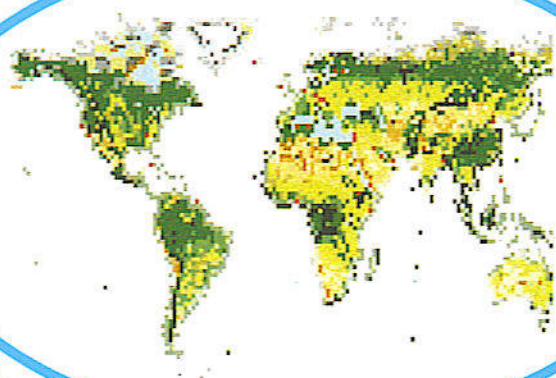


BIODIVERSITY FOCUS

**The Human Dimension of Biodiversity
DIVERSITAS Science Plan
International Biodiversity Observation Year
(IBOY) 2001-2002
Assembling The Tree of Life**



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Editorial

Scientific Responsibility in a Changing World

Never before has the world more clearly and concertedly needed leadership from scientists. The tragic events of September 11th, those that have followed, and the way that they have enhanced our collective perception of the horror of many years of terrorism in various parts of the world, have forced many of us to re-assess our priorities, both personal and professional. We have acquired a new perspective on our places in the world, and a more humble but more demanding sense of our obligations to that world. We see better our connectedness to our science, our colleagues, and the public that supports us, directly or indirectly.

Scientists provided much of the information that contributed to the development of airplanes, communication systems, and skyscrapers -- and bombs and the potential for biological warfare. The humanitarian goals of scientists to eliminate diseases have left a few reservoirs of disease agents, presumably for research purposes. We forget about the capacity of populations, including our own, to evolve reduced immunity when agents of selection are eliminated, though we are well aware of the evolution of resistance to various forms of treatment, such as antibiotics. New thought is now being applied to the evolution of disease and of resistance -- with luck, not too late.

We as scientists often fall into the trap of believing that we lead privileged, even charmed, lives because of our contributions to our science and the "life of the mind"; in fact, the very privileges that we enjoy carry with them significant responsibilities. We acknowledge our responsibilities to our families, our students, our professional institutions, and usually our cities and sometimes our nations, but rarely do we consider our world. We may claim that our work contributes to "making the world a better place," but what do we mean by that? We do have useful and responsible goals, among them better products, less disease, conserving nature and its resources, and contributing to better understanding of the ways that the processes that compose life develop and work, and the ways that living (and dead) organisms interact with each other and their environments. These are laudable and progressive. But something is missing. We pride ourselves on the independence and objectivity of our science, and therefore ourselves. In so doing, we often forget that one of our obligations should be to support that independence in others, but to understand what that independence can facilitate. The link is communication on a world-wide scale -- among scientists and by scientists with the public and their governing bodies. We may think we are communicating better because we have electronic modes, and communication is easier and faster. However, I fear that communication is in fact declining -- we are making more and more information available, but we are discussing, assimilating, and advancing that information less and less, as the information load increases. Further, I ask where is the responsibility for the information content and its use? When children can learn on the Internet how to make bombs and buy infectious agents, it is apparent that there is an abrogation of responsibility at many levels. Scientists must shoulder their responsibility to increase communication and to support mechanisms for quality assessment and dissemination that at the same time promote openness, objectivity, and independence.

If the world understood biology in an historical context, the evolution of conflict and altruism, modes of behavior, population structure and resource bases, and many other topics for which there is substantial comparative information, we might be more cautious with regard to the solutions (war?) that we propose. Solutions emerge from communication, discourse, understanding -- we need not agree on all points in order to find ways to survive. We will understand that there are different ways for different peoples in different locales, and see the complementarity of these approaches. The goal should be more than survival, else what are the "noble" attributes of *Homo sapiens*? Increasing globalization dictates economic inter-dependence of developed and developing countries and the sharing of values, perspectives, and goals. Education, in the broadest sense, is essential, but with some emphasis on the values, contributions (current and potential), and progressive goals of science for the benefit of both science and society. Education must become a much more interactive, wider-ranging, and sustained process if it is to become as effective as it might be. "Cradle to grave" education is not an unrealistic goal, and the inclusion of many forms of instruction, teachers, and audiences should be stressed.

The International Union of Biological Sciences is constituted to provide leadership in increasing and diversifying communication among scientists, particularly biologists in all areas of expertise, and of scientists with the public, policy makers, and other stakeholders in the products and goals of science. IUBS continues to develop scientific research development and dissemination programs, efforts in education with emphasis on biology, and communication among scientists. Under-resourced fiscally, IUBS depends for its progress on its greatest asset -- the expertise and commitment that its constituency volunteers. In this period of clear and present need for increased scientific leadership and communication about the nature of science, I earnestly request colleagues to band together to support and extend the efforts of IUBS to provide that leadership. We have a major role to play in restoring some cohesion to our troubled world.

2001 is nearly at an end. Many of us look forward now to Ramadan, Christmas, Hannakkah or Kwaanza, and the period of contemplation they provide. Best wishes from all of us at IUBS for a peaceful and productive New Year, in a world that begins to understand itself much better.

Marvalee H. Wake
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A Framework for a Program in the Human Dimensions of Biodiversity

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Introduction

The biological diversity of the earth supports almost every aspect of human existence--from the oxygen in the earth's atmosphere to all forms of human subsistence to antibiotics to recreation and psychological well-being. The services provided by functioning ecosystems maintain human necessities, including clean water and pollination of crops. Species diversity and ecosystem services hold substantial economic and individual values across all cultures (Daily 1997, U.S. National Research Council 1999).

Human activities are central to the losses in biodiversity that have occurred in the biosphere for several thousands of years. Human impacts on biodiversity include the loss of species, species-associations, and ecosystem functions. At the end of the Pleistocene Epoch (about 10,000 years ago), New World hunters of large-bodied mammals and birds almost certainly contributed to the decline and extinction of these species, particularly in North America (Martin and Klein 1984). Deforestation in Greece dates to the 1st millennium BC, in the Andes to more than a thousand years ago, and in Europe to our current millennium (Perlin 1989). In the Pacific, Polynesian seafarers left in their wake hundreds of islands with depleted animal and tree populations, resulting in numerous extinctions prior to the first contacts with Europeans (Diamond 1992). Aboriginal peoples caused late Pleistocene extinctions of 85% of the Australian megafauna by burning vegetation and hunting (Miller *et al.* 1999). The 20th century is characterized by accelerated loss of biodiversity (especially in the tropics), accelerated increase in human numbers, and intensification of land use. Competition with other species for land, loss of habitats, disruption of ecosystems, exploitation of species as "resources," introduction of exotic species, and the spread of environmental pollutants are the primary anthropogenic causes of extinction or endangerment of native species.

* The authors are current and former members of the Human Dimensions subcommittee of the U.S. National Committee for the International Union of Biological Sciences. This paper does not reflect the views of the U.S. National Academy of Sciences/National Research Council.

The most critical arena in need of a program of scientific is the understanding and ameliorating of the "Human Impacts on Biodiversity." In addition, several other components of human-dimensions research should be identified. One component is "Human Biodiversity" itself, the genetic and non-genetic diversity of our own species. Another component is "Human Perceptions of Biodiversity," the remarkable ability of humans to adapt to diverse and changing environments. This may have negative repercussions in the long run if the life-forms that we depend upon for subsistence, aesthetic pleasure, and biosphere health continue to decline. Our ability or willingness to recognize or respond to crises in biodiversity may be limited in various ways by culture and politics, an innate lack of responsiveness to long-term issues, or deferred pleasure. Another research component is the often subtle and complex "Interactive Dynamics between Human Diversity and the Environment." Humans have co-evolved and co-adapted with many species. How will losses in biodiversity affect our own evolution, health, and culture? How may new, emerging diseases affect *Homo sapiens*? How will losses in resources influence our nutritional well-being and health?

In this paper, we elaborate on these components in order to stimulate the development of an international program of research on the Human Dimensions of Biodiversity and to suggest areas of research that may be fruitful for international collaboration.

Human Impacts on Biodiversity

The impacts of human activities on the physical and biological environment are a major part of the "human dimensions of global change." Human activities are changing the biophysical world locally, regionally, and globally (Vitousek *et al.* 1997; Ayensu *et al.* 1999). (See the newly released report of the U.S. National Science Board Task Force on the Environment, 1999- Environmental Science and Engineering for the 21st Century). The human impacts on the environment are vast. They involve transformation and degradation of ecosystems, major alterations of biogeochemical cycles, and fragmentation of habitats. These changes are occurring now on such a large scale that they affect the functioning of many ecosystems, the persistence of many species, the quality of life for many human societies, and a rising cost to societies worldwide. In many instances, people recognize the role and value of ecosystem services only when they are disrupted.

The main specific threats to biodiversity today include habitat destruction and fragmentation, over-harvesting, introduction of exotic species, and pollution. These activities are usually not goals in themselves, but are the consequences of food production (including agriculture and aquaculture), construction, manufacturing of both short-lived and durable consumer products, energy consumption for transportation and domestic use and for industrial needs, certain health-maintenance practices, and the development of infrastructure for most transportation systems. These activities are "normal" aspects of the operation of most societies.

Despite the alarming generalizations about the magnitude of human impacts, there are also numerous examples of sustained and sustainable relationships between human cultures or enterprises and local environments. These examples tend to occur on small scales within highly localized contexts. The examples cut across cultures, levels of technology, levels of education, and political systems.

A general strategy for research about the human impacts on biodiversity is to document the most negative impacts of human activities and compare these impacts with real-world, experimental, or modeled alternative practices that provide the same services or resources with greatly reduced impacts. This approach highlights examples of sustainable human uses of biological resources and

fosters innovation in the discovery of more efficient or more benign methods of utilizing biological resources. The anthropogenic causes as well as the effects of biodiversity loss are embedded within a complex web of cultural and political actors (Vandermeer and Perfecto, 1995). Research can elucidate alternative practices of biodiversity utilization and their consequences. Fortunately, there are many actual and theoretical examples of biodiversity utilization (in subjects ranging from agriculture to construction to medicine) that are substantially more sustainable than the prevailing practices in industrial societies (Hawken *et al.* 1999). Ultimately, change in human practices involves the knowledge provided by research and changes in human values and policies.

Research into several broad, interrelated areas would improve our understanding of human impacts on biodiversity over a wide range of human cultures and subsistence patterns. The seven areas mentioned below could be different facets of a single comprehensive research program or the focus of different research programs.

Evidence from the Past (paleontology, prehistory, archeology, and history)

What can the past teach us about the interactions of humans with the environment? The fossil, archaeological, and historical records all contain information about the nature and magnitude of direct and indirect human impacts on their environments, including impacts on other species. How do the nature and magnitude of impacts change over time and space under different levels of technology or in different climatic regimes? A recent monograph summarized archeological evidence for four basic processes that cause impacts on the environment, including animal extinctions, habitat destruction, urban growth, and increasing societal complexity (Redman 1999). Archaeological information also provides insight into subsistence practices that have been sustainable over centuries and longer. Evidence from the past also bears upon the important question, "What is the 'natural' state of an ecosystem?" Most ecosystems have been influenced by human activities for millennia or more.

Cultural Variation

How do human impacts differ among different cultural practices of resource use, levels of exploitation, and methods of waste generation? Environmental histories of particular regions, resources, societies, or time periods provide important case studies of cultural responses to environmental challenges or resources. For example, the current combination of traditional and modern land uses in Mexico may be key to maintaining considerable biodiversity despite earlier dire predictions to the contrary (Gomez-Pompa and Kaus 1999). Different groups can exploit the same habitat with very different consequences for biodiversity. Understanding the cultural patterns underlying behaviors favoring environmental maintenance will be important (Atran *et al.* 1999; U.S. National Research Council 1999).

Subsistence

How do human impacts vary under different subsistence patterns, especially with different mixtures of native versus domesticated species? Subsistence patterns, present and past, vary widely in their impacts on native ecosystems. A survey of subsistence patterns should provide models of sustainable practices (i.e., practices with low impacts on native ecosystems) as well as information about high-impact subsistence patterns that can be generalized across cultures.

Indirect Effects

What are the indirect effects of human impacts, including the unintended or unexpected consequences resulting from particular subsistence patterns, health-maintenance practices, and other forms of resource use? Some of the most devastating impacts on species and ecosystem functions follow from the unintended consequences of manipulating biological resources or the secondary effects of intended changes. For example, leaching of nitrogen fertilizers into groundwater and streams has caused excessive enrichment of aquatic ecosystems, disrupting species composition and nutrient cycling (U.S. National Research Council 1989). Ongoing changes in global climate will potentially alter the abundance, distribution, and ecological associations of plants and animals (Morse *et al.* 1995).

Effects of Scale

How do human impacts vary at different spatial scales, ranging from that of individual dwellings to those of towns, cities, regions, and nations? Some activities may be ecologically damaging at any scale, whereas others may be relatively inconsequential at small scales but devastating at large scales, or vice versa. The fragmentation of most terrestrial habitats has affected the population dynamics of many species such that many rare species distributed across numerous small patches of habitat are probably functionally extinct (Hanski 1999).

Human Population Size and Density

How do human impacts vary in relation to different population sizes and densities? The component of human environmental impacts that is due to human population size varies in relation to levels of technology, resource consumption, political structure, and other cultural factors. Identifying the separate effects of population size and these cultural factors on the magnitude of environmental impact is a useful prerequisite for understanding how human populations in high densities can coexist sustainably with biodiversity.

Political and Social Systems

How do human impacts vary in relation to different political and social systems? Is social equity a prerequisite to an environmentally sustainable society? Different kinds of environmental impacts may arise under different levels of affluence vs. poverty, democratic vs. non-democratic societies, more globalized vs. more localized economies. In an increasingly global world community of humans, the impacts on biodiversity imposed by countries with some types of political or social systems may impact large regions of the globe, or the entire world. Understanding the impacts on biodiversity associated with sociopolitical systems will be essential for the long-term coexistence of man and the biodiversity on which he depends.

Human Biodiversity

Studies of the human dimensions of biodiversity include the diversity of the human species itself. There is a tendency to consider humans as an unchanging, detached influence on the environment, as if humans exist outside of the environment in which they live. However, our species also evolves and adapts to environmental change. An understanding of the environmental dynamics that involve humans should include humans as an integral part of the system. Our knowledge of biological variation and its sources within and among human populations is surprisingly limited, despite more than a century of modern scientific study.

Genetic diversity in humans has been studied almost since the discovery of Mendelian variation. However, only recently has it become possible to study genetic variation on a detailed basis. Diversity in human biological traits, which encompasses both genetic and environmental influences, has been studied longer. Yet the processes that generate biological diversity are poorly understood and are usually limited to simple association rather than to an integrated understanding of the links between the environment (physical, biological, and cultural), the biological traits themselves, and the underlying chemical and molecular basis of these traits. Thus, both genetic and phenotypic areas of understanding human biodiversity should be considered in future efforts.

Human Genetic Diversity

There is greater knowledge about human genetic variation than about that of any other species because collectively, through the studies of human genetic variation that have been conducted by hundreds of investigators (e.g., Cavalli-Sforza *et al.* 1994), we have extensive studies of a globally distributed species. However, the bulk of this work concerns variation of two types (Weiss 1998a). We have large amounts of data on genes associated with disease. Disease-related genes are usually studied in small subsets of populations, and we know relatively little about the total amount of extant genetic variation in these genes in the normal (unaffected) part of the population. We also have large amounts of data on genetic variation in certain non-coding, presumably selectively neutral, or nonfunctional DNA. From human populations around the world, this includes data on human mitochondrial DNA, Y-chromosome, microsatellite DNA, and immune-system DNA variation, and on variation associated with a few genes. These data enable us to construct a consistent picture of the distribution of human genetic variation around the world, to track settlement patterns in most regions of the world, and to help reconstruct the mode and timing of human origins (see U.S. National Research Council 1997).

