one of the most renowned coastal lagoon ecosystems, as well as to decisions on the future development of Venice and its lagoon. The approaches and insights described in the book will also be of interest to scientists working on coastal lagoon ecosystems in other parts of the world.

CALENDAR OF MEETINGS

IUBS – sponsored meetings are indicated in bold-type face
Additional information may be obtained from addresses in () parentheses

2000

E-mail: iubs@paris7.jussieu.fr <http://www.iubs.org>)

BIOTECHNOLOGY

11th Int'l Biotechnology Symposium and Exhibition

3-8 Sept., ICC, Berlin, Germany
(DECHEMA e.V., c/o 11th IBS,
Theodor-Heuss-Allee 25,
D-60486 Frankfurt a. Main, Germany
Fax: +49 (0)69 756 41 76 E-mail: info@dechema.de
<http://www.dechema.de/biotechnology2000>)

Int'l Marine Biotechnology Conference (IMBC 2000)

29 Sept.-5 Oct., Townsville, Australia
(Contact: Australian Institute of Marine Science,
P.O. Box 216, Aitkenvale, QLD 4814 Australia.
Ph: +61 (0)7 4781 6219 Fx: +61 (0)7 4781 5822
E-mail: imbc_2000@aims.gov.au
<http://www.aims.gov.au/imbc-2000>)

GENERAL BIOLOGY

Seminar Biology 2000 –on the occasion of 400 Years of the Birth of Modern Science Galileo-Galilei

23-28 Oct., Bogotá D.C. Colombia
(Contact: Hugo Hoenigsberg, Dept. of Genetics and Evolution, University Manuela Beltrán, Avenida Circunvalar # 60-00, Bogotá, D.C. Colombia
Ph: +57 1 546-0625, -0628
Fax: +57 1 546 0629
E-mail: hoenisbe@academica.umb.edu.co)

GENETICS

Ressources Génétiques: Connaissances et Gestion – 3^o colloque national

9-11 Oct., Toulouse, France
(Contact: BRG, 16 rue Claude Bernard, 75231 Paris cedex 05 France. Fax: +33 (0)1 44 08 72 63
E-mail: Brg@inapg.inra.fr)

IUBS

IUBS 27th General Assembly & Int'l Conference "Biological Sciences: Challenges for the 21st Century"

8-12 November, Naples, Italy
(Contact: Dr. Talal Younès, IUBS, 51 Bd Montmorency, 75016 Paris. Ph: +33 (0)1 45 25 00 09
Fax: +33 (0)1 45 25 20 29)

MOLECULAR BIOLOGY

International Conference on Cell Surface Aminopeptidases

15-18 August, Nagoya, Japan
(Contact: Kazuhiko Ino, Department of Obstetrics and Gynaecology, Nagoya University School of Medicine, 65 Tsurumai-cho, Showa-ku, Nagoya, 446-8550, Japan
Ph: +81 52 744 2261,
Fax: +81 52 744 2268
E-mail: smizu@tsuru.med.nagoya-u.ac.jp)

OCEANOGRAPHY

SCOR 25th General Meeting & Symposium "Nutrient Over-enrichment in Coastal Waters: Global Patterns of Cause and Effect"

10-13 October, Washington, D.C., USA
(Contact: Elizabeth Gross, SCOR Secretariat, Dept. of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 21218 USA
Ph: +1 410 516 4070
Fax +1 410 516 4019
E-mail: scor@jhu.edu)

PLANT PROTECTION

7th Arab Congress of Plant Protection

22-26 Oct., Amman, Jordan
(Contact: Dr. Walid Abu-Gharbieh, Faculty of Agriculture, Univ. of Jordan, Amman - 11942, Jordan
Fax: +962 6 5355577
E-mail: sacpp@ju.edu.jo)

BCPC Conference –

Pests and Diseases 2000
13-16 Nov., Brighton, England
(Contact: BCPC Conference Secretariat,
5 Maidstone Bldg Mews, Bankside,
London SE1 1GN, England
Fax: +44 (0)20 7940 5577
E-mail: conference@bcpc.org)

ZOOLOGY

The New (XVIII) Int'l Congress of Zoology

28 Aug.-2 Sept., Athens, Greece
(Contact: Dr. R. Polymeni, Hellenic Zoological Society, P.O. Box 3249 K.T., 102 10 Athens, Greece)

2001

GENERAL BIOLOGY

1st Int'l Conference on Biosystem Science
& Engineering ICBSE &
Int'l Conference on Endocrinology &
Molecular Morphogenesis &
Int'l Conference on Transgenic Animals
and Bio-Logic Engineering

21-27 Oct., Beijing, China
(Contact: Bangzhe J. Zeng, An der Hohnhorst 11,
31535 Neustadt a. Rbge., Germany
E-mail: Bangzhe@hotmail.com
<http://www.genbrain.net>)

ENDOCRINOLOGY

14th Int'l Congress of Comparative
Endocrinology

26-30 May, Sorrento, Italy
(Contact: Studio Congressi Cicala de Pertis,
Via S. Anna dei Lombardi, 38
80134 Napoli, Italy
E-mail : studiocongressi@napoli.com
<http://www.napoli.com/studiocongressi>)

LAKE BIODIVERSITY

ILEC Conference – 9th International
Conference on the Conservation and
Management of Lakes (Biwako 2001)

11-16 Nov., Oroshimo, Kusatsu, Shiga, Japan
(Contact: Secretariat of Biwako 2001,
Shiga Prefectural Government, 4-1-1 Kyomachi,
Otsu, Shiga, 520-8577, Japan
Ph: +81 77 528 3465, Fax: +81 77 528 4849
E-mail: lake2001@pref.shiga.jp
<http://www.pref.shiga.jp/lake2001>)

