EVERYMAN'S SCIENCE

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COVER PHOTOGRAPHS

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EDITORIAL

Most of the Indian population still resides in rural and suburban areas where the literacy rate is very low. Therefore, the recent science and technology development impacts are supposed to be very meager. But in fact our old culture of life pattern is so robustly developed by Rishis and Saints who acted as thinkers and were guiding factor of the society that most of the religious activities cater the need of food, shelter and medicines sustainably without depleting the natural resources for future generation. Some examples are the protection of high medicinal value plants like Tulsi, Pepal, Neem and Awala etc., which were given a flavor of religious worship to enhance their plantation and protection thus maintaining environment and improving health. In the area of material science the advancements were also very high, e.g., the noncorrosive iron pillar in Meharauli area at Delhi is an excellent example of forging technology and knowledge of corrosion preservation, the sweet wells on the sea shore of Rameswaram temples at Rameswaram, Tamilnadu, which are an excellent example of porous ceramic membrane technology with reverse osmosis and self-cleaning process having ion selectivity thus controlling the continuous availability of controlled mineral containing water having different natural color impacts and matching the color of water of that river on whose name the wells are named, floating stones on water in the same area as an state of art example of closed cell ceramic foams having high strength and prepared using naturally occurring materials etc.

But during recent past we have fallen in such an economic race that due to which our developmental process become unsystematic and unplanned which invited number of natural disasters and causing draught and flood in many parts of the country. The most disastrous accident due to unruly development occurred in Uttarakhand (Badrinath and Kedarnath) where thousands lives were lost.

It is a matter of simple realization that nature is like our mother and father and it creates, save and punish if done something wrong. Infact, the nature has provided us each and every thing as per our requirement e.g., most essential things are given to us in plenty without any effort like energy (Sun), air (Purified by Plants) and water (Rains and ground water). Those requirements which are not highly required are given in restricted way by posing some unusual properties e.g., radioactive substances are having a half-life and critical mass for their auto balance and use, nanomaterials have coagulation property so that they cannot exist in nature as such otherwise these may have number of ill effects on health when in contact with living beings. So nature as parent has tried to do its best to help us but it is on us how we are using these boons. Our own deeds cause the scarcity and depletion of these natural resources.

So, in brief every science and technology is available around us and infact we are trying to copy nature as far as our scientific developmental concepts are concerned. The nature is highly smart, sustainable and progressive.

So our effort is always to familiarize you with recent trends of biomimetic science and technology efforts going on all around world and providing an imagination to achieve excellence in sustainable ecofriendly growth with the regeneration of natural resources for betterment of all living beings.

Dr. Arvind Kumar Saxena
DMSRDE, Kanpur

"Whether you can observe a thing or not depends on the theory which you use. It is the theory which decides what can be observed."

— Albert Einstein

PRESIDENTIAL ADDRESS

MAN AND OCEAN : RESOURCES AND DEVELOPMENT

PROF. B. RAMACHANDRA RAO. D.Sc. (*HONORIS CAUSA*) F.N.A. F.ASc. F.N.A. Sc.

D distinguished Prime Minister, Revered Chancellor, Respected Chief Minister, Distinguished Scientists from abroad, Members of the Indian Science Congress Association, Ladies and Gentlemen.

It gives me great pleasure to take this opportunity of expressing my heartiest gratitudes to the scientific community for electing me as the President of Indian Science Congress Association and thus enabling me to preside over the seventieth session of the Indian Science Congress at Tirupathi. Addressing such an august audience committed to the pursuit of truth at an urge to explore the frontiers of knowledge one perceives and even encounters and adventure in ideas and insights, leading to the unfoldment of new layers of consciousness and voyage to a new discovery. Hopefully, this meeting of minds will generate incisive ideas and new vistas for harnessing the latent untapped potentials of the rich and varied resources of oceans for the benefits of mankind.

It may appear to be little digression but I would like to focus your attention on the origin of the focal theme. On my election to the President of the Indian Science Congress Association, during the last year, I was deeply concerned about the selection of the topic of the focal theme of the seventieth Science Congress several weeks, in a mood of introspection and reflection, an idea occurred to me that I should take up the theme of Man and the Ocean due to personal and scientific reasons. Let us not forget that oceans are known to be our last frontiers.

I have personal affiliation with the theme in a sense that my association with the sea extends to over half a century. I had a unique and rare opportunity of being brought up in close association with the sea right from my childhood days. As I grew up, I began to take a perceptive interest in the behavior of the sea in its various manifestations and closely observed the diverse rich flora and fauna of the coastlines in the spirit of an environmentalist. The waves, the currents tides and strems appeared to me like a rhythmic dance. I could not understand why the oceans which provide such remarkable resources of food, minerals, energy and petroleum also cause climatic fluctuations and spell catastrophe of worst magnitudes. What struck me most at that time was how the fishing community and even explorers and navigators had a insight into the art of living in harmony with the laws of sea and never arrogated to themselves the power of dislocating their equilibrium.