Those two types of data involve DNA associated with rare, harmful variation and with non-functional (or minimally functional) variation. Surprisingly, we still have very little data on variation in the functional aspects of genes in the general human population. We do not know the frequency with which disease-associated variation is present without causing disease and we do not know the relative frequency of functional (e.g., protein-coding or gene-regulating) variation with little or no pathological effect. There is a need for systematic, global surveys of variation in the functional parts of genes across the human genome, in large, representative samples of our species. This endeavor requires first obtaining an appropriate sample and then identifying variation in that sample. Issues related to the constitution and composition of the samples, the genes to be surveyed, the scale of the study, and the methodology and ethics employed must be addressed (Weiss 1998b). Proper large-scale sampling and analysis of human genetic variation are needed. Primary data should be obtained with a coordinated, international, and systematic survey program that includes sample collection, documentation, and electronic accessibility of the resulting information.

Human Phenotypic Diversity

Extensive surveys have been taken in many parts of the world to document the nature and extent of human variation in gross traits such as body size and shape (Roberts 1953; Eveleth and Tanner 1990; Bogin 1998). Skeletal, dental, and anthropometric measures such as height and weight provide

information on normal growth and development through young adulthood in many parts of the world; sometimes these are complemented by simple physiological measurements such as blood pressure (James and Baker 1995). A substantial body of work has identified climatic, nutritional, and socioeconomic influences on human biology (Eveleth and Tanner 1990; Bogin 1998). Much of the available information derives from studies in the first half of the 20th century. Major environmental and social changes that occurred in the last half of the 20th century may have altered earlier patterns of association. For example, a mid-century analysis of the co-variation of human morphology and climate reported substantial correlations between body morphology and mean annual temperature (Roberts 1953). In a reevaluation of those relationships researchers used data from the last half of the 20th century and reported that climatic factors continue to correlate with body morphology. However, nutritional changes in tropical populations had decreased the influence of climate (Katzmarzyk and Leonard 1998). It is likely that changes in environmental or cultural influences have generated new worldwide patterns of human variation that differ from those identified at earlier historical periods. Possible influential changes include dietary habits, exposure to infectious disease, activity patterns, rural-to-urban and international migration. Furthermore, the effects of a change, such as rural-to-urban migration or acculturation to a western diet, may differ from one setting to another. And new environments (e.g., mega-cities) and stresses (e.g., arsenic contamination of water, air pollution, or high-fat diets) generate the need for cultural and biological adaptation.

Modern technology and conceptual advances have led to the development of new measures, such as the investigations of endocrine, metabolic, and immune-system traits, that can enhance our understanding of the factors underlying human biological variation. For example, the availability of non-invasive measurements of endocrine function has facilitated the disclosure of the existence of a huge normal range of variation in steroid hormone concentrations among normal men and women throughout the world (Ellison *et al.* 1993).

It is important to assess the current state of knowledge of worldwide human variation in traits of scientific, biomedical, nutritional, and other interests, and to organize the collection of appropriate data to modernize our knowledge of variation in our own species. As with human genetic variation, understanding the magnitude, patterning, and origins of human phenotypic variation provides a major form of knowledge about the human species. This, too, requires proper large-scale sampling and collection of appropriate data in sufficient detail to identify patterns and processes.

Modeling Change in Human Diversity

The history of modern *Homo sapiens* is estimated to be relatively short in evolutionary terms (less than 200,000 years) and to have a common source (Africa). Historically, and especially in recent millennia, humans have experienced unstable demographic conditions. There has been extensive migration, intermarriage, and population growth in some geographic regions, while massive dislocation, relocation, or devastation due to cultural contact and conflict have occurred in other regions. As a result, we do not have an adequate population-genetic understanding of our species. We do not, for example, have adequate models to predict the geographic distribution and relative frequency of mutations at individual genes or of chromosomally linked variation (genotypes), nor do we have good ways to infer a history of natural selection, even for many variants with severe phenotypic effects. Also, we still do not have robust models to represent the genetic architecture (number of genes and variation at those genes) of complex human phenotypes, whether normal or pathological.

The huge explosion in knowledge of human molecular genetics needs to be integrated into an understanding of development and biological function in the living organism throughout the life cycle and across a variety of environments. We need models and data to relate genotypes or haplotypes to gene expression and gene function in the whole organism within its environment. Better conceptual, biological, and mathematical models of the processes of human evolution and adaptation will be required to provide general explanations for the patterns of worldwide variation in human genetics and biology.

Human Perceptions of Biodiversity

Human perception of the environment is a function of input from the senses, cognitive structuring of this information, and cultural modulation that produces experiences and values about this environment. Psychological processes, social traditions, and cultural values profoundly affect the ways in which individuals perceive the species in a given ecosystem. These species may be viewed as resources and commodities to be exploited and harvested or as elements of nature with which to interact non-destructively and to conserve, or as some combination of these perceptual/cultural modes. Better knowledge is required about human perceptions of the environment, and particularly about the ability to detect and act on environmental or ecosystem change. Fundamental questions, for which we have no answers at present, are as follows:

- (1) What are the psychological bases for perception of nature? Do we require a natural as well as a human-constructed environment for our own well-being?
- (2) What is the cultural variation in environmental perception that is almost certainly superimposed on our fundamental psychological perceptions? How do some cultures develop a more acute perception of nature and the surrounding environment than do other cultures?
- (3) How much must a natural environment change and over what time period before such changes elicit a response in human behavior? What changing elements/species of the ecosystem are perceived early on and which are perceived at a later time?
- (4) Action to prevent losses of biodiversity must operate through a hierarchy of existing political structures that range from local to regional, national, and global governments. How can this complex process be streamlined?
- (5) Finally, can the conflicting human short-term and long-term needs for ecosystem resources be resolved, and how can the economic costs of industrial production be estimated in the context of the extraordinarily expensive costs of that production in terms of expense to the environment?

The Psychological Bases for Perception of Nature and Environment

Environmental psychologists largely are interested in the influence of the environment on behavior and behavior outcome (mental health, well-being, stress response; Garling and Golledge 1993). Psychologists have conducted experiments to compare the effects of "natural" vs. "built" environments on human aesthetic interpretation and sense of complexity and interest (Hartig and Evans 1993). Other studies have demonstrated that exposure to a "natural" environment reduces stress when contrasted to exposure to an urban environment. Our evolutionary history is one of living as a species integrated within natural ecosystems. Our perceptual modes of "natural" ecosystems have a deep evolutionary history. Since agricultural villages arose about 10,000 years ago and cities arose a mere 5,000 years ago, our displacement from "natural" ecosystems is relatively

recent. We may ask, is the experience of "natural" ecosystems important to the emotional and perceptual well-being of humans? What biodiversity experiences satisfy human well-being?

Cultural Differences in Perception and Values

Human perception of the environment is highly culture specific. This perception depends on cultural beliefs, ideas, experiences, traditions, and socioeconomic contexts. For example, the identification of "nature" as an entity constituted of resources that are "God-given" for exploitation is ingrained in Western thought, particularly through Biblical text. Moreover, to grow up in an economically and environmentally impoverished environment allows one to think of this environment as normal, albeit unpleasant and filled with hardship. This remarkable ability of humans to tolerate a broad spectrum of conditions has in part allowed economic and environmental impoverishment to persist in many parts of the world. Bringing about cultural change is one of the most difficult challenges for the social sciences today, and sadly, there are limited examples of successes in this realm. How do values about the environment arise? In what ways do these values relate to values about property, gender differences, and social status? How can values about the environment be changed to reduce both the losses in biodiversity and the increases in environmental degradation? For each society and each nation, these questions center on fundamental ways of life that entail economics, subsistence, traditions, and environment.

Short-term versus Long-term Perceptions

Losses in animal and plant populations, declines in the number of species, and losses of ecosystems are gradual processes. Because of the human ability to adapt culturally to slow change, environmental transformations may not be readily perceived, except through declines in essential resources such as food or fuel items, or building materials. Once environmental resources are perceived to be in decline, then a competition may arise to harvest the declining resources, as in the "tragedy of the commons" (Hardin 1968). The degree to which resources/species are conserved depends on the urgency of the need, the cultural patterns of social cooperation or competition, the cultural knowledge of resource depletion in the past, and many other variables. For example, East African pastoralists faced with periodic and frequent drought have developed means of conserving and sharing to adapt to these relatively predictable conditions (McCabe 1990). On the other hand, decisions about whether a drought is underway may not be made until well into the drought period because the onset is so gradual (Galvin 1988). Gradual declines in population numbers of key species may also fit the drought model of "delayed perception." With this in mind, what is the time-frame over which individuals perceive undesirable environmental change? What rates of loss of biodiversity are perceived? How do tolerance levels for environmental change vary by culture, socio-economic class, and political system?

Influences on Policy

In democratic societies, the public can influence environmental policy, that is, human perceptions about the environment can influence policies by lobbying or voter action. However, translation from grassroots public opinion to governmental policy changes is a long and tedious road. Public opinion must be quite powerful to be carried to the level of government action. A simple sequence or process might be identified: (1) loss of biodiversity, (2) perception of negative environmental change (something lost/something undesirable), (3) consolidation and organization of social action groups, (4) dissemination of publicity/information, (5) strengthening of social support, (6) lobbying/voting, (7) legislative debate, (8) environmental policy change and development of new laws, and (9)

implementation of laws. What are the primary processes and human motivations that can influence this sequence of events? What is the time frame for each of these steps?

Economics versus Quality-of-Life

Individuals are not motivated solely by economic needs, but also by religious, social, and other values, some of which are traditional while others are more contemporary. There is a vast literature arguing that economic costs never take into account the environmental costs of production. By some estimates, environmental costs may be two-thirds of the total costs to society (Kaplan 1993). Among non-economic values, the aesthetic values of biodiversity are immediate, widely recognized, and potentially play a significant role in the management of biodiversity (Kiestler 1997). How are economic motivators that affect the environment balanced by other human needs such as green space, wildlife, and other aesthetic experiences? How are the short-term economic goals of profit balanced with the long-term goals of ecosystem sustainability and human well-being?

Interactive Dynamics between Human Diversity and the Environment

Changes in biodiversity have been influenced by the interaction of human cultural and biological diversity and by the heterogeneous environment within which cultures interact. Direct, negative human effects on biodiversity are well known and under investigation; the amplitudes of human variability, both genetic and cultural, are less well characterized. Several categories of the complex interactions among human and environmental factors are explored further below.

Coevolution

Coevolution of humans with other organisms has produced greater diversity within, or increased success of, certain species. Different cultures have selected different varieties of organisms, particularly highly domesticated species of plants (for use as food or ornamentals) and animals (for use as food or for utility or amusement). Other organisms have become successful as a consequence of human activity, for example, mosquitoes (*Culex pipiens*) in highly polluted standing waters, or weedy species in agricultural and other disturbed environments. Widespread pesticide use has selected for insects able to withstand the most toxic of pesticides. How has the coevolution of human populations with other species contributed to changes in the composition, diversity, and functioning of local ecosystems? What are the effects of these changes (including increased local biodiversity) at the regional scale?

Human/Microbial Interactions

Interactions between humans and microbes have produced some lethal consequences as human populations have grown or moved into new habitats. For example, HIV has become widespread, first as a consequence (apparently) of human incursions into areas where it was resident and then via transportation around the world through human migrations and interactions. The primary patterns of interactions between microbial species and humans are a consequence of the diversity of human behavior patterns. For example, secondary explosive growth of normally readily suppressed organisms (such as *cryptosporidia* or *pneumococci*) can occur in AIDS immuno-compromised individuals. Varieties of bacteria have been cultured to huge numbers for human applications in the suppression of bacterial infections (penicillin). Chemical control of bacterial or protozoal infections has produced strains with the ability to resist potent antibiotic agents (for example, malaria resistance to chloroquine, *staphylococcus* and tuberculosis resistance to penicillin and other antibiotics;

Institute of Medicine 1991, 1992). The interactions of the many microbes without known, significant medical or economic impact are hardly explored.

Characteristics of Species that Succeed in Human-dominated Environments

The biological characteristics that permit success of a species in the face of human expansion require careful evaluation. There is particular interest in introduced species capable of moving into new ecosystems and causing loss of native biodiversity. The common parameters or traits inherent in successful species can be examined and compared to those of threatened or endangered species. The goal is to recognize biological characteristics that permit some level of coexistence and long-term viability among species.

Constraints on Human Use of Species in Environments with Limited Potential for, and/or Unpredictable Reductions in, Productivity

What constraints are placed on human-environment interactions as a consequence of the limited productive potential either inherent in the environment or resulting from unpredictable events such as weather catastrophes or sudden influxes of refugees? For example, high-altitude and desert ecosystems have generally limited levels of productivity. Resident human populations are constrained in both size and their range of socioeconomic options in such environments. In addition, residents in many environments experience periodic, unpredictable, catastrophic events such as droughts, floods, or snowstorms. In such cases, subsistence strategies must rely on species capable of quick recovery from decimation and restoration of the resource base.

Human Uses of Biodiversity

Geographic variation in biodiversity has influenced the development and trajectory of human cultures (Diamond 1997). The domestication and husbandry of organisms have impacted individuals and the societies in which they live. In traditional societies, tens of thousands of organisms have been utilized for food, fiber, fuel, medicine, and a variety of other purposes. In contemporary industrialized society, the number of species employed has been greatly reduced. Documentation of interactions between traditional cultures and their environments is timely and revealing, especially for those practices that involve sustainable resource management. An inventory of species, and of their characteristics, uses, and biologies is crucial to protecting these resources. In addition, the interaction between industrialized peoples and the biodiversities of their environments is not well documented; similarly, the human-environment interactions of an important third group in the middle of the spectrum--immigrants from high-biodiversity regions who settle in urban areas of industrial nations--also needs documentation.

Other new uses of biodiversity include applications of traditional plant- and animal-based medicaments in the modern clinical setting. Professional groups not usually concerned with the conservation and use of biodiversity, such as those in the health-care professions, need to develop awareness and concern over the consequences of their activities on biodiversity.

Descriptive and predictive models are required to begin to understand human interactions with other species. These models must deal with the complex relationships between hosts and parasites (e.g., how can disease control be effected without affecting non-target organisms or inducing habitat destruction), human sustenance requirements (e.g., sustainable levels of food production), and long-term *versus* short-term valuations of diversity maintenance. Predictive models are under

development for viral and protozoal diseases (degree of chemical/immunological resistance) and for the dynamics of transmission in the face of insect vector populations (control strategies vs. insecticide resistance) and human behavioral characteristics.

Summary

General Research Directions

As a beginning, four programs of research under the "Human Dimensions" umbrella are outlined.

- 1) Human Impacts on Biodiversity centers on the formidable task of identifying some of the crucial issues associated with documenting and defining anthropogenically caused losses in biodiversity up to the present and identifying the socio-cultural processes involved.
- 2) Human Diversity deals with measuring and explaining the broad range of human biological variation and its genetic and phenotypic character. Human biodiversity is undergoing change (in the short-term and on an evolutionary time scale) resulting from changes in the physical, biotic, and socio-cultural environment.
- 3) Human Perceptions of Biodiversity considers the psychological and cultural bases for our environmental perceptions and how can they be changed.
- 4) Interactive Dynamics between Human Diversity and the Environment addresses the need for empirical data and general models on the patterns of relationship between humans and other species in both traditional and industrial societies.