MEDICINAL & AROMATIC PLANTS (WOCMAP 2001)

8-10 July, Budapest, Hungary
(Contact: Dr. Oszkár Köck, Nat'l. Inst. for Agricultural
Quality Control, P.O. Box 30, 93.
H-1525 Budapest, Hungary. Ph: +36 1 2123 127
Fax: +36 1 2122 673 E-mail: map.congr@ommi.hu)

PLANT PROTECTION

Seed Treatment – Challenges and
Opportunities

26-27 Feb., Wishaw, North Warwickshire, England
(Contact: British Crop Protection Enterprises
49 Downing Street, Farnham, Surrey GU9 7PH, UK
Ph: +44 (0)1252 733 072, Fax: +44 (0)1252 727 194
E-mail: md@bcpc.org <http://www.bcpc.org>)

Resistance 2001 – Meeting the Challenge

23-26 Sept., Harpenden, Herts., England
(Contact: IACR-Rothamsted, Harpenden,
Herts. AL5 2JQ, UK. Ph: +44 (0)1582 763113
Fax: +44 (0)1582 760981
E-mail: res.2001@bbsrc.ac.uk
<http://www.iacr.bbsrc.ac.uk/tmeeting.html>)

2002

HORTICULTURAL SCIENCE

XXVI Int'l Horticultural Congress

August, Toronto, Canada
(Contact: Dr. J. Van Assche, K. Mercierlaan 92,
3001 Leuven, Belgium
Ph: +32 (0)1 622 9427, Fax: +32 (0)1 622 9450
E-mail: info@ishs.org)

ORNITHOLOGY

23rd Int'l Ornithological Congress

11-17 Aug., Beijing, China
(Contact: Prof. Xu Weishu, 1-1-302 Beijing Sci. and
Tech. Commission Apt., Lingnan Rd. Beijing 100037,
P.R. China
Ph/Fax: +86 (0)10 6846 5605
E-mail: s-g@ioc.org.cn)

PARASITOLOGY

Xth Int'l Congress of Parasitology

August, Vancouver, Canada
(Contact: Prof. M. Zia Alkan, Dept. of Parasitology,
Medical Faculty of Ege Univ., Bornova-Izmir 35100,
Turkey. Fax: +90 (0)232 388 134
E-mail: alkan@med.ege.edu.tr)

PATHOPHYSIOLOGY

4th Int'l Congress of Pathophysiology

29 June-5 July, Budapest, Hungary
(Contact: Prof. Lajos G. Szollar, Institute of
Pathophysiology, Semmelweis University Medical
School, Budapest, P.O.B. 370, H-1445 Hungary)

BIOLOGY INTERNATIONAL

**The News Magazine of the
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The International Union of Biological Sciences is a non-governmental, non-profit organisation, established in 1919. Its objectives are to promote the study of biological sciences, to initiate, facilitate, and co-ordinate research and other scientific activities that require international cooperation, to ensure the discussion and dissemination of the results of cooperative research, to promote the organisation of international conferences and to assist in the publication of their reports.

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National Adhering Organisations

ARGENTINA- Consejo Nacional de Investigaciones Científicas y Técnicas

AUSTRALIA- Australian Academy of Science

AUSTRIA- Österreichische Akademie der Wissenschaften

BELGIUM- Royal Academy of Science, Letters & Arts

BRAZIL- Conselho Nacional de Desenvolvimento Científico e Tecnológico

BULGARIA- Bulgarian Academy of Sciences

CHILE- Sociedad de Biología de Chile

CHINA- Association for Science and Technology, Beijing

CHINA- Academia Sinica, Taipei

CUBA- Academia de Ciencias

CZECH Republic- Czech Academy of Sciences

DENMARK- Det Kongelige Danske Videnskaberne Selskab

EGYPT- Academy of Scientific Research and Technology

FINLAND- Delegation of Finnish Academies of Sciences & Letters

FRANCE- Académie des Sciences

GERMANY- Deutsche Forschungsgemeinschaft

HUNGARY- Hungarian Academy of Sciences

INDIA- Indian National Science Academy

IRELAND- Royal Irish Academy

ISRAEL- Academy of Sciences and Humanities

ITALY- Consiglio Nazionale delle Ricerche

JAPAN- Science Council of Japan

LEBANON- National Scientific Research Council

MEXICO- Consejo Nacional de Ciencia y Tecnología

MONACO- Centre Scientifique de Monaco

NETHERLANDS- Koninklijke Nederlandse Akademie van Wetenschappen

NEW ZEALAND- The Royal Society of New Zealand

NORWAY- Det Norske Videnskaps Akademi

PHILIPPINES- National Research Council of the Philippines

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ROMANIA- Romanian Academy of Sciences

RUSSIA- Russian Academy of Sciences

SAUDI ARABIA- King Abdul Aziz City for Science & Technology

SLOVAK Republic- Slovak Academy of Sciences

SOUTH AFRICA- Foundation for Research Development

SPAIN- Comision Interministerial de Ciencia y Tecnología

SWEDEN- Kungliga Vetenskapsakademien

SWITZERLAND- Swiss Academy of Sciences

TUNISIA- Association Tunisienne des Sciences Biologiques

UNITED KINGDOM- The Royal Society

U.S.A.- National Academy of Sciences- National Research Council

VENEZUELA- Consejo Nacional de Investigaciones Científicas y Técnicas