When I recalled those learning experiences which I had the benefit of obtaining from fishermen, maritime traders and explorers. I am transported into a state of joy and delight and this leads to the process of self-examination. Since those days, my only wish had been to understand the knowledge of the ocean, in-depth-knowledge being itself as an ocean—and this led me to read the memories of explorers, navigators and naturalists. What impressed me most was the magnificent observational data which Charles Darwin collected during his historic

* General President, 70th Indian Science Congress held during January, 1983 at Tirupati.

voyage in a Beagle ship. Perhaps today I consider as a part fulfilment of my childhood wish of doing some theoretical exposition on the ocean.

In a science and technological-based world, it is an irony of the human race that over three-fourths of the world's population in this biosphere is still living in a primitive condition and in an impoverished socio-economic environment. These people suffer from various kinds of constraints, malnutrition, deprivation of basic physical and social amenities, without any access to the modern educational, health, transportation and communication systems; because the benefits of the development have been taken away by the develped societies of the world and only a small fraction of the population of the developing societies could avail of the advantages of Science and technology. This imbalanced development and distribution of resources is inhibiting the goal of international world order to which the United Nations system is firmly committed.

In any analysis of the scientific and technological advancement, we should not overlook the fundamental fact that developed societies in their quest for the mastery over laws of nature went on exploiting the precious and scarce natural resources of the biosphere in a ruthless and in an indiscriminate fashion. This process has resulted in the shortages of non-renewable and even some renewable resources needed for the developmental tasks and brought about a staggering problem of environmental pollution and an ecological crisis. It never occurred to the scientists, technologists and planners that biosphere exists and survives by means of a delicate self-regulating and self-maintaining balance of natural forces. The constituents of the biosphere are inter dependent and man is just as dependent in his relation with the biosphere as any of the biosphere's other present constituents. This dislocation has become a source of great disturbance, and a cause of serious concern and currently the planners and policy-makers are looking before and after as how to evolve new strategies of development which are ecologically-oriented to prevent further danger to our biosphere.

In looking towards forward the further developmental scenario of the developing societies, one perceives gigantic problems of development involving an accelerated growth of food production for feeding millions of people who are ill-fed, providing them with the necessary medical, health and educational facilities and other basic amenities. This is an extremely difficult task at a time when the population of developing societies is expanding at an explosive rate and consequently the natural resources are depleting rapidly; and also their exploitation by Science and technology is not being accomplished in a balanced fashion. What are the alternatives and options before us ? It is fascinating to note that while Science and technology has accomplished a magnificent task in our generation by landing man on the moon, this feat has taught us some lessons of practical importance of estimating our prospects and choosing our policy on the earth. Even if moon is endowed with lot of precious natural resources, how far it would be an economical and viable proposition to exploit its rich resources for developmental purpose? A permanent colonialisation of the moon by the people of the earth would be an extraordinarily difficult task. In such a situation, can we look forward to the exploration of our ocean resources which are enormously rich and are waiting for exploitation to meet the requirement of food, chemicals, minerals fuel and energy? The ocean provides a unique challenge and an exciting promise for development.

It is conceivable that most of the ocean resources could not be exploited because of their inaccessibility, lack of technological capability and comparatively high cost of development. The ocean comprising nearly three-forth of earth's surface possesses vast latent, untapped potentials which could be appropriately exploited for the developmental purposes with the help of effective use of sophisticated instruments of Science and technology and highly trained manpower capability.

The developmental aspect of the ocean can be considered for the terrestrial environment from the following broad perspectives. To elaborate a little further, they can be used for transportation, source of food and other organic and inorganic materials, fresh water and energy, habitation industry and business activities, transmission of energy and functions of waste disposal, health, welfare and recreation, education and training, gaining of knowledge and understanding of national security and international relations. While undertaking a program me of the development of the ocean, it would be appropriate to proceed through an orderly sequence of analysis. In this process there are four major steps :

1. identification of the contemplated resource;
2. evaluation of the technological, legal economic, sociological and political factors;
3. estimation of the benefits anticipated, costs, involved, goals, needs and time schedules; and
4. implementation through arrangements for funds, authorization and assignment of responsibilities for management and regulation.