Humans are simultaneously the major contributors to biodiversity losses and one of the species most severely impacted by such losses. Hence, *Homo sapiens* is one of the central players in these dramatic events. Human activities are relevant to all biodiversity programs. However, social and biomedical scientists may not yet identify the consequences of loss in biodiversity as important to their own research. Thus, some education of "human-oriented" scientists is necessary, perhaps through symposia, workshops, and publications. In addition, there is a need to incorporate ongoing relevant research into a "Human Dimensions" program. Constituent International Union members of The International Council of Scientific Unions (ICSU), such as Anthropology and Ethnology (International Union of Anthropological and Ethnological Sciences), Geography (International Geographical Union), Nutrition (International Union of Nutritional Sciences), and Psychology (International Union of Psychological Sciences), might be encouraged to participate, either through their national committees or their international organizations. These activities should stimulate the interest and participation of other scientists.

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IUBS Biodiversity News

DIVERSITAS

Dear Colleagues,

The document that follows is the current draft of the new Science Plan for DIVERSITAS. With the prospect of new funding, and because of recent developments in biodiversity science, the sponsors of DIVERSITAS asked Acting Executive Director Dr. Anne Larigauderie to organize discussion of a revised framework for the DIVERSITAS program. The progress made by DIVERSITAS from 1991 to the present allows facilitation of a strongly problem-oriented approach, one that integrates perspectives of the biological disciplines and those of the social sciences to focus on issues of biodiversity science.

Following web-based "discussions", a Task Force was assembled and met August 31-September 2, 2001, to discuss and draft a new framework for DIVERSITAS. The document presents the proposed new Scientific Plan for DIVERSITAS, which has gone through several iterations since September. An implementation strategy, including a Steering Committee, is in preparation.

The draft Science Plan now needs review, discussion, and thoughtful input from the DIVERSITAS constituency and the larger science community. IUBS, as a co-sponsor of DIVERSITAS, requests that you review and comment on the plan. It is also available on the DIVERSITAS website: <http://www.icsu.org/diversitas/> Please send comments to the DIVERSITAS Secretariat (anne@icsu.org and prieru_richard@icsu.org) and to the IUBS Secretariat (iubs@paris7.jussieu.fr) and the IUBS representative to DIVERSITAS (mhwake@socrates.berkeley.edu). Your response will be most useful if we receive it by January 31, 2002.

Thank you!

Marvalee H. Wake

IUBS Representative to DIVERSITAS

DIVERSITAS Science Plan

This document is the draft of the new Science Plan for DIVERSITAS, the international programme of biodiversity science. DIVERSITAS is sponsored by ICSU, SCOPE, IUBS, IUMS and UNESCO, and belongs to a family of four global change programmes (IGBP, WCRP, IHDP and DIVERSITAS; see Annex 2 for a definition of acronyms). Three of these programmes (IGBP, IHDP and WCRP) have established a partnership, called the Earth System Science Partnership, to address global environmental problems, which DIVERSITAS has been invited to join.

DIVERSITAS recently held, from 31 August to 2 September 2001 in Paris, a meeting of a Task Force to review and redefine its mission and scientific objectives (see Annex 2 for Task Force

Membership). This document is the result of this discussion, and of a consultation of the scientific community prior to this meeting. It is intended as a preliminary text to be submitted for discussion to the scientific community. A draft implementation strategy is provided in Annex 1 to this document.

During the long history of life, Earth has experienced several periods of mass extinction. But the current extinction “crisis” differs from the previous ones in that it is occurring at an unprecedented rate, and is the direct result of human activities. Erosion of biodiversity occurs at various levels, from the genetic diversity of many natural and domesticated species to the diversity of our planet’s ecosystems and landscapes, through the tremendous richness of species. Current human-induced rates of species extinction are estimated to be about 1,000 times greater than past background rates. Biodiversity loss is a matter of concern, not only because of the aesthetic, ethical or cultural values attached to biodiversity, but also because it could have numerous far-reaching, often unanticipated, consequences for our life-support system. The capacity of natural and managed ecosystems to deliver ecological services such as production of food and fibre, carbon storage, nutrient cycling and resistance to climate and other environmental changes, could be reduced. Assessing the causes and consequences of biodiversity changes, and establishing the bases for the conservation and sustainable use of biodiversity, are major scientific challenges of our time.

The past decade has seen the birth of the Convention on Biological Diversity, of many conservation programmes aimed at protecting biodiversity, as well as many national research programmes dedicated to developing biodiversity science. Scientific efforts, however, need international co-ordination to address the complex scientific questions posed by the loss and change of biodiversity globally. Many of these questions also require a research framework integrated across disciplines. DIVERSITAS aims to establish an international, multidisciplinary network of scientists working on biodiversity which will address the scientific priorities presented in this draft science plan.

DIVERSITAS’ General Goals

The general goals of DIVERSITAS are:

- to promote integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge;
- to provide the scientific basis for an understanding of biodiversity loss, and to draw out the implications for policies for conservation and sustainable use of biodiversity.

DIVERSITAS will achieve these goals by synthesising existing scientific knowledge, identifying gaps and emerging issues of global importance, promoting new research initiatives, building bridges across countries and disciplines, investigating policy implications of biodiversity science, and communicating these to policy makers and international conventions.

DIVERSITAS’ structure

DIVERSITAS will articulate its science plan around 3 Core Projects.

- Core Project 1, “Understanding, monitoring and predicting biodiversity changes”, will assess (1) how biodiversity is changing, by contributing to the development of the scientific tools of biodiversity monitoring, (2) why it is changing, by investigating the socio-economic, ecological and evolutionary processes involved in species extinction and speciation, and (3) how it is expected to change, by developing the knowledge necessary to develop biodiversity scenarios for the future.

- Core Project 2, “Assessing impacts of biodiversity changes”, will assess how biodiversity changes affect ecosystem functioning and thereby the provision of ecological goods and services of relevance to human societies. A particular emphasis, within the context of ecological services, will be placed on impacts of biodiversity changes on human and livestock health.
- Core Project 3, “Developing the science of conservation and sustainable use of biodiversity”, will assess the effectiveness of current regulatory measures and incentives to protect biodiversity, investigate alternative social, political and economic motivators for biodiversity protection, and establish a scientific approach for optimising multiple usage of biodiversity, considering possible trade-offs between economic and environmental goals.

In addition to the three thematic core projects, a few integrated transversal networks, which embrace issues addressed in all the core projects, will be created around particular topics or ecosystems. Two such networks already exist, the Global Invasive Species Programme (GISP) and the Global Mountain Biodiversity Assessment (GMBA). A new transversal network, “Greening agriculture”, is proposed here.

Lastly, IBOY, the International Biodiversity Observation Year, is an initiative of DIVERSITAS that spans the whole programme. It is a one-time event to celebrate biodiversity, which will last from 2001 to 2002 (See page 28 of this issue).

Core Project 1: Understanding, monitoring and predicting biodiversity changes

To understand and predict the consequences of changes in biodiversity for natural ecosystems and human societies, it is first necessary to know how much biodiversity there is on Earth, how it is changing, and why. Despite the growing interest in biodiversity during the last decades, our knowledge of the true diversity of life that inhabits our planet is still very limited and fragmentary. While large animals and plants are reasonably well known, only a small fraction of the existing small-sized organisms, such as bacteria, protists, microarthropods and insects, has been discovered and described by science. Many of these organisms probably fulfil important functions in biogeochemical cycles, from local to global scales. Even in those taxonomic groups and locations where diversity has been described, diversity is changing rapidly following increasing human activities, so that there is an important need to monitor and assess these changes.

Finally, a predictive biodiversity science requires an understanding of the factors that cause biodiversity changes. Changes in the nature and intensity of human activities are known to lie behind the accelerated loss of biodiversity both locally and globally. These changes reflect demographic, cultural, political and economic factors. They have reduced and restructured most habitats, changed the distribution and abundance of species to support economic production, altered biogeochemical cycles and the chemical composition of soils, water and atmosphere. We need to understand these changes and the way they interact with the complex ecological and evolutionary processes. Core Project 1 will provide the basic knowledge that is required to assess the impacts of biodiversity changes (Core Project 2) and to develop strategies for the conservation and sustainable use of biodiversity (Core Project 3). It will contribute to assessing current biodiversity, develop the scientific bases for monitoring biodiversity changes, and provide critical knowledge on the processes that determine these changes, with a view to predicting future changes. Attention will be paid, however, to avoid duplication with already existing initiatives.

Focus 1.1. Assessing current biodiversity

There are a large number of players on the scene of inventorying and classification of biodiversity, such as the Global Biodiversity Inventory Facility, the Global Taxonomy Initiative, Species 2000 and the Tree of Life. DIVERSITAS will continue to promote such international initiatives as it has done so in the past, but does not intend to co-ordinate them directly since they now have an independent existence.

The main objective of this focus will be to stimulate and develop research into new areas that require special attention. In particular, it will:

- foster research on phylogenetic groups and habitats that have been insufficiently studied, such as micro-organisms in soils and sediments, and in freshwater, marine and extreme environments;
- promote the integration of new methods, such as genomic approaches, in the study of these organisms;
- link the phylogeny and functional ecology of these organisms.

For example, efforts should be made to characterize the metabolism of the new lineages of micro organisms that are being discovered in soils, sediments and marine environments, and to link their functional traits with their phylogeny. Phylogeny may then become an important tool to predict their role in biogeochemical cycles, which may be considerable, particularly in the oceans. This focus will thereby provide results that can be used by Core Project 2.

Focus 1.2. Monitoring biodiversity changes

Monitoring will be increasingly important for the signatories of the Convention on Biological Diversity when they report on the success of their conservation practices. New monitoring tools, such as remote sensing and molecular techniques, are needed to document biodiversity changes world-wide and evaluate the success of biodiversity conservation policies. For example, changes in ocean microbial communities could be monitored in time and space using molecular ecological techniques and correlated with physico-chemical conditions to increase our understanding of the microbial loop in marine ecosystems.

The objective of this focus is to develop the scientific bases for monitoring biodiversity, as well as the tools of monitoring and the use of these tools. It also aims to promote the integration of biodiversity monitoring and monitoring tools into global networks of observatories that are under development by other programmes. This focus will:

- foster the development of new methodologies and protocols;
- collaborate with existing projects (e.g., ILTER, BIOTA, BIOMARE, MAB biosphere reserves, GTOS, DAPTF) to promote a global network of biodiversity observatories;
- integrate modern techniques into monitoring methods (e.g., genomics, remote sensing);
- facilitate data storage and handling in a suitable way to serve to the construction of models and scenarios of biodiversity changes, as developed in Focus 1.3.

Focus 1.3. Understanding and predicting biodiversity changes

The major drivers of biodiversity loss are changes in the nature and intensity of resource use in both terrestrial and marine environments. The increasing integration of the global economy; together with consumption-led demand for land, mineral, water, fuels, fibres and food, has dramatically altered almost every ecosystem on the planet. These changes continue to fragment, restructure and expand the connections between almost all habitats. They have altered fundamental biogeochemical cycles, and with them the capacity to support the historic composition and abundance of species. Understanding the interaction between such social processes and the ecological processes they affect poses a major challenge to science. Our capacity to predict the dynamics of species gains and losses at local and regional scales depends on the development of the science of ecological changes in an increasingly tightly integrated world socio-economic system.

Land-use changes, resulting mainly from agricultural intensification, play a critical role in biodiversity changes. They involve the physical alteration, fragmentation and destruction of natural habitats as well as overexploitation, which are the most important causes of current species extinctions. More generally, they are an important determinant of the dynamics of species gain, loss and turnover over ecological time scales, and also affect evolutionary processes from gene flow to long-term speciation rates. These evolutionary implications have rarely been considered so far in conservation policies, and are only starting to receive some attention. Focusing on effects of land-use changes, therefore, has the potential to lay bridges across disciplines and to provide new insights into the dynamics and conservation of biodiversity. This focus will seek interaction with the IGBP/IHDP LUCC project on this issue.

A historical perspective would also help illuminate current trends. This focus will also cultivate links with the IGBP-PAGES programme to understand the historical processes that have shaped biodiversity as it exists today, including both natural processes and human actions. Assembling a network of scientists who document species gains, losses and changes over the last millennia as a result of human activities, for example, would be particularly useful.

The aim of this project is to improve our capacity to predict and hence to respond to biodiversity loss. The basic knowledge obtained will help identify the likely biodiversity effects of anthropogenic changes at different spatial and temporal scales, and the sensitivity of those effects to variation in climatic and economic conditions. This knowledge is essential if decision makers are to be able to assess the relative costs and benefits of different resource use options. It will support a range of decision-tools, including scenario building.

Accordingly, this Focus will:

- develop theoretical, experimental and empirical knowledge of the ecological and evolutionary processes that have shaped biological diversity in the past;
- develop an understanding of the impact of changes in the pattern and intensity of human resource use on ecological structure and processes, and the implications of this for biodiversity at multiple spatial and temporal scales;
- predict and evaluate the consequences of biodiversity change for the provision of ecological services, in order to support conservation and the sustainable use of biodiversity at the same spatial and temporal scales.

Collaboration with Foci 1.1 and 1.2 will provide relevant information on phylogeny-related species traits and documentation of current trends. This Focus in turn will provide Core Project 2 with critical knowledge to predict future impacts of biodiversity changes, and Core Project 3 with

information on ecological and evolutionary constraints that may help devise better conservation strategies.

Core Project 2: Assessing impacts of biodiversity changes

The potential impacts of biodiversity loss on the functioning of ecosystems and of the biosphere are currently receiving increasing attention, for two main reasons. First, little was known about the causal relationships between biological diversity and ecosystem processes until recently, despite numerous observational studies. Second, if biodiversity did affect ecosystem functioning, it could have important indirect impacts on the provision of ecosystem goods and services upon which human societies depend, such as production of food and fibre, carbon storage, soil fertility, nutrient cycling and resistance to climate and other environmental changes. Recent experimental and theoretical studies have provided evidence that this may indeed be the case. This considerably strengthens the need to further assess how biodiversity changes will affect human societies in the long term through the provision of ecological goods and services.

Core Project 2 will actively promote the development of research in this area, building on the existing collaboration between DIVERSITAS and IGBP-GCTE. It will investigate how the biodiversity changes studied and predicted in Core Project 1 affect ecosystem functioning and ecosystem services, thereby influencing strategies for the conservation and sustainable use of biodiversity (Core Project 3). It will further develop a particular focus on the impacts of biodiversity changes on human and livestock health.

Focus 2.1. Impacts of biodiversity changes on ecosystem functioning and ecosystem services

Our current knowledge on the impacts of biodiversity loss on ecosystem functioning comes mainly from recent theory and experiments on plant-based processes in temperate grasslands and laboratory microcosms. To reach greater generality and predictive ability, it is now vital to extend this knowledge to other organisms (animals, micro-organisms), other trophic levels (herbivores, predators, decomposers) and other ecosystems (forest, tropical, freshwater and marine ecosystems), in which environmental constraints and ecological processes may be vastly different from those explored so far.

