CHAPTER 1

Environmental Properties and Processes

The General Assembly of the International Council of Scientific Unions in October 1976, to which this Report is addressed, provides an opportunity for the scientific community to adopt a rational conceptual framework within which an orderly approach to environmental problems can be made. This development is timely. In recent years the world has endured reams of rhetoric, strident voices forecasting impending doom, and euphoric reassurances that there really is no problem. What is needed now is the most balanced consensus that the scientific community can achieve, based on a critical analysis, and, where possible, quantification of the problems. The aim of this report is to provide such a consensus – bearing in mind that the concept itself contains dangers. Diversity of viewpoint is an attribute which needs respect and careful treatment in the development of an intellectual framework. Scientists need not only consensus, to show the average balance of views in the informed scientific community, but also an indication of the range of informed opinion, as some measure of how far they may be wrong.

A. PERSPECTIVE

For this rational framework, a long-term perspective is essential. The earth started to form about 5 billion (10^9) years ago by accretion of cold particles chiefly of iron and magnesium silicates, iron, and graphite. It was too small to retain the primordial atmosphere of light gases. Gravitational collapse and radioactive decay caused the earth to heat up, and its material differentiated giving a central solid iron-nickel core, a liquid iron-silica shell, a mantle, and a lithosphere. In this process, degassing took place, forming a new atmosphere and hydrosphere. This atmosphere was devoid of free oxygen but contained methane, ammonia, carbon dioxide, and water vapour. Compounds of carbon, nitrogen, oxygen, and hydrogen were generated under the influence of energy sources such as lightning, solar radiation, or radioactive discharges, with mineral material serving as a template. The processes of life thus began about 3 billion years ago in the form of anaerobic chemoautotrophic organisms that were dependent upon ambient organic molecules for nourishment. The essential building blocks of life were formed and aggregated into cellular compartments. The fossil record shows that microscopic unicellular organisms occurred over 1,300 (and possibly over 1,700) million years ago, and the development of sexuality may have triggered marked increases in diversity and evolutionary rate.

Solar radiation and cosmic bombardment were primordially, and solar radiation is now, primary dynamic factors in the evolution and formation of the face of the planet. Tectonic and gravity forces, the original atmosphere, and the hydrosphere acted on the surface of magmatic rocks weathering their minerals to produce sand and silt, as well as colloidal and ionic solutions. Movement of the masses of suspended and dissolved mineral compounds in the atmosphere and redistribution of these compounds over the continent by water, sedimentation, and accumulation of salts in seas, ocean, and deserts occurred in the course of a billion years as part of very complicated processes. These abiotic phenomena still govern the geochemistry of our planet.

About two billion years ago, biological evolution took another revolutionary step. A few organisms succeeded in changing their mode of existence from one of dependence on fermentation and chemosynthesis to the more efficient mode of photosynthesis and respiration. This set the stage for the release of oxygen, the fixation of nitrogen, and further evolution as nuclei developed the capacity to divide by meiosis – a necessary precondition for higher life. As organisms that could not tolerate free oxygen were partially replaced by more efficient respiring forms, oxygen-mediating enzymes were added to the arsenal of chemical catalysts that govern metabolism and produce the structures prescribed by the DNA molecules. Carbon dioxide levels in the atmosphere were reduced, ozone appeared and formed a screen against incoming ultraviolet radiation, and organic deposits began to accumulate and form coal and oil fields.

The appearance of life and particularly the colonization of the land by plants profoundly changed the geochemical cycles. The original mineral surface was covered by green vegetation and film of humic soil, condensing large volumes of calories of fixed solar energy. Both land and ocean acquired a vast biomass of actively photosynthesizing plants and of animals and decomposers dependent on them. All this fundamentally changed the previous geochemistry of the earth. The cycles of a majority of chemical elements were re-oriented. New cycles of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, calcium, and many other elements were formed. As a result a more complicated system took shape: the biosphere – an environment of life and a product of life. Mineral geochemical cycles were transformed into biogeochemical cycles, inseparable from the activities and metabolisms of living organisms.

In the continuing evolution of more advanced life forms, invertebrates appeared about 500 million years ago and vertebrates 400 million years ago. The dinosaurs reigned during the interval from 200 million years to 60 million years before the present. Man emerged less than five million years ago and so-called modern man dates back no more than a few tens of thousands of years. Yet modern society, in spite of its short history, acts now in some areas as a force comparable with or even stronger than forces of mineral nature and living matter. Geochemical and biogeochemical cycles are now subjected to powerful interference by man. Deviations, disturbances, and sometimes total destruction of important portions of the biosphere can follow, with immediate or delayed changes of a local, regional, continental, or global nature.

