heading and what we are expected to find in the Museum of Science and Industry in 2076 A. D. Museum professionals say that a science museum serve as a mirror for contemporary science and technology—of man's achievement in the present day. To give our youth a visionary outlook and food for thought, I would advocate that science museum should also portray a glimpse of the future of science and technology. We may not have to take help of science fiction writers for projecting this future trend, nor is it necessary to predict what will actually happen 100 years hence. If we just conceptualise the trends in research and invention and can present them in a visual, audio-visual or through any other museological aid the people will know in advance the shape of things to come in the near and immediate future.

We know from our experience that great efforts are being made in finding new sources of energy. The harnessing of solar energy is engaging the attention of the scientists the world over. Can we not show in our museum the significance of this inquest and how the world will look like when the inquiry is successfully over? Perhaps another futuristic theme could be the use of new types of food. In tropical countries various types of vegetable proteins from unconventional sources are being thought of; research is in progress to convert non-edible oils into edible oils by hydrogenation or other methods; conversion of the inexhaustible water hyacinths in a tropical zone (which clog the rivers, lakes and ponds) into something edible for animal or human beings is also under consideration.

Can we not think of a museum gallery to depict all these futuristic trends in science and the consequence that will necessarily follow? If we can do this a science museum will be an ideal institution to depict in temporal sequence the evolution of scientific or material culture of man—his past attainment, present endeavour and the future expectation.

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OCEAN—A SOLUTION FOR INDIA AND THE WORLD

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The World's ocean produce about 80% of all proteins, yet so far man is using only an insignificant part of these riches. In recent years marine biology and oceanography, the sciences which help man to tap the waelth of this living treasure store in the most effective manner by turning the seas and oceans into a gigantic laboratory. Because of the world-wide continuity of the oceans and their conditions, International collaboration is essential so that comparative studies may be made on a broad geographical scale. Collaboration is desirable, also in order to achieve an adequate research effort on selected basic probelems.

AN essential way of estimating natural resources is the direct method of studying the resources themselves in those situations where such direct estimation is feasible. (Usually, this implies the existence of a commercial fishery). Research on resources cannot be carried out profitably in isolation, however, this is a principle which is recognised in the Fisheries Institutes where much important fundamental research has been done and where, for instance, a considerable effort is devoted to research on hydrography and planktonology. The yield of commercial fisheries is largely determined by the pattern of mortality, reproduction, migration and shoaling behaviour which, in their turn, are dependant on food supply and other biological, physical and chemical features of the marine environment of which fish form a part. Success in forecasting and regulating fisheries will depend on an adequate understanding of the whole eco-system.

Many fishery biologists have pointed out that serious obstacle to progress in fisheries research is the unsatisfactory state of present knowledge of the ecology and physiology of marine organisms in general. The investigations should be directed, therefore, towards an improvement of our understanding of the basic ecological mechanisms which control the abundance, distribution and productivity of marine organisms, of all kinds throughout the tropic chain in the sea.

There is an urgent need to acquire this fundamental knowledge in the regions which are easily accessible to man, such as the coastal areas, the littoral zones, the waters of the continental shelf, the estuaries, lagoons, and mangrove swamps. These are the areas in which man is already imposing changes through exploitation, pollution, land reclamation, and other activities. There are also the regions which offer the most immediate prospects of improving resources through human intervention. The importance of studies in the open ocean should not be overlooked, however. The detection and measurement of ecological mechanisms will be dependant, in part, on the opportunity to make comparisons, between different environments ; coastal and oceanic, continental shelf and slope, tropical, sub-tropical and temperate. The individual contribution should, collectively, provide the material for such comparative studies. The programme should form a sufficiently representative time series for the elucidation of general principles and it is essential that long-term variation shall be studied as this a major source of difficulty in planning the efficient utilization of marine resources in many parts of the world. The programme should be implemented through a co-ordination of the activities of laboratories rather than by a large international survey. It is hoped, however, that the basic methods and objectives of the programme will be incorporated into such surveys in the future, particularly in expeditions to little known part of the seas. There are already in existence a number of well developed international organizations in marine sciences, particularly in fishery biology, marine biology and oceanography.

The study of seasonal variation, one of the most consistent features of biological events in the sea is the seasonal cycling of organisms and nutrients. It is clear that there is a wide range of geographical variation in the magnitude, regularity on pattern of these cycles, but even the basic description of them is known for only a few localities in which classical studies have been carried out. Although seasonal variation is relatively slight in many tropical areas, one of the main objectives would be the detection and analysis of the factors which maintain stability in these areas compared with those which result in maximal variation in high latitudes. It is suggested that such comparative studies would contribute towards the detection and understanding of controlling mechanism will be defined in the form, perhaps, of traverses stretching from the shore to the seaward limit attainable with the available ships and manpower.