Emphasis should also be progressively shifted from the small scale typically considered in recent experiments to larger spatial and temporal scales, at which management decisions and human-induced biodiversity changes take place. As mentioned in Focus 1.3, land-use changes are currently the most important driver of biodiversity changes, a trend likely to be reinforced in the future by the increasing pressure exerted on land use due to demographic and economic changes in human societies. Therefore the knowledge developed in Focus 1.3 on the impacts of land-use changes on biodiversity should be used to assess the impacts of realistic scenarios of biodiversity loss induced by land-use changes on ecosystem processes at landscape scales.

Lastly, it is important to go beyond a basic science assessment of the effects of biodiversity changes on ecosystem functioning, and include impacts on ecosystem goods and services of societal relevance, which few studies have done so far. The development of research in the area of ecosystem goods and services will add a missing socio-economic perspective to current research into the relationship between biodiversity and ecosystem functioning, and require collaboration with Core Project 3.

Thus, the priorities for this focus will be:

- to extend current knowledge on plant-based processes in temperate grasslands to other organisms, other trophic levels and other ecosystems;
- to assess impacts of biodiversity changes at larger temporal and spatial scales in interaction with other environmental changes, in particular land-use changes;
- to extend current research beyond a basic science perspective and focus on impacts on the provision of ecosystem goods and services of relevance to human societies.

Focus 2.2. Impacts of biodiversity on human and livestock health

A topic of great societal relevance in this area concerns the potential impacts of biodiversity changes on human and livestock health. This focus will develop an ecological context for health, and in particular an understanding of the ecological bases for infectious diseases, including emerging diseases. Historically, approaches to the study of emerging diseases in humans and livestock have focused on treating infectious agents and producing medicines to combat them. These approaches have not generally placed infectious agents (virus, parasites, microbes) in their ecological context, nor examined the complex factors leading to emergence of diseases. For example, changes in land use with accompanying decreases in local and regional species diversity entail the simplification and homogenisation of the landscape in which diseases might spread with greater ease. What is the impact of climate change, deforestation, invasive species or habitat fragmentation at the regional level on the occurrence and rate of transmission of infectious diseases? If such relations could be shown, they would be very important when accounting ecosystem services and assessing the importance of preserving biodiversity and ecosystem functioning. The ultimate goal of this ecological approach is to contribute to developing a broader, predictive science of infectious diseases.

Core Project 3: Developing the science of conservation and sustainable use of biodiversity

The primary driver of biodiversity changes is human activity. Effective solutions for the sustainable management of biodiversity therefore lay in understanding how individuals and societies value that biodiversity, especially those who have ownership of, and who directly utilise, living resources and the biogeochemical systems on which they depend. Many of the present international conventions and directives, national policies and local regulatory tools have not resulted in the sustainable management of biodiversity because they do not recognise and deal with the underlying motivations of individuals and states (see, e.g., the global failure of marine fisheries policies).

There has been considerable progress in understanding the more proximate mechanisms generating biodiversity changes, such as land-use changes, habitat fragmentation, pollution, invasive species (Core Project 1), as well as the effects of such changes on ecosystem processes, goods and services (Core Project 2), but incorporating such values into strategies which provide incentives for the sustainable use of biodiversity requires the integration of a much broader range of natural, social, political and economic sciences. Establishing such an interdisciplinary community of like-minded researchers is a primary aim of DIVERSITAS under Core Project 3. The task will be challenging and most likely require the establishment of a new discipline to occupy the vacant ground between the traditional sciences. This core project will seek advice from and collaboration with IHDP.

Focus 3.1. Evaluation of the effectiveness of protective measures and incentives for achieving the conservation and sustainable use of biodiversity

This focus has two short-term objectives (3.1.1, 3.1.2) and a longer-term project (3.1.3).

3.1.1. Effectiveness of current protective measures and regulations

Policies to protect biodiversity have been in place since the 1950's, but they clearly vary in their effectiveness. At present, policy makers have few analyses from past experience from which to draw lessons in devising more effective policies. Whilst there is a plethora of claims concerning the virtues of particular policy types, this is not matched by a rigorous scientific evaluation of those claims.

This project will:

- analyse international, national, local and non-governmental biodiversity protection policies;
- identify existing databases on resource and indicator species relevant to those policies to evaluate the success of those policies in achieving their stated aims;
- develop comparative analyses of biodiversity policies to establish their effectiveness in different contexts and develop new areas in policy science which enable a creative response to unanticipated issues of global change.

3.1.2. Establishing the scientific basis for applying the precautionary principle

The precautionary approach has been used in the context of discussions on climate change and the Rio declaration concerning the actions which should have been taken in the face of uncertainty. However, the approach needs to be more precise and placed on a rigorous scientific footing if it is to be used operationally. A basic concern is whether the precautionary principle can be sustained by biological and ecological arguments. Specifically, the scientific community needs to provide guidelines about what information is needed to apply the principle, when care needs to be exercised (e.g. identify situations where non-linearities in biodiversity change make the precautionary principle particularly important) and when ignoring caution leads to biodiversity change. A major objective of this project is the identification of formal risk-assessment tools required to objectively and rigorously apply the principle in different contexts.

3.1.3. Biodiversity changes: social, political and economic motivators

If current strategies are inadequate, which is often the case, we need to understand why. Interdisciplinary teams of researchers from the ecological, social and economic sciences are needed to clarify which causes are most important under different conditions. These include:

- individual values, feelings, and education;
- effects of local societies and cultures on individual behaviour;
- legal and regulatory measures, including local, federal, and international policies;
- economic incentives for the conservation and sustainable use of biodiversity.

For any given region, the goals of this research are to determine which of the above factors can be modified to stem the loss of biodiversity, and to seek novel solutions that promote more sustainable

practices. For example, modest shifts in government subsidies and/or market forces (e.g., carbon credits) could have major effects on the economic and land-use decisions made by farmers, ranchers, and foresters, which in turn could lead to changes in biodiversity. As part of this project, the effects of globalisation and free-trade agreements on national biodiversity plans should also be investigated. Additional efforts could focus on biodiversity that is especially difficult to manage and/or preserve, such as populations of marine species or migratory birds.

Focus 3.2. Establish scientific approaches for optimising multiple uses of biodiversity, considering possible trade-offs between economic and environmental goals

Societies make choices regarding land management, such as the conversion of a natural system to a production system, or the incremental changes of production regime, which have a major influence on biodiversity and ecosystem services. These services are generally not taken into account, and trade offs are not assessed. This focus will develop the science required to optimise multiple usage of biodiversity, which include consideration of immediate profits, longer-term profits ("economic sustainability"), benefits of ecological goods and services, and the recreational/cultural value of scenic areas and native species. Modelling the sustainable use of biodiversity in this way could facilitate adaptive management plans that respond to changing economic and ecological factors.

This type of approach could be taken to determine how biodiversity can be enhanced in human-dominated environments on land and at sea. This focus could develop studies for agricultural landscapes, forests, rangeland, and fisheries, as well as studies of the impacts of intensive vs. decentralised animal production systems (chicken, pigs, aquaculture) on the conservation and sustainable use of biological diversity.

As a first case study, DIVERSITAS will develop a transversal network on agricultural goods and services ("greening agriculture"), which will consider trade-offs between economic and environmental goals (see next section).

3.3. Future Foci

In addition to these two foci, DIVERSITAS would be interested, in the future, in developing particular aspects of conservation and restoration related to biodiversity. Conservation and restoration ecology are relatively young fields that are central to the mission of DIVERSITAS. In conservation ecology, many new approaches have proved useful, especially research on metapopulation dynamics, reserve design, and the use of DNA markers to understand processes like migration, colonisation, founder effects, inbreeding, and hybridisation. Further studies along these lines will be extremely useful for managers and decision makers.

In the field of restoration ecology, many efforts focus on regaining basic ecosystem services such as erosion control and improved water quality, but this may or may not entail restoring or at least improving biological diversity. For example, restored or artificial wetlands often have low biodiversity. Given the importance of biodiversity to many human endeavours, further research is needed to understand how various restoration methods affect biodiversity. A future DIVERSITAS project could encourage research on the methods and economics of restoring biodiversity in various habitats and regions.

4. Transversal Research Networks

In addition to the three thematic core projects, a few integrated transversal networks, which embrace issues addressed in all the core projects will be developed around particular topics or ecosystems. Two such networks already exist, the Global Invasive Species Programme (GISP), and the Global Mountain Biodiversity Assessment (GMBA). A new transversal network, “greening agriculture”, is proposed.

4.1. Global Invasive Species Program (GISP)

The Global Invasive Species Program (GISP) is a partnership among specialists on invasive alien species (IAS) dedicated to minimizing the spread and impact of invasive alien species (IAS) in a timely and effective manner. These specialists include scientists, lawyers, environmentalists, educators, policy makers, economists, and resources managers from multiple sectors, worldwide. GISP was established in 1997, following a UN Conference on Alien Species held in Trondheim, Norway that clearly pointed to the need for greater effort to raise awareness of IAS problems and to develop and share best practices for prevention and management.

The Scientific Committee for Problems of the Environment (SCOPE), along with partners from the United Nations Environment Program (UNEP), The World Conservation Union (IUCN), and CAB International (CABI), initiated the collaboration required to address this issue and continue to engage with new partners in an innovative program dedicated to addressing the threats of invasive alien species with a holistic approach. GISP joined DIVERSITAS in 1998. The mission of GISP is to assist governments, international organizations, and other institutions in their efforts to minimize the spread and impact of invasive alien species.

GISP is now in its second phase, whose goals are to develop new tools, evaluate best management practices, articulate a new global strategy and action plan to help nations come to grips with the problems of biological invasions. Promoting empowerment of local, national and multinational communities to draw on the best available tools to improve pest prevention and control systems immediately and to identify priorities for the development of new tools to achieve longer term success.

For more information about GISp, please visit: <http://jasper.stanford-edu/gisp/>

4.2. Global Mountain Biodiversity Assessment (GMBA)

Mountains of the world are hotspots of biological diversity. The compression of thermal life zones and the fragmentation of the landscape into a multitude of microhabitats, each inhabited by a suite of specialists, creates this extremely high diversity. Biological diversity is considered essential for the persistent functioning and integrity of mountain ecosystems and this dependency is likely to increase as environmental conditions change. Steep terrain and mountain climate in combination with severe land use pressure cause mountain ecosystems to rank among the most endangered landscapes worldwide.

The Global Mountain Biodiversity Assessment, launched in 2000, synthesizes knowledge on the ethical, ecological, economic, and aesthetical values of high mountain biodiversity, in order to tackle issues of societal relevance such as mountain biological diversity and land use management (fire, grazing and erosion). Workshops include biologists, social scientists as well as local land use managers. The GMBA has the following objectives:

- to document and synthesize knowledge on the biological richness of the mountains of the world and its change through direct and indirect human influences ('global change');
- to investigate the mechanisms which create and maintain mountain biodiversity and the functional consequences in both, natural and rural high elevation terrain;
- to stimulate new research activities with a comparative emphasis and of large scale scope ;
- to shape a corporate identity of the global scientific community on mountain biodiversity.

For more information about the GMBA, please visit: <http://www.unibas.ch/gmba>

4.3. Greening Agriculture

This transversal network will focus on agricultural systems. It will promote research on how contrasting land-use patterns affect biodiversity, ecological economics, and standard economic gains. Consider a landscape in which native species are largely confined to a few discrete nature preserves that are separated by large areas of intensively farmed crops. This could be contrasted with a landscape in which small, interconnected patches of natural and semi-natural habitat are scattered throughout. In the latter case, patches that are suitable for native species occur over large areas of private land that has multiple uses and is farmed less intensively. Questions to be addressed include:

- What are the economic costs and benefits of each system for farmers, and how might these factors be modified to include ecological economics?
- How should remnant patches of forest or grassland be configured to provide farmers with ecological services such as soil conservation, pollination, and reduction of pest populations?
- What types of natural biological diversity does each type of landscape support, and how sustainable is each system in terms of the conservation of biodiversity?
- How does the agricultural biodiversity of cropping systems and crop species, including GMOs, affect natural biodiversity?
- What is the optimal size and distribution of natural and semi-natural patches for conserving biodiversity in a given region?
- What economic incentives can be used to increase the amount of biodiversity that can be maintained on privately owned farmland?

Data are directly relevant to possible changes in the European common agricultural policy, and possibly elsewhere, towards a "greener agriculture".

Annex 1: Task Force Composition

The task force, which met in September, and drafted the science plan is composed of the following scientists:

Dr. Shelley ARNOTT Laurentian University, Canada	Freshwater ecology, taxonomy
Prof. Robert BARBAULT Université Pierre et Marie Curie, France	Ecosystem functioning and biodiversity, population biology
Prof. Valery K. BROWN University of Reading, United Kingdom	Entomology, ecosystem functioning and biodiversity, land use
Dr. Gretchen DAILY Stanford University, USA	Conservation, ecosystem services
Prof. Rodolfo DIRZO UNAM, Mexico	Conservation, population biology
Prof. Andy DOBSON Princeton University, USA	Vertebrate ecology, conservation, epidemiology

Prof. Michael DONOGHUE
Yale University, USA
Prof. Carlo HEIP
Centre for Estuarine and Coastal Ecology, The Netherlands
Dr. Pablo INCHAUSTI
Ecole Normale Supérieure, France
Prof. Louise JACKSON
University of California, USA
Prof. Calestous JUMA
Harvard University, USA
Prof. Norbert JUERGENS
University of Hamburg, Germany
Dr. Purification LOPEZ-GARCIA
Université Pierre et Marie Curie, France
Prof. Michel LOREAU (co-chair)
Université Pierre et Marie Curie, France
Prof. Keping MA
The Chinese Academy of Sciences, China
Prof. Ronald MITCHELL
Stanford University, USA
Prof. Charles PERRINGS
University of York, United Kingdom
Prof. David RAFFAELLI
University of York, United Kingdom
Dr. Robin REID
International Livestock Research Institute, Kenya
Prof. Osvaldo SALA
University of Buenos Aires, Argentina
Prof. Ian SANDERS
University of Lausanne, Switzerland
Dr. Peter SCHEI
Directorate for Nature Management, Norway
Prof. Bernhard SCHMID (co-chair)
Universität of Zürich, Switzerland
Prof. Allison SNOW
Ohio State University, USA
Prof. Ian F SPELLERBERG
Lincoln University, New Zealand
Dr. Susanne STOLL-KLEEMANN
Potsdam Institute for Climate Impact Research, Germany
Prof. Nigel STORK
James Cook University, Australia
Prof. Andreas TROUMBIS
University of the Aegean, Greece
Dr. Martin WELP
Potsdam Institute for Climate Impact Research, Germany

Representatives of Sponsors in Task Force

Dr. Peter BRIDGEWATER
Director, Division of Ecological Sciences, UNESCO
Dr. Larry KOHLER
Executive Director, ICSU
Prof. Brian MAHY
President IUMS, and Natural Center for Infectious Diseases,

Botany, taxonomy
Freshwater and marine ecology
Terrestrial ecology, ecosystem functioning and biodiversity
Agriculture
International environmental policy
Botany, taxonomy, monitoring
Freshwater and marine ecology, taxonomy, molecular biology
Ecosystem functioning and biodiversity, modelling
Botany
Environmental science and policy
Ecological economist
Aquatic ecology, ecological scientist
Wildlife conservation, sustainable development, public policy
Botany, ecosystem functioning and biodiversity
Soil microbiology, host-pathogen interactions, evolution
Environmental policy, human dimension of biodiversity
Ecosystem functioning and biodiversity, foodweb, population biology, conservation
GMOs and biodiversity, population and evolutionary biology
Conservation, indicators, ecological services
Ecological sociology
Entomology, conservation
Botany, ecosystem functioning and biodiversity
Ecological sociology

Ms. Véronique PLOCC-FICHELET
Executive Director, SCOPE
Prof. Marvalee WAKE
President IUBS, and UC Berkeley, USA
Prof. Jane LUBCHENCO
Chair-Elect ICSU, and Oregon State University,

GA, USA
 Prof. Harold MOONEY
 Secretary General ICSU, and Stanford, USA

USA
 Prof. Diana Wall
 DIVERSITAS-IBOY, U. of Colorado, Fort Collins,
 USA

Annex 2 : List of acronyms used in DIVERSITAS draft Science Plan

BIOMARE	implementation and networking of large scale, long term MARine BIODiversity research in Europe
BIOTA	Biodiversity Monitoring Transect Analysis in Africa
DAPTF	Declining Amphibian Population Task Force
GCTE	Global Change and Terrestrial Ecosystems
GISP	Global Invasive Species Programme
GMBA	Global Mountain Biodiversity Assessment
GTOS	Global Terrestrial Observing System
IBOY	International Biodiversity Observation Year
ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Programme on Global Environmental Change
ILTER	The International Long Term Ecological Research Network
IUBS	International Union of Biological Sciences
IUCN	The World Conservation Union
IUMS	International Union of Microbiological Societies
LUCC	Land Use and Land Cover Change
MAB	Man And Biosphere (UNESCO)
PAGES	Past Global Changes
SCOPE	Scientific Committee on Problems of the Environment
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	The World Climate Research Programme

Building Bridges for Biodiversity: Progress of the International Biodiversity Observation Year (IBOY) 2001-2002

By Gina A. Adams and Diana H. Wall
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The International Biodiversity Observation Year (IBOY) has reached its half-way point. This article reviews its evolution and progress during 2001 and describes activities being planned for 2002 to assemble its achievements and pass them on for the benefit of long-term programs.