ISSUES

Perhaps, the time has come when the scientists, planners and policy makers and leaders in diversified areas of life must address themselves to the following crucial issues involved in the process of development of the ocean resources, both latent and identified, for the benefit of mankind. If the natural resources of the land—both renewable and non-renewable—are getting exhausted and account of the ruthless and indiscriminate exploitation by the developed societies, while the need for an optimum use of scarce resources has assumed a grater urgency in the developing societies in a view of their expanding population, can we look forward to the potential resources of the ocean to meet the emerging and foreseeable threats of food problem, protein deficiencies, and the shortage of mineral, fuel, energy, oil and others? How far the ocean research, especially in the developmental sector, can facilitate and accelerate the pace of development to improve the condition of the impoverished section of population, which constitutes two-third of the total world population, who despite various breakthroughs in Science and technology are living ill-fed, shelterless and without any access to modern communication system, modern transport and other basic amenities of life which are essentials in any civilized society. If the agriculture system of most of the developing societies especially in India, is still dependent on the vagaries of monsoon, how far multi-disciplinary research, specially in the areas of oceanography and climatology could regulate a balance so that the fluctuation in the rainfall could be minimised? How far the rich and varied flora and fauna of ocean reflecting the environmental diversity, which is being destroyed by indiscriminate and ruthless exploitation of these resources in the process of industrial development, could be prevented? How to accomplish the developmental task without dislocating the rich and varied fauna and flora of the coastlines?

In any analysis of the developmental strategy, we should not overlook the fundamental fact that ecological balance is the result of natural evolution which dates back to several millions of years since the evolution of life on this planet. But this balance got dislocated due to a combination of factors and how to restore this equilibrium is a problem of problems.

If oceans are one of the major means of national and international trade and commerce, why did we not pay adequate attention to optimise their use for transportation and navigational purpose? If the operational cost works out cheaper through oceans transportation in comparison to land, why are the developing societies not adequately exploiting this benefit?

If ocean's voyages could contribute either explicitly or implicitly to the enrichment of human civilization through the monumental discovery of theory of "*Origin of Species*" by Charles Darwin

based on the observational data collected during his voyage on a ship called *Beagle*, why did our scientists, planners and policy makers pay little attention to the scientific expeditions on the high seas for discovering the hidden secrets of nature in the sea and use them for various developmental purposes ?

If the task of harnessing the potentials of ocean resources for developmental purposes are of crucial importance, did we not pay adequate attention to the development of necessary infrastructure and capabilities which are urgently needed to accomplish the said task, when our land resources are in short supply?

Some of the other challenging issues are :

Can we augment our sea food resources by modern methods of marine aquaculture ?

Can we augment our fresh drinking water resources by modern methods of desalination ?

Is it possible to unfold the origin of monsoon and avoid recurrent droughts?

Are we not inadvertantly changing the global climate and local weather by polluting the ocean?

Can mankind draw perennially the power from the sea by new and cheaper methods?

Can we exploit economically the rich potential of off-shore oil at a time when we are caught up in the midst of a major energy crisis?

Can't we learn to mine the vast, yet untouched mineral deposits of the ocean economically?

Are the oceans a safe dumping grounds for the radioactive waste?

It is not a fact that living in a inter-connected world with global systems and sub-systems, our problems of development have assumed global dimensions and are of global scale and naturally global developmental strategies and priorities are needed for the maintenance of ecosystem and a healthy life on the planet ? Is it not essential in the process that we have to cut across artificial barriers which divide us into nationalities and races and work out a coherent plan of action on a global scale for harnessing the rich potential for our oceans for development? If the developed societies are earnest and sincere in their approach towards developing the coastlines of the third and fourth worlds, is this not a unique challenge and an opportunity before them ?

RETROSPECT

Looking retrospectively, oceans have been a potential source of food, energy and transportation from the dawn of human civilization. This becomes evident from the fact that our earlier settlements of population took place primarily on the coastline or by the side of sea. There are enough evidences based on religious literature, mythological legends, Vedas, Upanishads and Puranas giving great significance to rivers and sea. Indeed, the people of ancients days looked at the rivers and sea with respect and awe and had a clear perception and insight as man has to live in harmony with the natural phenomena.

Although ancient Indians could not develop scientific techniques for observation, they had a keen sense of observation of phenomena like ocean currents, winds, tides and the diurnal and seasonal variations. As an evidence of their understanding of the ocean and also their engineering skill, it may not be out of place to refer to the recent archeological excavation at Lothal in the state of Gujrat, which revealed the remains of a well-designed dockyard built by the Harappan civilization five thousand years ago. There is thus ample evidence to show that the engineers, at the time, knew how to build sturdy sea craft and dockyards. Obviously, they understood well the tidal phenomenon and cleverly used high tide period to bring in the sea craft into the dockyard for repair and maintenance. From archeological evidence, we could infer that the Lothal civilization was successful in harnessing the potential resources of rich coastline for food, energy, trade and other developmental activities.