Against a summary of several billions of years of evolutionary history in a few sentences, what can we say of the future? Only that the remaining solar energy and the low probability of cosmic collisions suggest that the earth should be habitable for at least another hundred million years. Can the human species, which is astute enough to use modern plate tectonics to predict the shape of the continents 25 million years from now, learn so to manage itself during the next few decades that the habitability of the planet is assured?

B. KEY PROCESSES IN THE BIOSPHERE

The population/resources ratio of the world as a whole, and of some regions in particular, is shifting. Mounting population or rising demand for increasingly scarce resources make increasing demands on the biosphere, parts of which deteriorate while others are made more useful to humans. Four key processes which are essential for the functioning of the biosphere and therefore for the maintenance of the environment are:

(a) the conversion of light energy from the sun into the chemical energy which sustains plant and animal (including human) life;

(b) the biogeochemical and hydrological cycles by which essential mineral nutrients are passed through the biosphere to sustain plant, animal, and human life;

(c) the processes by which all living organisms pass through their life cycles multiply, and adapt themselves by continuing evolution; and

(d) the processes of perception, communication, processing, and transmission of information which make possible the interaction of living things with each other and with their environment.

The natural environment is a complex, interacting system of physical chemical, and biological components. Solar energy provides the driving force for many of the chemical and physical processes as well as biological activities. Atmospheric and oceanic circulation, weathering of rocks, and habitat conditions for all organisms depend intimately on the levels of radiation from the sun.

Many habitat conditions are only predictable to a certain degree. Superimposed on the regular seasonal and diurnal cycles there are fluctuations which can be conveniently described as random, since so far their prediction is only possible in terms of statistical probability rather than as specific events. These fluctuations cover a wide range of time scales, embracing short-lived turbulent phenomena and long-term climatic oscillations. Climate, in particular, has great natural variability from place to place, decade to decade, and even over hundreds of thousands of years as the repeated Pleistocene glaciations demonstrate. Yet life on earth has been possible only because global climate has remained, within certain limits, relatively constant over several thousand million years. Climatic changes obviously affect all living organisms, and to the natural fluctuations are now added the possible effects of human activities. Such effects are well marked on a local scale, for example where 'heat islands' are created over cities, but are more difficult to detect regionally, and probably are not yet visible globally despite rising levels of atmospheric carbon dioxide and changes in the amount of particulate matter suspended in the air. One major group of environmental problems arises from this unpredictability of the climate, whose trends and oscillations can affect agricultural production, energy consumption, aridity, and biogeochemical processes over large areas. Projects I, II, V, VI, and VII of the SCOPE Mid-term Programme touch on these applications, but the main thrust of international effort is within the ICSU-World Meteorological Organisation (WMO) Global Atmospheric Research Programme (GARP).

Solar energy, harnessed by photosynthesis, provides the driving force for all ecological processes. There are limits to the capacity of green plants to trap incoming solar radiation and use it to produce carbohydrates. It has been calculated that no more than 5 percent of solar radiation reaching the earth's surface today is absorbed by plants. Much of this is re-radiated. Only a very small fraction is actually converted into carbohydrates and made available as a chemical energy source for plants and animal consumers. One group of contemporary human problems surrounds the possibility of developing strains of plants with higher photosynthetic efficiency, a greater capacity to intercept radiation, or a wider environmental tolerance, particularly to limited water, so that the 'green area' of the planet is expanded, thereby enhancing potential food production for humans and livestock. The possibility of expanding the land area under cultivation is, however, generally thought to be small, and losses appear to balance the gains from irrigation and new cultivation.

In all terrestrial habitats the soil is of vital importance. The soil serves as an energy, water, and nutrient storage system which smooths the effects of fluctuations in rainfall and other climatic variables. It provides a habitat for organisms decomposing organic remains and recycling the substances they contain. In the soil there are complex interactions between biological and inorganic components of the system. Soils depend on their living microflora and fauna, and on the vegetation that covers them, for their properties and have taken millennia to develop to maturity. Drastic changes in vegetation cover can lead to destruction of soils and losses of nutrients and fertility: a phenomenon frequently recorded in the past and still likely to accompany unwise development of new lands for cultivation. The accelerated growth in the network of towns, villages, industries, and communications systems today is often accompanied by virtually irreversible soil loss. Desertification, erosion by wind, and salinity and waterlogging of over-irrigated land are also major causes of loss. Probably 25 million hectares of land are being lost annually from such causes, many of them unnecessarily.