IBOY is an initiative of DIVERSITAS, the international program of biodiversity science. The idea for an IBOY arose at a 1998 meeting of the Scientific Steering Committee of DIVERSITAS. A regional arm of DIVERSITAS, called DIVERSITAS in Western Pacific and Asia (DIWPA), announced plans for an intensive, international biodiversity survey, to be called the International Biodiversity Observation Year. Recognizing the potential of a short-term, intensive 'year' to raise

awareness of important research findings about the state of the living planet, the DIVERSITAS Steering Committee adopted IBOY as a global effort. They defined its overarching goals as to:

- (i) network and integrate biodiversity researchers to advance a holistic understanding of biodiversity and its connections to society
- (ii) increase communication of science-based information on biodiversity and its importance, to a broad audience

Since the beginning, IBOY was envisaged as a broad initiative that would engage a diverse spectrum of biodiversity stakeholders. In order to maximize the scope of IBOY, it was decided that its structure and activities should be developed from the 'bottom-up', rather than the 'top-down', by inviting the community to propose activities for IBOY. Thus IBOY became a grassroots effort of an international community of biodiversity researchers, educators and media who proposed projects that would deliver new information on biodiversity in 2001 and 2002. IBOY does not fund these projects, but coordinates activities to draw them together for add-on value.

Today, over one hundred projects with activities in more than one hundred and forty countries are participating in IBOY and proposals for new projects continue to arrive at the IBOY Secretariat. Nearly half the projects are led from developing countries. Each project address one or more of these important questions:

- (1) What biodiversity do we have and where is it?
- (2) How is biodiversity changing?
- (3) What goods and services does biodiversity provide?
- (4) How can we conserve biodiversity?

The projects are nearly as diverse as biodiversity itself. They explore multiple scales of biodiversity, from a survey of microscopic prokaryotes to quantifying the metabolic diversity of ecosystems. Some are conducting taxonomic inventories of poorly known taxa and habitats, while others are exploring complex interactions between biodiversity and ecosystem services or agriculture. They span habitats from the deep-sea abyssal plains of the Atlantic Ocean, to the canopies of tropical rainforests. While some projects are pure research, others apply science for conservation, including a project to compile DNA banks for endangered species and programs that increase local community benefits from biodiversity such as traditional crops and native honeybees. The projects utilize the extensive toolbox available to modern biodiversity research and communication, including molecular techniques, satellite imagery, remote operated diving vehicles, informatics, and state-of-the art filmmaking techniques. More information on the IBOY projects can be found at: <http://www.nrel.colostate.edu/IBOY/projects.html>

A special issue of *Trends in Ecology and Evolution* marked the launch of IBOY in January 2001 and outlined IBOY's approaches for bringing add-on value to its diverse array of projects (Wall *et al.* 2001). These included: pushing the frontiers of science through an intensive research focus and collation of fragmented data; forging links between disparate elements (such as biological, physical and social sciences) to advance a more holistic science, for example by increasing information transfer and understanding across disciplines; and increasing public awareness of biodiversity and access to up to date scientific information for decision-making.

IBOY made significant steps towards these goals in 2001. In March IBOY cohosted, with the US National Committee on DIVERISTAS, a panel on *Human Dimensions of Biodiversity* at the American Institute of Biological Sciences Annual Meeting in Washington DC, USA. The panel brought together biologists Dr. Andrew Dobson from Princeton University and Dr. Ann Kinzig from

Arizona State University, and anthropologist Dr. Cynthia Beall from Case Western University. The panel and an audience of researchers, teachers, policymakers and media considered the contribution of biodiversity to systems that humans value, how different societies perceive biodiversity and biodiversity loss, and the need to include the human influence on biodiversity (both positive and negative) in ecological studies. The session and IBOY were reported as a lead story in *The Scientist* (Bunk 2001).

In June 2001, IBOY convened its first international meeting “*Building Bridges for Biodiversity: The First Meeting of IBOY Project Leaders*”. The meeting was hosted by the US Fish and Wildlife Service at the National Wildlife Refuge, Patuxent, Maryland, USA and was sponsored by the US National Science Foundation and an anonymous US Foundation. Thirty-three project leaders, and members of the IBOY Advisory Board and Steering Committee from fourteen countries participated. Dr. Diana Wall, Chair of IBOY, opened the meeting with a review of the goals and progress of IBOY. In the keynote address Dr. Thomas Lovejoy, Chief Biodiversity Advisor at the World Bank, outlined some of the major challenges and opportunities confronting the biodiversity research community. He emphasized the advances that can be made by a collective of biodiversity experts working along a continuum from basic to applied research, that “add up to more than the sum of their parts.” Over the next day and a half, the project leaders presented the latest activities and findings from their projects. It was a rare opportunity to share information on science and biodiversity across disciplines and cultures that rarely meet. A small selection of the topics included:

- the extent and impacts of terrestrial invasive species
- developing a biodiversity atlas of the oceans
- enhancing use and conservation of neglected and underutilized crop species around the world
- a competition to digitize natural history museum records and award Gambian schoolchildren with much needed computers
- evaluating and monitoring global declines in amphibian populations
- an inventory and internet database of caterpillars of Costa Rican forest canopies and their symbionts and food sources
- a digital library and ‘safe house’ for images and sounds of extinct and endangered species
- assessing diversity of deep-sea chemosynthetic mussel beds
- a global survey of invertebrates in leaf litter and their effect on decomposition, and an educational webpage on soil and litter biodiversity
- biodiversity conservation initiatives by the world’s major faiths

On the second day participants discussed the status of interdisciplinary biodiversity research. Major conceptual advances in recent decades were identified including quantification and mapping of biodiversity, especially for previously poorly known groups such as microscopic and extremophile species; improved understanding of evolutionary relationships through phylogenetics; recognition of the human dimension of biodiversity; and analyses of relationships between biodiversity and ecosystem functioning. Many of these advances could be attributed to methodological advances such as molecular techniques, GIS and remote sensing, informatics and relational databases, and increasing interdisciplinary research. Significant gaps in biodiversity knowledge and priorities for research were also identified. Several priority areas identified were those for which significant advances had also been noted. For example: improving quantification and mapping of biodiversity; developing general theories on the relationship between biodiversity and ecosystem functioning; and incorporating human dimensions such as economics and management strategies into biodiversity research. Other priorities included improving predictions of biodiversity response to global change and developing bioindicators for biodiversity and ecosystem health. The overlap between recent

advances and future priorities in research underscores the participant's overall consensus that, while there has been significant progress, biodiversity remains a major scientific frontier. The findings will form the basis for a series of small IBOY workshops in 2002 that will develop interdisciplinary research recommendations for addressing critical biodiversity problems.

On the final day of the meeting, IBOY project leaders participated in a Media Communications Training Workshop, led by Burness Communications, a media relations firm based in Washington DC, USA. The workshop provided training on writing and distributing press releases on research findings and conducting media interviews. Select members of the media were invited to attend the meeting and gave the IBOY project leaders opportunity to hone their media communication skills. Resulting media coverage included a lead story in *HMS Beagle* (Powledge 2001) and a series of articles on the radio show *Pulse of the Planet*, which are being broadcast on more than 300 stations worldwide throughout autumn/winter 2001.

The IBOY Secretariat promotes media relations to help its project leaders communicate their findings to a broad audience. To date, the Secretariat has issued five press releases that have resulted in over twenty-five articles in scientific, conservation and popular press, and radio programs on *Pulse of the Planet* and *EarthWatch Radio*. There have been stories on IBOY and its projects in the major newspapers of some countries, including *Jornal do Brasil* and *El Universal* (Venezuela), in *National Geographic* magazine, and on the websites of international news services such as *PresseText* and *Environmental News Network*. However, in general major publications for general audiences from the media centers of Europe and North America, and high impact scientific journals have not run news or feature articles about IBOY. A recent article in *The Scientist* attributed this to "the all-embracing nature of biodiversity that makes appreciation of it more difficult to grasp than that of biodiversity's products, such as particular plants and animals".

IBOY leaders are planning a number of activities for 2002 that they hope will change this and capture high-impact media interest in biodiversity and the compelling science-based case for its conservation. They are encouraging national celebrations of biodiversity that can capitalize on the growing public and media interest in IBOY. In November 2001, the Board on International Scientific Organizations of the US National Research Council sponsored a meeting to plan a US-wide Biodiversity Observation Event. The IBOY Secretariat convened the meeting which brought together twelve national leaders in biodiversity research and education from institutions including the Smithsonian Institution, Conservation International, National Geographic Society, World Wide Fund for Nature and Earth Day Network. They developed a plan for a nation-wide event in 2002 that will engage researchers and educators from organizations such as museums, botanic gardens and schools in activities to increase science-based awareness of biodiversity. The IBOY Secretariat encourages other nations to celebrate IBOY with national events, and will be pleased to assist in their development where it can.

Participants hope to draw IBOY to a close with a 'World Biodiversity Science Summit' to showcase the new biodiversity information generated during IBOY. Policymakers and media, as well as scientists, would be encouraged to attend the meeting, so that the central role of biodiversity in sustainability can be widely discussed. Importantly, this summit could pass on the momentum and coalitions IBOY has produced to programs such as DIVERSITAS, to advance biodiversity research and conservation in the long-term.

The IBOY is an initiative of DIVERSITAS. Intellectual sponsorship is provided by the International Union of Biological Sciences (IUBS), International Union of Microbiological Sciences (IUMS) and United Nations Educational Scientific and Cultural Organization (UNESCO). IBOY has been

endorsed by the Sixteenth International Botanical Congress (IBC) and the Second World Conservation Congress of the World Conservation Union (IUCN). The Fifth Conference of the Parties to the Convention of Biological Diversity (CBD) invited parties to participate in the IBOY. Financial sponsorship of IBOY is provided by the US National Science Foundation (NSF), International Council for Science (ICSU), Center for Applied Biodiversity Sciences (CABS) at Conservation International (CI), International Group of Funding Agencies (IGFA), DIVERSITAS and two anonymous US foundations. We acknowledge the support of the US National Committee for DIVERSITAS and the Board on International Scientific Organizations of the US National Research Council.

More information on IBOY , including its projects, meetings and publications can be found from <http://www.nrel.colostate.edu/IBOY>

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Assembling the Tree of Life

An International Symposium, to be held on 30 May - 1 June, 2002, at the American Museum of Natural History, New York, NY, USA

It has been over a decade since there has been a general synthesis of knowledge about the history of life. Recent years have seen remarkable advances in our understanding of organismal relationships, thus the time is ripe to take stock of the state of current knowledge. Moreover, accumulating knowledge about phylogenetic relationships is playing an ever more important role in addressing societal problems, from diagnosing disease agents, predicting outbreaks of infectious disease, to identifying and tracking invasive species. Knowledge of phylogenetic relationships is also at the heart of all comparative biology, and numerous biologists outside mainstream systematics are using hypotheses of relationships to interpret a host of biological phenomena, including the history of behavioral, ecological, and developmental change.

The Tree of Life Symposium will bring together dozens of the world's authorities to produce a summary of our current knowledge of life's history that will at once propel the science forward to new understanding and at the same time be accessible to the broad general public. A major objective of the symposium is to bring the Tree of Life into society and the classroom.

The period 2001-2002 has been designated the International Biodiversity Observation Year (IBOY) by the international biodiversity science programme, DIVERSITAS. As part of IBOY, a series of signature projects has been identified that will be international in scope, advance knowledge in biodiversity science, and communicate that new understanding to society. One of the flagship IBOY initiatives is Assembling the Tree of Life (ATOL).

Venue

The Tree of Life Symposium will be held at the American Museum of Natural History, New York, 30 May - 1 June, 2002. It will include three full days of scientific papers summarizing current understanding of phylogenetic relationships of all major groups of organisms. In addition, a series of plenary lectures will address the importance of phylogenetic knowledge for advances in human health, genomics, developmental and comparative biology, as well as the implications of phylogenetic knowledge for understanding humanity's place in nature.

Sponsors

The Tree of Life Symposium is a product of the International Biodiversity Observation Year of DIVERSITAS. Its major sponsors are the American Museum of Natural History and Yale University, the International Union of Biological Sciences (IUBS), one of the sponsors of DIVERSITAS and IBOY, as well as the U. S. National Committee/IUBS.

Participants

The following is a list of scientists who have agreed, at this time, to participate in the symposium; others have been invited. Papers will be multi-authored, thus numerous other leaders in phylogenetics can be expected to attend.

Participants in plenary talks or panels: Rita Colwell, Sean Carroll, Terry Bates, Douglas Futuyma, David Hillis. Invited speakers: Norman Pace, Sandra Baldauf, W. Ford Doolittle, John Taylor, Michael Donoghue, André Adoutte, Ward Wheeler, Jacques Gauthier, Hervé Philippe, Rytas Vilgalys, Charles Delwiche, Kathleen Pryor, Pamela Soltis, Timothy Littlewood, Frederick Schram, Mark Siddall, David Lindberg, Jonathan Coddington, Michael Whiting, Andrew Smith, Melanie Stiassny, David Cannatella, Michael S. Y. Lee, Joel Cracraft, Maureen O'Leary, and Bernard Wood.

Contact for Information

To place your name on the mailing list for the conference and to receive further details regarding the conference and registration, please send an e-mail with your name and mailing address to tolsymposium@amnh.org.

Algal Biotechnology Industries and Research Activities in China

By C. K. Tseng

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Introduction

For ages, China has been using a few algae for food and other purposes, notably *Porphyra*, *Laminaria* and *Nostoc* for food, *Gloiopeltis* for colloidal substances and *Sargassum* for fertilizers. A few hundred years ago, Chinese people, especially those of Fujian province, began to cultivate *Gloiopeltis* and *Porphyra* by rock cleaning methods. The algae industry started with the formation of New China in the 1950s. There are now a sizable aquaculture industry, a phycocolloid industry, a chemical and drug industry and a food, feed and fertilizer industry, with many enterprises involved in algal industries in China.