Having determined the basic objectives on methods including the possibility of defining standard of inter-comparable techniques, it is fortunate that number of national and international working groups are already considering these problems. The International Biological Programme (IBP) has taken up the experimental and field studies in consultation with international organisations such as, Scientific Committtee on Oceanic Research (SCOR), International Oceanographic Council (IOC), Indo-Pacific Fisheries Council (IPFC), United Nations Educational, Scientific and Cultural Organisation (UNESCO) and Food and Agricultural Organisation (FAO).

There is an immediate need for an active and major research programme for the development of methods of study of biological productivity in the sea. Productivity of the sea can be defined as the capacity to produce and is commonly used as a qualitative term for indicating the fertility of any ocean region. Indeed, most biological studies relating to controlling factors lead to and are essential to an elucidation of the problem of quantitative and qualitative production of plants or animals in the sea. Studies pertaining to production in the sea are of vital interest to several marine sciences, particularly to the physical, chemical, biological or geological, because of their bearing on the extent, time and spatial distribution of organic and inorganic constituents of the water and of the bottom. The need to improve knowledge of the part played by the benthos in the production of organic matter is being neglected. And it is essential to select these research topics in which methods and knowledge had reached the stage where international co-operation is likely to be fruitful. The problems of sampling and estimating production and turn over the benthos seems to be formidable that there is some doubt about the feasibility at this stage of study on the benthos. However, assessments of marine productivity which ignores the benthos especially and of the coastal and inshore regions too. So it will be necessary to make a special study on benthos for the analysis of spatial and seasonal variation.

A joint panel of . New Oceanographic Tables and Standards has been set up by Scientific Committee on Oceanic Research (SCOR) considers the intercomparison of measurements of salinity, temperature, chlorinity, density, conductivity and refractive index. It has already drawn up recommendations for the standardization of conductivity measurements and for the relations of these to chlorinity. It is highly desirable that stability and mixed layer depths shall be studied as background for example, to the investigation of phytoplankton blooms and nutrient circulation. Water currents are of major biological importance through the transport of nutrients and organisms. New methods have been developed recently for the determination of reactive phosphorus, nitrate and other nutrients (ammonia—nitrogen) in the seawater. There are relatively large amounts of dissolved organic substances in sea water, but very little is known about temporal and spatial variations of this material, together with organic detritus, in heterotrophic growth.

The measurement of chlorophyll provides one of the best means of estimating the total plant material in the sea. The spectrophotometric method has become standard and recent work has led to improvements in methods of extracting the pigment, in calibration and the equations used to express the results as chlorophyll. It might be thought that the total of all phytosynthetic pigments should be measured in laboratories with suitable facilities and an attempt made to distinguish between dead and living phytoplankton. The uptake of C^{14} must be used to measure photosynthesis in oligotrophic areas though the simple method of measuring oxygen production may be adequate in autotrophic zones. The problems of quantitative sampling of zooplankton are extremely difficult and so a thorough programme of research into methods and their comparability is essential. It may be necessary perhaps two nets with different meshes combined in one sampler which will provide an adequate sample of the majority of the herbivores. It is important that such a sampler shall be suitable for use from small ships as well as big ones, there may be strong practical as well as scientific advantages in using a high speed sampler. In addition to counts and identifications it will be necessary to express the results in terms of weight of herbivore matter under a unit area or in a unit volume of water.

It has been necessary to select organisms such as fish which are most likely to yield profitable results. Since the food supply of fish fundamentally depends upon plankton, the importance of plankton to fisheries is basic. The richness of plankton production depends on the mixing of the waters due to the upwelling process so that nutrient rich water from the deeper layers is brought to the surface layers where the fish can use it. The richest fisheries of the world are related to the areas of richest plankton production and are on the continental shelves, where there is good feeding and depths which can be economically fished. Insufficient mixing of the water masses is the most important cause for the poor fisheries due to inadequate nutrients for plant growth and so paucity of the plant plankton (phytoplankton) to animal plankton (zooplankton) as food for the fish. Ways can be found to extend these studies to all those kinds of organisms, many of them in the benthos, which are used by man or which are potentially valuable as resources.

In general, the objective would be to study the place of fish, and of other resource stocks, in the trophic network in the sea with the emphasis on seasonal and spatial variations. It will be necessary to distinguish between those stocks which are used by man and those which are not. Information about the first is provided by fisherman, for the second, other methods are needed. In the fishes, areas of the seas, the catch per unit effort by statistical squares is available for a variety of species. The collection of fisheries statistics has greatly improved in many regions. Estimation of abundance derived from fishery statistics should be checked by other methods, including egg and larval surveys. In the unexploited areas, such surveys might be supplemented by acoustic techniques. Both methods could be used from research vessels of marine biological as well as fisheries institutes.