A proportion of the plant material in the world is consumed directly by herbivorous animals, among which invertebrate species substantially outnumber the vertebrates. Man's livestock and the wild species he crops are in a minority. In most cases it takes between 4 and 10 kilograms of plant material to make one kilogram of even the most efficient herbivore. There is a comparable loss in the conversion of the flesh of herbivores to the flesh of those predators that consume them. Moreover, it is not the fate of every plant to be eaten or every herbivore to be taken by a predator. About 80 percent of the energy fixed at each level in the system is ultimately released by the death of the organism to the decomposers that return it to constituent inorganic materials and nutrients. The bulk of the decomposers are microorganisms, the total biomass of which is estimated to be of the same order of magnitude as that of the animals. The essential, positive role of microorganisms in biogeochemical cycles, in waste treatment, in agriculture, and in industry is often underestimated when compared with their pathogenic effects on men.

Just as the features of any plant or animal community at any time are the outcome of many interacting factors and components, so the continued production of new organisms by evolution is altering the composition of ecosystems. Human intervention further modifies the dynamics of environmental systems and the context within which such evolution proceeds, and so accentuates these processes. Genetic adaptability depends on the presence of genetic variation (a large gene pool) and genetic recombination (by sexual reproduction). Only those species having a large gene pool and capable of rapid recombination are likely to survive in a rapidly changing environment.

C. MAN'S USE OF THE ENVIRONMENT

Man, as a herbivore and carnivore with a very wide dietary range, is remarkably well equipped to exploit the variable habitats of the world, and as a hunter, fisherman, and forager he consumes a substantial number of different plant and animal species. The processes of domestication, however, have concentrated in recent times on only about 100 species of plants and a smaller number of animals, while the domestication of the microbial world started only a hundred years ago. Another group of contemporary environmental problems surrounds the question of how food production can be improved by the wiser use of the plant, animal, and microbial diversity.

One way of doing this would be to rationalize the consumption of animal matter, the production of which – in comparison with plant food production – is both less efficient in terms of energy conversion and more stressful in terms of environmental impact. There are, however, parts of the world, unsuited for cultivation, in which an animal crop – whether from wild or domesticated species – is the wisest form of land use. Many affluent national societies are wasteful in their nutritional use of converted solar energy, both because of their unnecessarily high meat consumption and by their habit of reprocessing valuable animal protein sources (such as milk or fish) through herbivores in order to produce more desirable food such as meat. With mounting world population it is questionable whether this pattern of use can continue and there is a considerable scientific effort, of which SCOPE and ICSU must take cognisance, seeking to increase the equitable use of world food resources and to provide more efficient ways of securing a nutritionally adequate diet for the whole population of the planet.

Another approach which has considerable promise is to expand the range of species which are cropped and particularly utilize species which were not attractive to man in the past but which are capable of providing a higher productivity on areas of land not suited to traditional crops. Early man was dependent on those plants that produced substantial volumes of readily digestible food uncontaminated by toxic or unpleasant oils or alkaloids. He was also dependent upon herbivores that were capable of relatively easy management. He tended to carry out genetic improvements within the narrow range of stock domesticated early in history. The number of new additions to the total range of livestock within recent centuries, at a time when scientific knowledge has expanded dramatically, has been extraordinarily small. In recent years, research has shown that a number of large wild ungulates are capable of producing meat using unimproved natural vegetation on the same kind of scale as improved domestic stock eating much more heavily managed and altered vegetation. Methods of extracting leaf protein from a range of plants have opened up the possibility of cropping wild self-sustaining vegetation without the management effort of intensive cultivation – although the energy costs of these techniques of protein extraction are at present high. There is a need for critical ecological study of these alternative ways of harnessing the energy resources of the world for human welfare. They link to questions of the conservation of the world's genetic resources which clearly become of added importance with the possibility of more direct utilization of a greater number of species.