1. Aquaculture Industry

The first algal aquaculture industry in China started in the 1950s with the aquaculture of *Laminaria*. *Laminaria japonica* is a cold temperate species endemic to the Japan Sea. China has been employing the *Laminaria* for food for more than 1000 years. A long time ago, Chinese physicians applied the name “Kunbu” to an East China Sea seaweed, *Ecklonia kurome* (Tseng and Chang, 1961), and used as an anti-goiter drug. Later, the Chinese found in Korea another plant, *Laminaria japonica*, with similar function, and more than one thousand years ago, they found that it was also produced in even larger quantities in Japan. From that time on, China imported large quantities of *Laminaria* from Korea and Japan, totalling as much as 46,000 t of dried *Laminaria* in 1929.

In 1927, when the City of Dalian (Dairen) was still under occupation by the Japanese, they imported large quantities of logs from Hokkaido and northern Honshu of Japan on which were sporelings and young plants of *L. japonica*. With these sporelings and young plants as the basis, the Japanese started *Laminaria* cultivation in Dalian using the traditional Japanese method. We devised the summer sporeling method in 1955 (Tseng, Sun and Wu, 1955), in which the *Laminaria* zoospores are collected in early summer, the young gametophytes and juvenile sporelings cultivated in enriched seawater in cool room maintained at about 10 °C and moved to the sea when seawater temperature drops to about 20 °C in the autumn. This “summer sporeling method” was accepted by the industry in the 1950s and has become the standard method for the large *Laminaria* cultivation industry in the country today. The industry produces about 900,000 t dry *Laminaria* (>4 million tons wet *Laminaria*) per year by the raft method, as devised by Mr. Li Hongji (1990) of the Shandong Aquaculture Institutes in the early 1950s, with the help of Zhang JC, Suo RY and six other colleagues of the same institute.

The second algal aquaculture industry is the purple laver or *Porphyra* cultivation industry. In China, this industry started a few hundred years ago in the Fujian Province by the traditional rock cleaning method. The rocks that had good growth of purple laver were cleaned sometime in autumn to create space for the *Porphyra* spores to attach and grow. Our ancestors did not know anything about *Porphyra* spores. It was Dr. Kathleen Drew who found that *Porphyra* spores do not germinate to become the leafy *Porphyra* but rather give rise to a microscopic plant, the *Conchocelis*; however, she

did not discover how the *Porphyra* grows from the *Conchocelis*. It was Kurogi in Japan and Tseng and Chang (1954) in China who solved the problem independently. We now know that in nature, the *Conchocelis* grows on molluscan shells and its spores, the conchospores, develop to become the leafy *Porphyra*. In the early 1960s, the Chinese Ministry of Fisheries conducted a national campaign in Fujian for growing *P. haitanensis* by two different methods: the conchospore method and the traditional method. The success of the conchospore method finally convinced the public that our theory was correct. Numerous experiments by Professor X. G. Fei proved that preservation of the various strains is best effected by growing free living *Conchocelis*. At present, he has 20 species and 120 strains from China and other parts of the world under cultivation (Fei, 1999). The purple laver industry is next to the *Laminaria* industry in size and is the second largest seaweed cultivation industry in China, producing about 20,000 t dry *Porphyra* or about 200,000 t fresh weight.

The third algal cultivation industry is the *Undaria* industry. *Undaria pinnatifida* is a food alga better than *L. japonica* in taste and protein contents. As in the case of *L. japonica*, *Undaria* was first cultivated in Dalian when still under Japanese occupation in the 1940s by the traditional throwing stones method. China has her own *Undaria* in Zhejiang and Fujian Provinces, but the *Undaria* under cultivation in Dalian came from Japan. In the early 1940s, Qingdao had also its *Undaria* cultivation but the mother plant came from Korea. In the early 1960s, *Undaria* was cultivated by methods similar to those devised for *Laminaria* cultivation. The gametophytes and young sporelings are cultivated under normal room temperature, and no cooling is necessary since it is a warm temperate plant. At present, *Undaria* is produced in Liaoning and Shandong provinces. The total production is about 50,000 t wet weight annually, about 90% produced in Dalian, Liaoning Province (Wu, Hu and Li, 1999).

The fourth algal cultivation industry is the eucheumoid industry, producing the phycocolloid carrageenan. The eucheumoid algae consist of three algal genera: (1) *Eucheuma denticulatum* (formerly called *E. spinosa* and *E. muricatum*) producing iota-carrageenan; the raw material is produced in large quantity in Taiwan and is known in China as *Qilincai* (meaning unicorn vegetable), a rather common food alga in China, (2) *Betaphycus gelatinum*, for a long time known as *E. gelatina*, producing beta-carrageenan, under cultivation in the Qionghai and Wenchang districts of Hainan Province since 1962 and (3) *Kappaphycus alvarezii*, producing kappa-carrageenan and introduced by Professor C. Y. Wu from the Philippines in 1985, which is under cultivation in several places in Hainan Province.

Betaphycus gelatinum grows naturally in Hainan in the sublittoral region and is most abundant in about 1 m below the low tide region. At first, divers were sent to insert cuttings on the sublittoral reefs, but since 1974, a new cultivation method has been devised. The living thalli are collected by divers and cut into pieces and fastened to coral branches with rubber rings or threads and thrown into sublittoral reefs, where divers rearrange them in order. The annual production has remained at about 300 t dry plant for quite a few years (Tseng, 1981).

Kappaphycus alvarezii was initially cultivated on floating rafts where pieces of the plant were tied to the raft ropes. When Prof. Wu introduced the species to Hainan, he cultivated it on rafts and was bothered by schools of small fish eating the seaweed. It is now grown in the Qionghai and Lingshui districts on the east and the Chengmai district on the west of Hainan Province. The annual production is as yet unknown.

The fifth algal cultivation industry is the *Gracilaria* industry. *Gracilaria*, known as *Jiangli* in China, has been appreciated as a food, as feed for culturing marine animals and formerly also as a binding material in the preparation of lime for painting walls. The most important use of *Gracilaria*,

however, is the preparation of agar. Formerly, almost all the agar was made from *Gelidium* spp., especially *G. amansii* in Japan and China, and practically monopolized by Japan. But now with *Gracilaria* as the other important agarophyte, several countries are involved, and *Gracilaria* agar constitutes about 60% of the agar of the world. At present, most of the agar in China comes from *Gracilaria lemaneiformis* and other imported *Gracilaria*, and *G. tenuistipitata* var. *liui* is used as a good feed for culturing marine animals.

In the 1950s, we studied the germination of the spores of *G. vermiculophyllis* (formerly variously called *G. asiatica*, *G. confervoides* and *G. verrucosa*); they gave rise to disc-like thalli and took several months to give growth of erect branches (Tseng and Chen, 1959). It is clearly not practical to take such a long pre-cultivation time to grow an annual plant. The idea of employing spores in mariculture of the *Gracilaria* was therefore abandoned, and we tried to use cut branches for propagation. In the case of *G. lemaneiformis*, cut branches grew in Qingdao to about 20-fold in its best growing season with water temperatures of 12-22 °C for about 4 months a year. Recently, Prof. Fei cultivated the Qingdao plant in Zhangjiang City, Guangdong Province and obtained an increase of 100-fold in a growing season. From these plants, he selected a strain which can endure higher temperatures and grew it in Nanao, Shantou City, Guangdong Province, where several kinds of marine animals were cultivated. He obtained a growth of a thousand times the original weight in a growing season of about 4 months (Professor X. G. Fei, pers. comm.). This strain is excellent for growing in a warm temperature region and highly polluted sea.

In Hainan, *G. tenuistipitata* var. *liui* is cultivated in ponds just by scattering the cut plants at random. In Taiwan, cultivation of *Gracilaria* was initiated in 1967. By 1977, *Gracilaria* ponds occupied 2.21 hectares, production reaching 6804 tonnes. The production areas are located mostly in the Pingdong (Pingtung) and Tainan districts in southern Taiwan. Cuttings of the *Gracilaria* are uniformly planted in the bottom of the ponds, tied to bamboo sticks or covered with old fishing nets to avoid drifting (Tseng, 1981). About 4,000-6,000 kg fresh *Gracilaria* are planted in one hectare.

The sixth algal cultivation industry is the microalgae industry. Two kinds of microalgae are now cultivated on a large scale. The first one is *Spirulina*, which was introduced to China by Prof. Jian-Ren Miao of Jiangxi Academy of Agriculture in 1982 from France and India. In 1985, Dr. R. D. Fox of France visited Prof. Miao and presented to him two species of *Spirulina*, *S. platensis* and *S. maxima* (Miao, 1999). Professor B. T. Wu of the South China Sea Institute of Oceanology also obtained seeds of *S. platensis* from Lake Chad, and after a few years of selection experiments, he obtained the SCS strain adapted to seawater cultivation. He carried out an experiment in Sanya, Hainan, and pointed out several advantages of cultivating the seawater strain in tropical parts of Hainan, such as higher cultivation temperatures, higher protein contents, higher yield and cheaper costs when compared to freshwater culture (Wu et al, 1992). In our national research program (Project 75-05-03) on proteinaceous feeds, we decided to try large scale cultivation of *Spirulina*. We decided that the best places for *Spirulina* experiment should be the tropical or subtropical region, and that seawater culture should be employed, since preliminary experiments showed that seawater culture produced on the average $12 \text{ g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$, much more than freshwater culture, which was less than $7 \text{ g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$. In the subtropical Huilai county, Guangdong Province, cultivation was carried out in 3000 m² outdoor raceway ponds, and between 14 August and 5 November, an average biomass yield of $10.3 \text{ g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ was achieved. It was further pointed out that culturing in seawater medium has an added advantage of utilizing waste land near the beach, rather than valuable farm land. Production in Sanya City has reached as high as $20 \text{ g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ (Wu, Tseng and Xiang, 1993).

In China, mass cultivation of *Dunaliella salina* is effected with brine rather than seawater. The brine comes from a solar saltwork, and solvents are added. The production plant has 8 rectangular production ponds with an area of 1,350 m² (Guo, 1991).

2. Phycocolloid Industry

There are three kinds of phycocolloids involved: algin, carrageenan and agar. For many years, China had a very small agar industry, employing traditional methods of extraction.

The first phycocolloid industry of importance is the algin industry. When I was in the States in the 1940s, I was involved in research on agar raw materials and made a survey of the American seaweed industry. I visited Kelco Co. of San Diego, Calif. which used *Macrocystis* as the raw material in the manufacture of a unique commercial commodity, algin. Algin was discovered by Stanford in 1883 and manufacturing processes were patented by Krefting in 1896, by H. C. Green in 1936 and by V. C. C. Le Gloahec in 1938, 1959, 1940 and 1941. I was surprised by the widespread uses of algin in various industries, especially in stabilizing ice cream, in making dental and other impression materials, and in sizing textiles (Tseng, 1946). When I returned to China, I decided to help to start an algin industry in China. In 1951, we started to extract algin from a common local brown seaweed, *Sargassum confusum*. In 1952, we succeeded in obtaining algin by alkali digestion (Ke Xue Tong Bao, 1953). To turn the production of the product into an industry, it must have commercial uses. The first thing I tried was using it as a sizing material in the textile industry. As a sizing material, algin is much better than starch in that it fills the cloth more completely, is tougher and more elastic; most important, starch has to be made from cereals, and China in the early 1950s was facing a serious shortage of food. So our experiment was to employ algin to take the place of starch as a sizing material. Our success with an experiment in the fifth textile factory in Qingdao was reported to the municipal government and led, in a few years, to devoting a part of the Qingdao alcohol factory to algin production, using wild *S. confusum* as the raw material. The wild *Sargassum* was practically depleted in a few years. Fortunately the cultivation of *L. japonica* was successful and the raw material of the industry has shifted to the *Laminaria* ever since. The *Laminaria* is, however, a cultivated plant and is more expensive as a raw material. We have, therefore, had to try to find more uses of the *Laminaria*. From a sample of the *Laminaria*, we produced, beside the algin, iodine and mannitol (Ji, 1997; Ji *et al.*, 1963). Actually both iodine and mannitol are by-products of the algin industry.

The algin industry in China formally started in the late 1960s with cultivated *L. japonica* as the raw material. At present, beside our own *Laminaria*, we have to import raw materials such as *Ecklonia* from South America. Our maximum annual algin production capacity is 13,000 t, undoubtedly one of the largest algin productions in the world. Uses of our algin have extended to various food industries as stabilizers, as a thickening agent in medical industries, as an impression material in dentistry and as anti-coagulant material in making tooth paste (Ji, 1997).

The second phycocolloid industry is production of the carrageenan. The raw material used is the eucheumoid algae, especially *Betaphycus gelatinum* of Hainan and *Eucheuma* and *Kappaphycus* imported from the Philippines. For a long time, *Betaphycus* was treated as an agarophyte and employed as a minor material together with *Gelidium* in the production of agar. In the sixties and

seventies, the *Betaphycus* was dealt with independently, and the product was sold in thread form as “agar.” In recent years, carrageenan has been independently produced, 85% of the raw materials, *Kappaphycus* and *Eucheuma*, are imported from the Philippines, only 15% are derived from local product, the *Betaphycus*. At present, about 2500 t of carrageenan are produced in China, mostly in powder form. About 60% of the carrageenan produced is exported.

The third phycocolloid industry is the production of the agar (Tseng, 1944, 1946, Tseng et al., 1952). Agar is the oldest phycocolloid produced in China but now the smallest in production. More than 90% of the raw material is from *Gelidium amansii* obtained by diving about 5 m in the sea in Qingdao. The agar is made by simply cooking the raw materials and freezing the product to get rid of the water. The product is in the form of threads or powder. In recent years, another agarophyte is becoming more and more important. This is *Gracilaria*, which now supplies 60% of the agar raw material in China. Two species of *Gracilaria* are involved, *G. lemaneiformis* and *G. tenuistipitata* var. *liui*. Old thalli of *Porphyra haitenensis* are also employed as raw material (Ji, 1997). Current annual production in China is about 500-600 t.

Agarose is a refined product of agar which contains very small portion of sulfate radical (about 0.1-0.5%) and now increasingly employed for biochemical and medical purposes. To make agarose, the *Gelidium* containing very small amount of the sulfate radical is more suitable. At present less than 100 kg of agarose is produced in China annually.

3. Chemical and Drug Industry

Seaweeds contain many kinds of chemicals and drugs required by humans. One of the best known is iodine, present in large quantities in algae such as *Laminaria*. China is an iodine deficient country and even in new China, almost 40% of the population, more than four hundred million people, suffers in iodine deficiency and has to import large quantities of iodine annually. The Chinese government declared some years ago that the iodine deficiency problem should be solved in the year 2000. *L. japonica* has almost 5% iodine in its thallus, and in China it is a by-product of the algin industry. If all the *L. japonica* produced in China could be used in iodine production, more than 2000 t of iodine could be produced annually, which would be sufficient for health and industrial use. However only 200 t of iodine are currently produced from the *Laminaria*. The Institute of Oceanology has been engaged for many years in iodine studies and has found that iodine exists in seaweeds in an organic and an inorganic state. The organic state of iodine is readily taken up by humans. In *L. japonica* 12-14% and in some *Sargassum*, 38% of the total iodine produced is in the organic state. The institute has devised a method of extracting organic state iodine, and the method is now used to produce 100 t of seaweed organic iodine tablets. Phycocyanin is extracted from *Spirulina platensis* and β -carotene from *Dunaliella salina*.