The studies of biological production outlined above would be of limited value without a basic knowledge of the distribution and abundance of the most important species and communities. In some areas this knowledge exists or its foundations are well laid, in others it will be necessary to solve the most fundamental problems of taxonomy and morphology. For these reasons, and because each marine situation presents its own local problems, the work should have a quantitative basis sufficient to determine the relative abundance of different species and to allow the combination of results towards biogeographical atlases. Special attention should be paid to fish eggs and larvae, their food and predators, and the detention and plotting of unconventional resources as well as those which are exploited by man. Attempts should be made to ensure that bacteria, fixed algae and the benthic animals are adequately studied. The kind of field observations are designed to provide the basic material for an analysis of spatial and temporal variations in some of the major biological elements of the sea. The results should provide some of the principal terms required for the formulation and testing of mathematical models of marine productivity.

One topic is requiring for the estimation of productive rates in animal populations as a parallel to the estimation of photosynthetic production. The study of nitrogen as a primary nutrient should not be divorced from knowledge of nitrifying bacteria, involving work on populations in the field as well as metabolic studies in the laboratory. Nutrients are estimated in the sea by chemical methods, but we need to know whether they are all usable by organisms ; biological tests or assays may be necessary to test this point. Dissolved organic substances should be investigated in relation to particular organic material in living organisms and detritus (this is one of the topics in which spatial and temporal variations may be particularly important). The chemistry of excretion by both plants and animals should be studied in this context.

There is a great deal of information about the nutritional requirements and general physiology of a few organisms. However, we are entirely ignorant of the food and physiology of important organisms in many marine communities. Although benthic animals and some of the planktonic herbivores may be attractive particularly urgent attention as they are so numerous and their part in the circulation of organic material must be very great indeed. The blue green algae and seaweeds as far as possible their physiological studies should be performed on organisms taken recently from the sea and kept in very dilute media approximating to natural sea water and similar to those occurring in the sea. An important objective of such experimental physiology should be the study of seasonal and other temporal changes. For example, it is known that growth factors are important in diatom development and it is thought that growth requirements differ in different phases of the life cycle, but very little is known of any spatial or temporal growth promotion substances in the sea. There is insufficient knowledge about internal waves in the sea and their effect on the distribution and abundance of organisms ; these effects may be particularly important in considering the differences between shelf and slopes regions.

There will be full collaboration between physical and biological oceanographers as in any marine programmes, but there are special topics in which joint work is particularly important. One of the programmes of UNESCO and FAO is the International Indian Ocean Expedition (IIOE—1960-65) which brought us knowledge about the Indian waters ; the highest productivity of the Arabian Sea is strongly supported by oceanographical investigations that the waters of the Arabian Sea are continuously enriched by upwelling and related phenomenon which bring the richer nutrient water from below to the surface and are able to support heavy fish populations. Hence, nearly three fourths of the total sea production is from the west coast. In contrast to this, waters of Bay of Bengal are of a somewhat static character with a comparatively higher temperature, lower amount of nutrient salts, lower plankton production and consequently lower quantity of fish catches from the east coast.

It is high time that the Advisory committee on Marine Resources Research (ACMRR) and the Food and Agricultural Organisation (FAO) should investigate the possibility of developing world programme of Marine Research so that ocean wealth can be exploited at the maximum to meet the minimum requirements of the comonm man.

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MAN'S PRESSING PROBLEMS AND THE ROLE OF SCIENCE EDUCATORS

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Hand in hand with man's progress due to science and technology, problems facing mankind are becoming more and more challenging in recent years, demanding increasing application of science and technology with all their sophistication.

INDEED, science and technology have never faced as serious a challenge as the ones posed by the pressing problems of mankind today. We, as scientists have always believed that many of these problems can be solved—if at all—by the application of science. It, therefore, becomes important to discuss the role of science in solving man's pressing problems while teaching science courses in schools and colleges, This is not merely to underscore the importance of science alone, but also because today's young students will be the managers of society around 2000 A. D., when these problems are likely to hit them the hardest.

Let us briefly examine some of the serious problems of today. The foremost of these is the problem of energy. We have essentially used up the petroleum resources of the world and the energy demand is increasing every year (Fig. 1). However much we may augment the energy requirements by nuclear

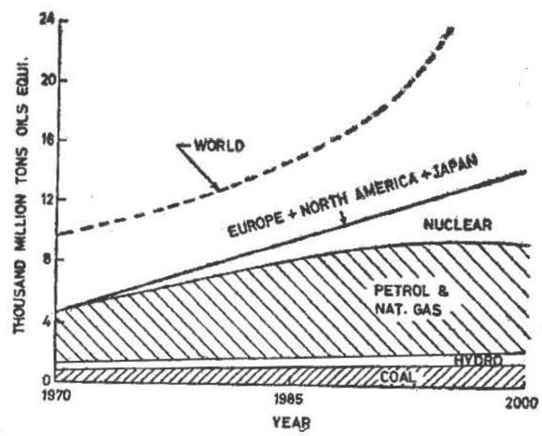

Fig. 1. World Energy demand.

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