This whole question of improved food production is linked to another, namely the extent to which environmental systems possess a degree of homoeostasis: that is a self-regulating capability. In the natural environment the composition and appearance of types of vegetation and their associated fauna are the result of a great number of interacting factors, and they inevitably display change in response to fluctuations in climate, as well as to the activities of man. Sometimes, as when a lake fills in with sediment, there is a natural succession, each vegetation type building up a layer of peat and altering the habitat in favour of shallower rooting species and ultimately of woodland. These successional processes are, however, slow and at any time most natural vegetation appears to possess a degree of stability and resilience. The 'resilience' of a system is a measure of its capacity to withstand environmental stresses. Pressed beyond certain limits, stresses can no longer be absorbed and an ecosystem will change rapidly to a different configuration. For example, if a semi-arid grassland is over-grazed, a point is reached at which it rapidly becomes bare and eroded, and natural recovery is then either very slow or impossible. Exploited populations can similarly be so depressed by over-cropping that their recovery takes many decades, as has recently been demonstrated by the larger whales and by some oceanic fisheries.

There is argument over the extent to which the resilience of a system is related to its species diversity. In relatively constant and favourable environments a large number of species is generally present and the system is characterized by a high order of interspecific competition. Under these circumstances, diversity does appear to be related to stability: perturbations, such as selective treecutting, that fall short of gross physical disruption are followed by changes in the relative abundance of component species rather than alterations in the overall structure of vegetation and fauna. Moreover, the greater the potential productivity of a site, the faster it generally recovers after disturbance. In other habitats such as deserts or polar and alpine environments, where physical disturbance of the habitat and environmental stress are great, the range of species present is much less, yet species are often remarkably constant in their presence for decades, if not centuries. In these cases, there is apparent stability despite a low level of diversity, probably because environmental conditions remain much the same over long periods and all the species present are adapted to them. However, human impact may cause particularly severe damage in these highly stressed areas and recovery is very slow.

In areas such as National Parks and equivalent reserves, or lands under ecologically sound forest and range management techniques, there is usually a low energy supplement associated with human activity. In contrast, there is usually a high energy supplement in intensively used rural and urban lands. In between is a range of increasing habitat modification usually associated with an increasing amount of energy input and a decreasing dependence on the natural environment and biota.

Although these phenomena are not always linked (for example, low energy input rural land-use is, in many developing countries, also associated with marked habitat modification), it is apparent that as the degree of habitat modification increases, and as exotic species are substituted for natural species, a knowledge of the structural and functional relationships of the original ecosystems becomes less relevant to the management of the modified systems. These systems can nonetheless be retained in a highly productive and stable state, as is evident in many deforested and drained areas of Western Europe and in ancient irrigated systems of central and Southeast Asia. On the other hand, in areas that are utilized essentially as managed natural systems, a knowledge of the original structural and functional relationships is probably important as a foundation for effective long-term management, consistent with both conservation and maintenance of productivity. These systems include many terrestrial woodland ecosystems and arid or cold regions, as well as areas that have been difficult to cultivate because of topography, high water table, or other factors. They also include many aquatic ecosystems, including those of the sea.

The oceans cover 70 percent of the earth's surface and provide about 70 million tonnes per year of high-protein food. Hitherto they have been exploited by methods that are essentially mechanized and often competitive hunting rather than carefully managed cropping, and some resources have, as a consequence, been wasted by over-exploitation. It is believed by some investigators that, with proper management, the yield from the oceans could be greatly expanded and this production sustained. New species (such as the krill of the Antarctic) are being cropped as well as the more traditional fisheries. This expansion in the use of the seas must be based on adequate scientific knowledge, relating the productivity of exploited stocks to overall ecological balance. In addition, account needs to be taken of the interplay between the exploitation of oceanic life for food and the expanding development of seabed energy and mineral resources The Scientific Committee on Oceanic Research (SCOR) within ICSU, and the Food and Agricultural Organisation (FAO) among intergovernmental agencies play a major part here. Marine resource management and marine pollution have received little attention from SCOPE and are only referred to briefly in this report.

Ecosystems traditionally utilized for agriculture and fisheries are being intensively studied by FAO and many other governmental and non-governmental international and national organizations. By comparison, the managed natural systems have received relatively little attention, yet when they are used unwisely by man they rapidly become unstable, with associated severe, and sometimes essentially irreversible, changes. For these reasons, Project II in SCOPE's Mid-term Programme concentrates on managed natural ecosystems.