Seaweeds also contain substances found to be useful as drugs. *Digenea simplex* from Prata Island contains the strong anthelmintic, kainic acid, which is also present in *Caloglossa leprieurii* of Fujian and the provinces south of the Changjiang River. In *Chondria armata* and *C. crassicaulis*, a common seaweed also of Fujian Province, the anthelmintic, domoic acid is found. These anthelmintics are recommended for children infected with intestinal worms. FPS is a drug made from Fucose-containing sulfated polysaccharide and is effective against uremia. PSS is prophylere glycol alginate sulfate made from algin and is effective in heart and brain disease.

4. Food, Feed and Fertilizer Industry

Cultivated algae such as *Laminaria*, *Undaria*, *Porphyra* must undergo processing for the food industry. Formerly, the seaweeds were just dried and the products on sale were often mixed with mud and sand. In contrast, Japan has more than 200 kinds of marketable products from seaweed. In China, we have, so far, only a few kinds of seaweed food products on the market, such as knob *Laminaria* and sheet *Porphyra*, and artificial jellyfish and sharks fin made from algin. *Spirulina* is now a well known health food and appears on the market in form of tablets. Undoubtedly the algal food industry will increase and more algal food articles will appear on the market.

Since the initiation of animal aquaculture, unicellular algae such as *Tetraselmis*, *Cryptomonas* and *Nitzschia* have been cultured and used as feed for the larvae and also adults. The microalgae are cultivated in culture tanks indoors and in ponds outside; tubular photoreactors are used only in experiments. Macroalgal feed, such as *Gracilaria* for animals such as abalone, are collected and fed directly to the animals.

Seaweed has also served as a fertilizer for a very long time. Formerly, the entire seaweed was used and either buried in the soil until rotten or burned and ash obtained; however, this meant that the organic constituents were all lost and only K and a few other inorganic constituents remained. In recent years, liquid fertilizer has been employed, such as *Maxicrop* for England, *Seaborm* of the U.S. and *Kelpak* 66 of South Africa. Liquid fertilizer has the benefit of retaining certain constituents including microelements and growth regulators useful for plant growth. The Institute of Oceanology has cooperated with a firm in the manufacture of seaweed liquid fertilizer, and a production of ten thousand tons is expected this year (Yan, Fan and Han, 1998).

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Current Trends in Evolutionary Biology

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Summary report of the 8th Congress of the European Society for Evolutionary Biology (ESEB),

held 20 – 25 August, 2001, in Aarhus, Denmark

The study of Evolutionary Biology is currently a most exciting field, energised particularly by the confluence of new molecular techniques and powerful computer facilities. Its relevance to Agriculture, Medicine, Environment and Human Society is also coming to be more appreciated. It is the aim of the ESEB to stimulate these fields of study, and a considerable amount has been achieved in its brief 14 years of existence.

The ESEB's major event is its congress. Held every two years, this conference – that covers the field of evolutionary biology in a wide sense but with emphasis on processes and mechanisms of evolutionary phenomena – provides an excellent opportunity for personal international scientific exchange in this rapidly growing field.

Seven hundred participants from all continents came to Aarhus, with representatives from all the Western European countries and North America, but also with greatly increased participation from Eastern Europe, South America and Asia and Australia.

The subjects of the symposia were highly diverse and refreshingly different from each other, while, at same time, complementary. The five plenary talks were representative of the major domains of interest of the congress:

Andrew G. Clark (University Park, USA): Population genomics

Deborah Charlesworth (University of Edinburgh, UK): Patterns of polymorphism in plant populations

David Haig (Cambridge, USA): Kinship theory of genomic imprinting

Nancy Moran (Tucson, USA): Evolution and genomics of bacterial symbiots

Andrew Read (Edinburgh, UK): Evolution of malaria.

One of the major new features of the congress was the emergence of evolutionary and ecological functional genomics. The results, detailed in the 2 symposia dedicated to this field, show that genomics and proteomics will greatly facilitate the discovery of candidate genes in an assumption-free fashion. However this approach alone will not establish that these genes affect the distribution and abundance of organisms in space and time. To do so will require application of diverse pre-genomic disciplines (biochemistry, ecology, evolutionary biology, physiology, population biology). Thus, the conclusion of these symposia might be that, today, the major challenge to evolutionary and integrative biology within a post-genomic context will be setting up multidisciplinary collaborations rather than resolution of the research problem itself.

Another important topic discussed by the congress was the theory of speciation. While the basic framework for understanding speciation was laid down in the early days of evolutionary biology, recent years have seen a change in emphasis. Most notably, greater attention is now given to the role of selection as a cause of divergence (as in the corresponding symposium). This change may reflect the fading influence of theories of founder effect and chromosomal speciation, together with the increasing prominence of ecological studies of natural populations. New approaches have also been introduced, many made feasible by the abundance of molecular markers. Genes that determine species can be located and, in some cases, isolated. Speciation is the topic that links the interests of virtually all ecologists and evolutionary biologists. This symposium reflected some of this diversity and presented a fascinating snapshot of a fast developing field.

In recent years, increasing attention has been focused on efforts to bridge the gap between the fields of evolutionary and developmental biology. The colour patterns in living organisms provide an ideal

opportunity to study the reciprocal interactions between evolution and development. The symposium devoted to this matter illustrated the possibilities of convergent analysis by population genetics and molecular developmental genetics. On the other hand, the symposium on “Evolutionary developmental genetics in insects and arthropods” gave a lucid account of a field that is progressing by far the fastest in the study of the evolution of developmental processes.

Of course, the molecular processes of gene evolution were also abundantly addressed. However, whether the mutations in the early developmental genes – which often have a dramatic effect – are as important in evolution as they are in the laboratory, remains an open question. Expressing the view of many population geneticists, Budd argued that consideration of these genes must take place in the context of the functional morphology of the host organism, and that it is the latter that must be given priority. His conclusion that developmental genes might play only a minimal role in providing the basis for natural variation is, of course, provocative, but has the advantage of pointing out the inadequacies of a strictly “gene evolution” approach to evolutionary problems.

A way out of this opposition between population geneticists and molecular evolutionists may be indicated by the results of Stern *et al.*, who found that genes whose mutations in the lab have major developmental effects also exhibit minor but potentially significant interspecific differences through their actions later in development. In other words, major developmental genes may also have minor effects on phenotype. That this may well be a more generally applicable hypothesis is suggested by the surprisingly small number of genes revealed by the sequencing programs in complex genomes. If it were the rule that major developmental genes were also involved in minor morphological differentiation, one might imagine that the evolution of such genes is brought about by their involvement in these latter traits. This would create a situation that would simultaneously satisfy both the insistence on gradual and viable changes maintained by the population geneticists, and the necessity of accounting for the observed divergence of major developmental functions.

This year, the John Maynard Smith Prize, presented by the ESEB to the best recent PhD candidate, was awarded to Dr. Alexander Badyaev of Auburn University, USA. Alexander Badyaev's research focuses on the evolution of sexual dimorphism and the evolutionary links between secondary sexual traits and sexual behaviour. His work is particularly outstanding, because he has exploited naturally occurring variation in sexual dimorphism to skilfully examine a series of questions at the interface of micro-evolution, macro-evolution and developmental biology.

Largely due to the success of its periodical, The Journal of Evolutionary Biology, the Society is solvent and wishes to allocate money to new initiatives. It is considering additional personal achievement awards at various academic career stages. Other possibilities include sponsored lectures, essay prizes, Internet development and educational awards.

OBITUARIES

Takuya ABE (1945-2000), Masahiko HIGASHI (1954-2000) and Shigeru NAKANO (1962-2000)

Takuya ABE, Masahiko HIGASHI and Shigeru NAKANO passed away in a boat accident in the Sea of Cortez (California Bay) in Mexico, with Professor Gray Polis of the University of California at Davis and one of his graduate students on 27 March, 2000.

Takuya was a famous termite ecologist, specializing on their evolution from the viewpoint of relations between nests and feeding places as well as of endoparasites, and their effects of matter circulation in tropical forest ecosystems. Takuya received the degrees of B. Sc., M. Sc. and D. Sc. from Kyoto University in 1967, 1969 and 1975, respectively, under the supervision of late Professor Masaaki Morisita and me. He became an instructor of Department of Biology, College of Science, University of Ryukyus in 1972, then rose to an Associate Professor, and changed to the Associate Professor of Animal Ecology, Faculty of Science, Kyoto University, in 1983. Upon the initiation of the Center for Ecological Research, Kyoto University, in April of 1991, he became a Professor of the Center and chaired of the Division of Evolutionary Ecology until the date of his death. He was to be charged with the direction of the Center as of 1 April, 2000.

In 1967, Takuya was recognized as a determined graduate student working on food sharing mechanisms among ant species in my laboratory. In the last year of his graduate course, he went to Malaysia for an investigation on termites in a tropical rain forest led by Professor Tatu Kira. After that date, he conducted his field work with his colleagues and graduate students also in Kenya, Thailand and Australia, with excellent fundamental records on the food and feeding habits, social system and evolution of termites, as well as on their action upon matter circulation in tropical rainforest ecosystems. When establishing the Center, as its first director, I invited him as the Professor in the Division of Evolutionary Ecology.

With some graduate students, he discovered the nitrogen fixation and C-N balance of the termite-bacteria complex. He edited some books, e.g., structure and function of soil communities and on biodiversity, an ecological perspective and served the Ecological Society of Japan and others as Secretary-General, and journal Chief Editor, etc. He kindly played the role of the acting directorship to a creative basic research program, an integrated study on biodiversity conservation under global change and bio-inventory management system (DIVER) headed by me and financially supported by Japan Ministry of Education, Science, Sports and Culture since 1996.

Masahiko was a prominent scientist of mathematical ecology, specializing on the dynamics of energy and matter and indirect effects in food webs. Masahiko received the degrees of B. Sc. and M. Sc. from Kyoto University in 1978 and 1980, respectively, under the supervision of late Professor Ei Teramoto, and his Ph. D. from the State University of New York at Syracuse in 1984 under the supervision of Professor George J. Klir. He joined the Institute of Ecology, University of Georgia, as a postdoctoral fellow in 1983 under the supervision of Professor Bernd Patten. In 1988, he got a job in Mathematics, College of Science and Technology, Ryukoku University, as a lecturer and then an Associate Professor. In 1993, he joined the Center for Ecological Research, Kyoto University, as an Associate Professor, and in the following year, he became a Professor and chaired the Division of Temperate Ecology until the date of his death. Since 1994, he also served as a scientific research adviser to the Ministry of Education, Science, Sports and Culture. And since 1998 he held the chair of Professor in the Preparatory Office of National Institute of Global Environmental Sciences (established in April, 2001 as National Institute of Humanity and Environment).

In 1977, I recognized Masahiko at first as a mathematical ecologist with an exceptionally good ability in field work. During the year in the United States, he also investigated in many fields, such as Okefenokee Swamp, Georgia. For his excellent ability for field work, in addition to his brilliant mathematical works, I invited him as a Professor to the newly established Center mentioned above.

After joining the Center, he became an invaluable adviser and collaborator to his colleagues and graduate students from the theoretical point of view and conducted many works in the broad fields of ecology. C-N balance in ecosystems, general theory on conflict resolution between related members, and sympatric speciation by sexual selection were a few examples of his recent works.

Shigeru was a brilliant ecologist, especially in Salmonid fishes and matter exchange between terrestrial and lotic ecosystems. Shigeru received the degrees of B. Fish. and M. Fish. from Mie University in 1985 and 1987, respectively, under the supervision of Professor Makoto Nagoshi, and his Ph. D. from Hokkaido University in 1991 under the supervision of Professor Kenkichi Ishigaki. He joined the local government of Kamitakara-mura Village as a curator of the Museum of Japan Alps in 1988 and moved to work for the Experimental Forest in Hokkaido University in 1989 as an instructor and then an Associate Professor. In 1999, he joined the Center for Ecological Research, Kyoto University as an Associate Professor. He was also nominated as a member of the National Institute of Humanity and Environment.

After returning from an international cooperative research project on Lake Tanganyika, he worked very hard on the ecological study of river resident salmon and charr populations in the Japan Alps and Tokachi mountain area in Hokkaido. Then, he joined a bilateral study on salmonid fishes between Professor Kurt Fausch in Colorado State University and myself with the financial support of the Japan Society for Promotion of Science and the US. National Science Foundation, and he became the active leader of its Japanese team, both in Hokkaido and Montana. He also worked on salmonids in Alaska and Kamchatka.

For the last few years, he was conducting large field experimental projects on matter circulation, food-web dynamics and maintenance of biological diversity between interactive forest and river ecosystems in Tomakomai Experimental Forest in Hokkaido, with a broad range of experts, colleagues, technical staff and graduate students. This work is one of the most brilliant investigations on the relation between biological diversity and ecological complexity in Japan.

Having been repeatedly impressed by the development of his ecological research work, I was extremely pleased when he joined the Center and looking forward to his future research.

All the three persons had devoted their efforts greatly to IUBS, DIVERSITAS and its network in western Pacific and Asia (DIWPA).

The loss of three very promising young scientists: Takuya, Masahiko and Shigeru, in 2000, in a boat accident in North America, coming after the loss of Tamiji Inoue, who died in 1997 in an airplane crash in Borneo Island, represents a severe blow to ecology in Japan and Asia. The sudden death of all four, intervening at the most productive and creative period of their scientific career, is extremely sad, and the place they left behind will be hard to fill. I am confident that their colleagues and friends will keep exploring the ways and avenues they have opened for ecological research in Japan, Asia and the Pacific.

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PUBLICATIONS REVIEW

DISPERSAL

Edited by J. Clobert, E. Danchin, A.A. Dhondt, and J.D. Nichols. Published by Oxford University Press, 2001 (451 pages).

This book provides a timely and wide-ranging overview of the study of dispersal and incorporates much of the latest research. The causes, mechanisms and consequences of dispersal at the individual, population, species and community levels are considered. The potential of new techniques and models for studying dispersal is also explored. Throughout the book, theoretical approaches are combined with empirical data, and care has been taken to include examples from as wide a range of species as possible. The conference that led to this book was held in Roscoff (France) from 23 April to 1 May, 1999. It was co-sponsored by the CNRS-France, the NSF-USA and the IUBS.

THE ECONOMICS OF BIOLOGICAL INVASIONS

Edited by Ch. Perrings, M. Williamson and S. Dalmazzone. Published by Edward Elgar, UK & USA, 2000 (249 pages).

The growth of international trade and travel means that more species are being introduced to more places than ever before. This book represents a concerted effort to understand the economic causes and consequences of biological invasions. It discusses the theoretical and methodological issues raised by invasion, including control strategies, modelling options and policy conditions that predispose countries to biological invasions. Also included are case studies of fisheries, agricultural systems, tropical forests and protected areas affected by invasive species.

GLOBAL STRATEGY ON INVASIVE ALIEN SPECIES

Edited by J. A. McNeely, H.A. Mooney, L.E. Neville, P. J. Schei and J. K. Waage.

Published by IUCN in collaboration with the GISP Programme of SCOPE, 2001 (50 pages).

This publication is based on contributions from the team leaders of the eleven main components addressed under phase one of the Global Invasive Species Programme. This Strategy summarizes key findings of the Synthesis Conference held September 2000 in Cape Town, South Africa, and presents ten strategic responses that address mitigating the threats of invasive alien species.