Modern agriculture has arisen through a process of increasingly intensive injection of human management effort into the environment. Forest clearance replaces a diverse system, with a high order of competition, substantial proportion of the total nutrients locked up in the standing crop, and in which annual production represents a relatively small proportion of the total living matter in the system, by one much more typical of earlier successional stages. This is commonly a grassland, where the annual production is large in proportion to the standing crop or where the whole system is made up of annual species. A high proportion of the nutrients cycles through the system each year. There is much more rapid change and a much greater potential for change if human management is withdrawn. Commonly (but not invariably) abandonment of management is followed by resumption of the successional process back to forest. Cornfields and pastures are maintained as such in most temperate regions by the continuity of human management and where this is withdrawn woodland may quickly return. Intensively managed crops are commonly composed of but a single species, and management effort is needed to exclude other plants and those invertebrate and other pests which feed on the crop.

Modern agricultural and urban systems have replaced an ecological situation in which nutrients were cycled from plant to herbivore to carnivore and back from all of these to the soil by decomposers within one general area by a more linear flow of nutrients through the transport of plant material or meat from the countryside to the city and the discharge of the nutrients down the sewage systems to the sea. Phosphate, for example, is only slowly replenished from the environment, coming from the sea or from the weathering of phosphatic rock. In modern agricultural management it has been necessary to take deliberate steps to replace the nutrients lost if fertility is to be sustained. These systems operate efficiently in the highly managed agriculture of wealthy countries. In contrast, the extension of agricultural systems onto new lands in countries without a substantial technical and economic base has often been accompanied by the wastage of living resources and nutrients and the development of unstable types of vegetation with a lower productivity and higher incidence of soil erosion than is desirable or necessary. Another group of modern environmental problems stems from this basic fact that much of the land now being developed for agriculture in the tropics and subtropics does not have an inherently high natural fertility, tends to suffer from problems of erosion or salinity, and requires considerable management from the outset if such fertility is to be sustained or enhanced. Traditional methods of agricultural development applied to fertile land in developed countries or adapted to a shifting cultivation system in which land is returned to be fallowed under forest for decades are not appropriate to the needs of rapid agricultural development where populations are mounting.

One group of modern environmental problems stems from man's need to use the energy resources of the biosphere more wisely and avoid activities that will cause a loss of stability, a wastage of genetic diversity and nutrients, and a consequential impaired productivity. There is a conflict here. Many agriculturalists consider that maximum productivity can only be achieved by the most intensive cultivation system that can be devised and by maintaining stability through crop protection and husbandry techniques. Such systems clearly conflict with the maintenance of genetic diversity; they are not balanced by natural factors; and the modified ecosystems may not be as tolerant of stress.

The need to develop new land at all is a reflection of man's mounting population and poses further significant environmental problems. It is a feature of all animal populations that their numbers are ultimately limited. In the prehistoric past, man has been no exception to this rule. Some of his traditional limiting factors have been much the same as in animal communities, namely competition for food and other resources, disease, and the struggle for living space and societal status. These have sometimes found their expression in famine and warfare. In contrast, even some simple cultures have evolved effective social checks on human numbers, Much of the world has for the present time escaped from the original zoological population limits through better agriculture backed by industrial technology, a stability of national frontiers, and medical technology. The result has been an unparalleled growth in the numbers of the human species, although this has not been spread evenly over the globe or associated everywhere with the same advances in living standards.

It is now universally agreed that every effort must be made to prevent the collapse of societies in which the original limiting factors would again take their toll. This requires the development of humane, self-imposed controls on human fertility, adjusting populations to the appropriate levels in different countries. Medical, agricultural, economic, and industrial development, education, and enhanced production may help this process by improving the standard of living and satisfaction with life which, in turn, provides the most certain and effective incentive to population regulation. Many of these issues go far wider than the expertise of ICSU or SCOPE. However, there are still inadequacies in scientific knowledge, and it might be a task of SCOPE to aid in understanding the basic dynamics of human populations, to explain the interrelationships between man and environment, and to consider the situation in which the natural limiting factors, are likely to come into operation most swiftly and with greatest impact if societies fail to attain the goals of social and behavioural population control.

Pollution is one offshoot of man's mounting numbers and increased industrial technology: its nature and extent depends on the type of society and technology, the levels of scientific knowledge, and the degree of determination to impose controls even if they reduce profits. Those pollutants that are on an upward trend in the world as a whole have not all been demonstrated to be potentially hazardous on a global scale. Most pollutant problems today are localized, creating 'hot spots' in small areas of the biosphere, where they have caused acute damage to small groups of people and to crops, livestock, and natural flora and fauna and where some of the incidents have been tragic. Some pollutant problems recur over the world (a phenomenon which is sometimes called 'the measles effect'). Chemical variables, including pollutants, are among the factors which affect the growth and performance of crops, the flow of energy to man, and the well-being of man himself, and for this reason SCOPE must attach importance to pollution problems and must consider these within the total ecological context.

The overall lesson is that environmental systems must be looked on as dynamic and interacting wholes. The basic patterns of energy flow are fundamental. So is an appreciation that man, is his widening impact on the world, has reduced the diversity of natural systems and taken upon himself an increasing obligation to regulate the systems he has modified so as to prevent their changing to configurations less suited to the support of human life. Man's generation of pollution, although it has been partly counterbalanced by the development of technology capable of controlling that pollution, nonetheless poses a further demand for management effort. Industry is now acceptable on its present scale in some areas simply because of the amount of endeavour devoted to its regulation, so that the desirable products are obtained without the unacceptable side-effects. As human population mounts and technology creates the products that in some societies are considered essential for a secure and high standard of living, the proportion of the environment managed by man is bound to expand. As a result, the naturally self-regulating unmanaged component on which man .nonetheless depends for the recycling of nutrients, the stability of atmospheric systems, and the maintenance of genetic diversity is bound to contract. It is clearly essential that man's numbers be in balance with the environment on a national or regional basis at a level where human needs and aspirations are satisfied and the stability and diversity of the biosphere are sustained. This argument stands separately from the largely unscientific but strongly held social viewpoint in many areas of the world that an interrelationship between man and something approximating to wild nature is desirable as a part of the total sum of human happiness and hence a legitimate social objective.

D. MAN'S ROLE WITHIN THE BIOSPHERE

Environmental problems, in the sense that human impact has altered natural ecological processes, have existed almost as long as man himself. Fire, deforestation, and massive predation characterized some of the earliest human activities. Until man discovered sources of non-somatic energy however, particularly from fossil fuels, human populations remained relatively small, and environmental impact relatively local. With the scientific-technological-industrial revolution has come an exponential increase in population growth, and momentous increase in the environmental demands of many individuals. These are associated not only with basic needs for food and shelter, but also with the immense socio-cultural infrastructure that some peoples have created to satisfy their perceived needs for goods and services.

Human populations, personal needs, and agricultural and industrial production have all increased more rapidly than has the awareness of their impact. The ability to enhance human nutrition, fertility, and longevity has increased much more rapidly than the consciousness of the need to avoid excessive population pressures. The ability to increase the supply of goods and services by massive inputs of raw material, technology, and energy has occurred much more rapidly than the consciousness that these activities are liable to produce by-products and side-effects which can have deleterious effects on the environment. All this has been exacerbated by growing social and economic inequalities at both national and international levels in many regions of the world.

By tapping the stored solar energy available in fossil fuels and the power of the atom, by manipulating natural materials and synthesizing new ones, by an enhanced understanding of life processes, genetic laws and the chemical nature of a gene, and by the recently acquired and rapidly expanding capacity to handle information, the human race has introduced significant perturbations in these natural processes. The implications are many:

(a) The capacity to use energy multiplies the work-performing capability of an individual hundreds of times and makes modern transportation, construction, and manufacturing possible. It also multiplies man's potential destructive effect on the environment.

(b) The capacity to manipulate materials provides a whole host of new and useful consumer goods, ranging from petrochemical products to hand computers. It makes possible the 'Green Revolution' by providing new varieties of seeds, insecticides, and fertilizers. It is also the source of air, water, and land pollution that can pose a hazard to human life and comfort.

(c) The capacity to influence biological processes has led to new and more productive strains of grain and breeds of animals, and it has prolonged human life expectancy. It has also aggravated the explosively expanding demands of more and more people for limited resources. It is posing problems of genetic engineering, DNA recombination, and the ethical practice of medicine. It has also led many people to stress the need for environmental and genetic conservation.

(d) The capacity to handle information may turn out to have the most portentous impact of all. Scientists can observe parts of the universe veiled from the human eye. They can manipulate machines millions of kilometers away. They can be in instant audio and visual communication with millions of our fellow men; they can perform calculations and solve problems that were impossible, in a practical sense, just a few years ago. These skills impose enormous ethical demands, and society needs to develop better ways of ensuring that they are applied to improve man's use of the environment, rather than increase hazards.