A GUIDE TO DESIGNING LEGAL AND INSTITUTIONAL FRAMEWORKS ON ALIEN INVASIVE SPECIES

Edited by C. Shine, N. Williams and L. Gündling. Published by the IUCN Law Centre, Environmental Policy and Law Paper N° 40, 2000 (138 pages).

This paper represents an important contribution by the IUCN Law Centre to the Global Invasive Species Programme (GISP). It provides abundant examples of the various approaches that have been utilized to deal with alien invasive species from local to global levels.

INVASIVE ALIEN SPECIES A Toolkit of Best Prevention and Management Practices

Edited by R. Wittenberg and M.J.W. Cosk. Published by CAB International, 2001 (227 pages).

This toolkit provides an overview, advice by example, and sources for further information on best management practices for invasive alien species, to assist and direct those involved with biodiversity conservation and land management. The focus is on invasive species affecting biodiversity, but many examples are drawn from traditional sectors such as agriculture and forestry, reflecting the diverse problems caused by invasive alien species.

CALENDAR OF MEETINGS

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

2002

**AEROBIOLOGY /
BIOMETEOROLOGY**
**16th Int'l Congress of Biometeorology &
15th Conference of Biometeorology and
Aerobiology**

28 Oct - 1 Nov, Kansas City, Missouri, USA
 (Contact: Dr. Wayne Decker, 207 Gentry Hall, UMC,
 Columbia, Missouri 65211, USA
 Tel: ++1 (573) 882 6592
 Fax: ++1 (573) 884 5133
 E-mail: deckerw@missouri.edu

AFRICA
African Renais-Science Conference
 27-31 March, Durban, South Africa
 (Contact: Prof. Himansu Baijnath, Ward Herbarium,
 Department of Life & Environmental Science, University
 of Durban-Westville, Private Bag X54001, Durban 4001,
 South Africa
 Tel: ++27 31 2044464
 Fax: ++27 31 2044364
 E-mail: botany@pixie.udw.ac.za

BIODIVERSITY
Tree of Life Symposium
 30 May - 1 June, New York, NY, USA
 (Contact: Joel Cracraft, Dept. of Ornithology,
 American Museum of Natural History, Central Park West
 at 79th St., New York, NY 10024
 Tel: ++1 (212) 769 5633
 Fax: ++1 (212) 769 5759
 E-mail: tolsymposium@amnh.org or
cracraft@amnh.org)

DIPTEROLOGY
**5th International Congress of
Dipterology**
 29 Sept - 4 Oct, Brisbane, Australia
 (Contact: Sally Brown, Conference Connections, P.O.B.
 108, Kenmore, Queensland 4069, Australia
 Tel: ++61 7 3201 2808
 Fax: ++61 7 3201 2809
 E-mail: sally.brown@uq.net.au

HORTICULTURAL SCIENCE
**XXVI Int'l Horticultural Congress:
Horticultural Art & Science for Life**
 11-17 August, Toronto, Canada
 (Contact: IHC c/o Congress Canada, 49 Bathurst St.,
 Suite 100, Toronto, Ontario, Canada M5V 2P2
 Tel: ++1 (416) 504 4500
 E-mail: IHCreg@congresscan.com
<http://www.ihc2002.org>)

ICSU
**27th General Assembly of the Int'l Council
for Science & Associated Meetings**
 20-28 September, Rio-de-Janeiro, Brasil
 (Contact: ICSU Secretariat, 51 bd de Montmorency,
 75016 Paris, France
 Tel: ++33 (0)1 45 25 03 29
 Fax: ++33 (0)1 42 88 94 31
 E-mail: secretariat@icsu.org
<http://www.icsu.org>)

BIOINFORMATICS
Int'l Conference on Bioinformatics 2002
 6-8 February, Bangkok, Thailand
 (Contact: Dr. Prasit Palittapongrarnpim
 Tel: ++66 2 6425322 to 31 Ext. 114
 Fax: ++66 2 2488304
 E-mail: incob@biotec.or.th
<http://incob.biotec.or.th>)

MARINE BIOLOGY
**37th European Marine Biology
Symposium**
 5-9 August, Reykjavik, Iceland
 (Contact: 37th EMBS Secretariat
 E-mail: embs@hi.is
<http://www.37embs.is>)

MICROBIOLOGY
**12th Biennial Congress of the South
African Society for Microbiology**
 April, Bloemfontein, South Africa
 (Contact: Dr. J. Albertyn
 Tel: ++27 (0)51 401 2223
 Fax: ++27 (0)51 444 3219
 E-mail: albert@sci.uovs.ac.za

ORNITHOLOGY**23rd Int'l Ornithological Congress**

11-17 Aug., Beijing, China

(Contact: Prof. Xu Weishu, 1-1-302 Beijing Sci. and Tech. Commission, Apt. 30, Lingnan Rd., Beijing 100037, P.R. China. Tel/Fax: ++86 (0)10 6846 5605

E-mail: abstract@ioc.org.cn<http://www.ioc.org.cn>**PALEOBOTANY****6th European Paleobotany-Palynology Conference**

29 August - 2 September, Athens, Greece,

(Contact: Prof. Evangelos Velitzelos, Dept. of Historical Geology and Paleontology, Faculty of Geology, University of Athens, 15784 Athens, Greece

Tel/ Fax: ++30 (0)1 727 4162

E-mail: velitzel@geol.uoa.gr**PARASITOLOGY****Xth Int'l Congress of Parasitology**

August, Vancouver, Canada

(Contact: Prof. M. Zia Alkan, Dept. of Parasitology, Medical Faculty of Ege University, 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)

SOIL SCIENCE**17th World Congress of Soil Science (WCSS)**

14-21 August, Thailand

(The Secretariat, 17th Kasetsart University, P.O. Box 1048, Bangkok 10903, Thailand

Tel: (662) 9405787

Fax: (662) 9405788

<http://www.17wcsc.ku.ac.th>**SPACE RESEARCH****2nd World Space Congress & 34th COSPAR General Assembly Commission F: Life Sciences as Related to Space**

10-19 October, Houston, Texas, USA

(COSPAR Secretariat, 51 Bd de Montmorency, 75016 Paris, France

Tel: ++33 (0)1 45250679

Fax: ++33 (0)1 40509827

E-mail: cospar@cosparhq.org<http://www.copernicus.org/COSPAR/COSPAR.html>**SUSTAINABLE DEVELOPMENT****ICSU Workshop on "Sustainable Development- The Role of International Science"**

4-6 February, Paris, France

(Contact: Dr. Sylvia Karlsson, IHDP Secretariat, Walter-Flex-Str. 3, D-53113, Bonn, Germany

Tel: +49-228 73 90 53 direct

Fax: +49-228 73 90 54

Email: karlsson.ihdp@uni-bonn.de**TAIB SYMPOSIUM****IUBS/CNRS Symposium "Integrative Biology and Biological Complexity"**

4-6 February, Paris, France

(Contact: IUBS Secretariat, 51 bd de Montmorency, 75016 Paris, France

Tel: ++33 (0) 1 45 25 00 09

Fax: ++33 (0) 1 45 25 20 29

E-mail: iubs@paris7.jussieu.fr<http://www.iubs.org>**2003****AUXOLOGY****10th International Congress of Auxology**

27-30 April, Buenos Aires, Argentina

(Contact: Sociedad Argentina de Pediatría, Coronel Díaz 1971, C1425DQF Buenos Aires, Argentina

Tel: ++54 11 4821 8612

Fax: ++54 11 4821 2319:

E-mail: auxo2003@sap.org.ar<http://www.sap.org.ar/auxology2003>**MEDICINAL AND AROMATIC PLANTS****3rd World Congress on Medicinal and Aromatic Plants for Human Welfare (WOCMAP-III)**

3-7 February, Chiang-Mai, Thailand

(Contact: K. H. Baser, Secretary General, ICMAP, Anadolu University Medicinal and Aromatic Plant and Drug Research Center (TBAM), 26470 Eskiesehir, Turkey

Tel: ++90 222 3352952

Fax: ++90 222 3350127

E-mail: info@icmap.org<http://www.icmap.org>

IUBS
**IUBS Conference “Biological Sciences,
 Development and Society” &
 28th IUBS General Assembly**

29 November- 4 December, Cairo, Egypt
 (Contact: IUBS Secretariat, 51 Bd de Montmorency,
 75016 Paris, France
 Tel: ++33 (0) 1 45 25 00 09
 Fax: ++33 (0) 1 45 25 20 29
 E-mail: iubs@paris7.jussieu.fr
 http:// www.iubs.org)

**ICRO-UNESCO Training Courses
 2002**

**Molecular Biology – Principles and
 Protocols**

12-26 May, Garki-Abuja, Nigeria
 (Contact: Dr. Oyekanmi Nashiru, Ontario Cancer Inst.,
 Princess Margaret Hospital, Dept. of Medical Biophysics
 [7-111], 610, Univ. Ave., Toronto, Ontario,
 Canada M5G 2M9; Fax: ++1 (416) 946 6529
 E-mail: onash@uhnres.utoronto.ca)

**Frontiers in Reproduction: Molecular and
 Cellular Concepts and Applications**

19 May - 29 June, Woods Hole, Mass., USA
 (Contact: Dr. Asgi T. Fazleabas, Dept. of Obstetrics &
 Gynecology [M/C 808], Univ. of Illinois at Chicago,
 820 South Wood St., Chicago, IL 60612-7313, USA
 Fax: ++1 (312) 996 4238 E-mail: asgi@uic.edu)

**Theoretical and Practical Aspects of
 Molecular Breeding in Cereals**

27 May - 7 June, Martonvasar, Hungary
 (Contact: Dr. Zoltan Bedő, Agricultural Research Inst.,
 P.O. Box 19, H-2462 Martonvasar, Hungary
 Fax: ++36 22 460 213
 E-mail: bedoz@mail.mgki.hu
 or: szakacse@mail.mgki.hu)

**Cell Motility Molecular Motors and the
 Cytoskeleton**

27 May - 7 June, Rio de Janeiro, Brazil
 (Contact: Dr. L.C. Cameron, Laboratorio de Bioquímica
 de Proteínas, Universidade do Rio de Janeiro,
 Avenida Dr. Xavier Sigaud, 290
 Urca - Rio de Janeiro - RJ, Brazil CEP 22290 - 180
 Fax: ++5521 2275 0836 E-mail: cameron@unirio.br)

**Transgenesis, Stem Cells and Reproductive
 Biotechnology**

17-29 August, Taipei, Taiwan, China
 (Contact: Dr. Chii-Ruey Tzeng, Taipei Medical Univ.
 Hospital, 252 Wu Hsing St., Taipei, Taiwan, China
 E-mail: tzengcr@tmc.edu.tw)

**Computer Applications in Molecular
 Biology**

7-12 September, Teheran, Iran
 (Contact: Dr. Bahram Goliaei, Bioinformatic Centre, Inst.
 of Biochemistry and Biophysics, Univ. of Teheran,
 P.O. Box 13145-1384 Teheran, Iran
 Fax: ++9821 640 4680 E-mail: goliaei@ibb.ut.ac.ir)

**Supramolecular Complex Formation in
 Cellular Signalling**

22 September - 4 October, Santiago, Chile
 (Contact: Dr. Andrew Quest, Programa de Biología
 Celular y Molecular, Instituto de Ciencias Biomédicas,
 Facultad de Medicina, Casilla 70086, Santiago 7, Chile
 Fax: ++56 2 738 2015 E-mail:
aquest@machi.med.uchile.cl)

Cell Signalling

14-26 October, Shanghai, China
 (Contact: Dr. Qi-shui Lin, Shanghai Institute of
 Biochemistry, 320 Yue Yang Rd., Shanghai 200031,
 China
 Fax: ++86 21 6433 5474 or 6433 8357
 E-mail: qslin@server.shcnc.ac.cn)

**Cell Biology of Neural Development –
 Molecular Mechanisms of Neurogenesis**

4-14 Nov., Buenos Aires and La Plata, Argentina
 (Contact: Dr. Néstor G. Carri, IMBICE, CC 403,
 1900 La Plata, Argentina
 Fax: ++54 221 425 3320
 E-mail: cimbic@netverk.com.ar)

**ICRO-UNESCO Training Courses
 2003**

**The Baboon as a Model for the Study of
 Human Reproduction**

January, Nairobi, Kenya
 (Contact: Dr. Gerald Schatten, Director, Pittsburgh
 Development Center, Magee-Women's Research
 Institute, 204 Craft Ave., Pittsburgh, PA 15213, USA
 Fax: ++1 (412) 641 6156
 E-mail: pdckpw@mail.magee.edu)

BIOLOGY INTERNATIONAL

**The News Magazine of the
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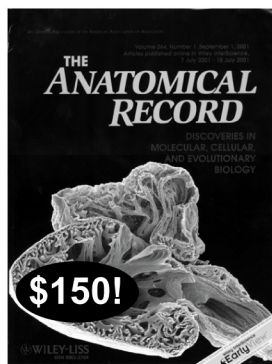
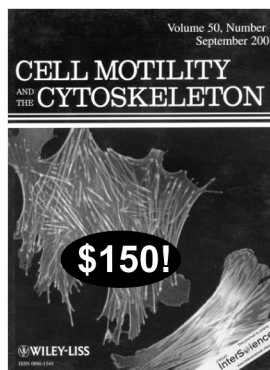
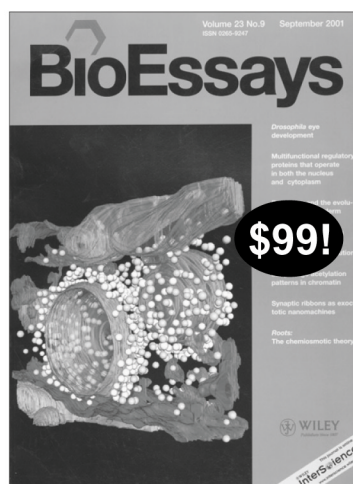
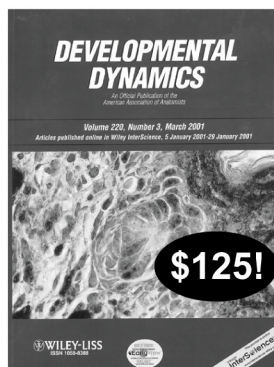
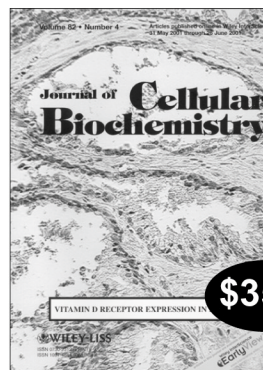
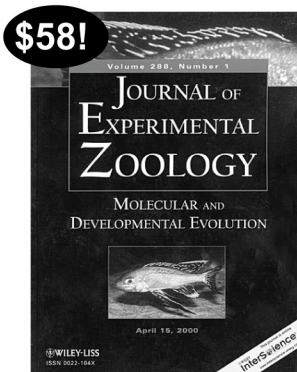
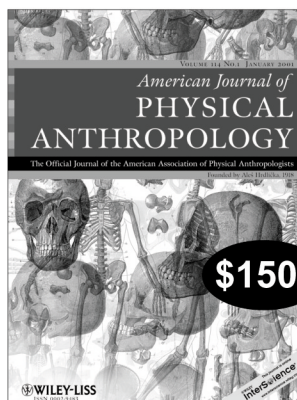
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