These skills bring within reach a theoretical capacity to greatly enlarge, over a few decades, the transformation of the natural resources of the earth into the goods and services necessary to sustain life and to satisfy human aspirations. Thus, the possibility, which requires social action if it is to be realized, of a better life for all in the near-term future is enormously increased. On the other hand, together with this expansion in man's influence, there will almost certainly be a doubling in the world population – also over a period of decades. It is possible that the 'carrying capacity' of the earth may be exceeded with tragic consequences.

The capacity of earth to support human population evidently depends on a balance between population density and life style on the one hand and available natural resources on the other. It is affected not only by primary production and by available energy sources, but also by the level of scientific knowledge leading to their wise use. The sun can be regarded as a renewable energy resource but has not, so far, been used directly for technological purposes simply because of the wide availability and cheapness of concentrated, stored solar energy in non-renewable forms such as coal and oil. Today, people are increasingly occupied with finding replacements for these fossil fuels when economically extractable reserves are exhausted. The potential of nuclear energy resources is large but their use brings waste disposal problems which have not yet been solved satisfactorily.

Any breakdown in carrying capacity would not be likely to strike the entire world at once. The world is heterogeneous in structure and climate. There is enormous variability in environments and ecosystems, and biogeochemical cycles vary likewise. These variations are manifest as constraints on human society. The environment, agriculture, and type of settlement experienced by an inhabitant of the tropics inevitably differs from that of the dweller in temperate or sub-polar zones. Fertility of soil, the availability of water, minerals, and non-nuclear energy sources, and exposure to the natural hazards of volcanic or climatic variability cannot be made the same everywhere. Taken together with the enormous differences between and within human societies, these variations lead unavoidably to variations in the nature and magnitude of environmental problems and human priorities over the globe. Although the implication is that environmental stresses will be manifest initially at a regional level, the local tensions thus created may nonetheless spill over to create wider dangers.

Global generalizations are dangerous if they over-simplify and lead to unreal solutions. However, there are certain social issues, applicable to different degrees in different places but to some extent everywhere, which need to be examined and related rationally to environmental factors. Among these are:

(a) the need for a concerted effort to increase and sustain food production so that the large proportion of the present human population that is inadequately fed approaches a reasonable standard of nutrition, and provision is made for the hundreds of millions of extra individuals that will need food during the next few decades;

(b) the need to bring human populations into balance with their environment in a manner compatible with individual choices and with the aspirations of those nations which still need or can tolerate more people;

(c) the need to reduce the disparity in the per capita rate of converting natural resources into goods and services. The great, and in some areas widening, gaps between the per capita earnings of sections of the world's population are widely considered unacceptable as is the growing gap between rich and poor within many countries. Further substantial increases in material consumption by the more affluent individuals in all countries is simply not compatible with the total needs of present and future generations;

(d) the need for rational utilization of natural resources, taking realistic account of national rights but providing adequately for both present and prospective inhabitants of the earth. Conservation of resources and of energy (by recycling and other means) is likely to be increasingly important;

(e) the need to conserve meaningful samples of types of ecosystems in as unaltered a state as possible, not only as national heritages, but more importantly as reservoirs of information about natural processes and as natural repositories of unique and irreplaceable genetic material;

(f) the need for a wiser approach to the design of human settlements. The process of urbanization may be irreversible, but in some cities the disadvantages of aggregation of family units outweigh the advantages. More attention needs to be given to the creation of towns organized to supply employment and essential services and to sustain social and environmental quality;

(g) the need to reduce the disparity in scientific and technological manpower. While many of the more serious environmental problems of nutrition, health, and housing manifest themselves most strongly in the developing countries, the problem-solving capability is largely concentrated in the developed countries;

(h) the need for adequate quality in man's physical environment, and hence action to combat present inequalities. This involves considerations of health, education, economics, and aesthetics which, in turn, determine our management of air, land, and water; and

(i) the need for peace and security in life and property in the face of natural and man-made hazards. As the world's population density increases accompanied by increase in the capital value of property and dependence upon technology, the potential for catastrophe enlarges.

Many of these issues go beyond the role of SCOPE, and indeed, that of science, but science must organize itself to foresee the problems and contribute to their solution.

It is within the context of these basic environmental processes and properties and man's interaction with them – and needs from them – that Chapters 2, 3, and 4 have been developed and that SCOPE's plans for future work are put forward.