India with its long coastline of 5800 miles has always been a seafaring nation. From times

immemorial, Indian merchants carried on trade with several countries all over the world by using indigenously built sea craft. Many foreign nationals from England, Portugal, France and Spain visited India several centuries ago and established trade relations with different kingdoms is our country. There is ample evidence to show that our ancient Indians had sound knowledge of ocean and seacraft and that they had a flourishing trade with many countries for several thousand of years. Yet, modern literature on the subject traces the origin of the sea-going craft from 2000 B.C. The Greeks and Romans were the first to exploit the sea for navigational purposes. The first economy based on sea-breeze trade was that of Minoan Crate between 1700 and 1400 B.C. Myceneans, Phonicians, Greeks and Romans subsequently increased the scale of marine trading (and warfare) throughout the Mediterranean and beyond.

The first institutional attempt to promote the exploration of ocean for adventuring and trade purposes was undertaken under the patronage of Prince Henry, the Navigator in the fifteenth century. During the sixteenth to eighteenth century, we witnessed for the first time remarkable development in the sea-faring activities and the emergence of new techniques by the dedicated efforts of a few sea explorers and adventurers like Columbus, Magellan and Cook. These adventures were primarily the result of the initiative and efforts of a few dedicated individuals who made a historic contribution towards the world-wide European colonisation. The Portuguese, Britishers and French were the major European powers who were able to acquire the necessary capability in the sea-faring activities. Indeed, the extent to which they were able to wield power was determined by their navigational capability. Let us not forget that the British colonisation of the greater part of the globe could be attributed to their pre-eminent position in their mastery of knowledge of the ocean and their navigational capability. Since the understanding of the ocean was at an embryonic stage, even those countries which were able to acquire some knowledge of the ocean did not do much beyond the preparation of the coastal charts ocean and the lore of the seaman and fisherman. Very little effort was made by these explorers to investigate various inputs of the ocean and how they could be successfully harnessed for the developmental tasks. Over the years, most of the governments remained satisfied with the use of oceans for only trade and commercial purposes and did not take the initiative for promoting the research work in the area due to a combination of factors. It was only with the development of maritime activities, navigators and sailors took some degree of interest in the ocean currents. Benjamin Franklin was able to produce a chart of the Gulf Stream which he eventually published in the *Transaction of the American Philosophical Society in 1786.* Capt. James Cook, the British explorer also collected scattered oceanographic informations during his three celebrated voyages. There were some of the sporadic attempts but no organized attempt was made to study the ocean as one of the major scientific disciplines.

It was during the 19th century that a few serious attempts were made by explorers and navigators to study this area in some depth due to a combination of factors. Partly this interest was the result of the rapid increase of interest in Science, in general, and partly because of the emergence of disciplines like Physics, Chemistry, Biology and Zoology, which provided the necessary support for the growth of Oceanography. The person who could be given the credit for laying the foundation for science was Mathew Fountaina Maury (1806-73), a naval officer of remarkable vision and foresight. His first book, *New Theoretical and Practical Treatise on Navigation* published in 1836 was received with considerable interest and curiosity. With enormous observational data collected during his voyage, he was able to work out charts of major currents, prevailing winds and storms tracks which became part of every navigator's equipment.

The potential value of charts showing the direction and strength of winds and currents was

soon realised by the navigators and sailors who used to sail earlier without an accurate knowledge of winds and storms and had to face many hazards of sea life. The oceans are vast and the data at Maury's personal disposal was limited. He overcame these difficulties by enlisting the aid of navigators of the world. He got the support from various navigators and Maury's charts were able to cut the sailing times drastically.

The average voyage between London and San Francisco, for example, was shortened by 180 days. In 1855, he published the first textbook of Oceanographic Physics–*Physical Geography of the Sea*. He is also credited with inspiring the establishment of the official meterological office in both Great Britain and Germany.

Another naturalist who contributed immensely to the enrichment of our ocean knowledge was Edward Forbes (1815-54). He was truly in the tradition of Aristotle and took up his mission of carrying on extensive research in the area. In analysing biologicial collections, he made full use of geological knowledge of the day, relating the succession of fossils in rock strata to living marine plants and animals and tracing the effect of the past history of land and sea on the present distribution of these organisms. He pointed out that the shape of the sea fotton of an important environmental factor. He noted that the Chemistry and Physics of the sea—the concentrations and interactions of nutrients and minerals held in the water and the play of currents—were important influences in the lives of marine animals. He was truly a lively genius, with a free and independent spirit that roamed over a wide range in quest of knowledge and occupation. He was the most brilliant and inspiring naturalist of his day. He made original contributions to knowledge in several branches of nature. He will be remembered for his celebrated and erroneous theory of the Azoic Zone. This theory is the result of his research in the Mediterranean.

Another famous natural scientist was Charles Wylle Thomas (1830-82), who led the most celebrated oceanographic expedition in history, the voyage of the *Challenger*. The *Challenger* Expedition of 1872-76, mounted by the British Government, to collect oceanographic information was a landmark in the history of ocean. This expedition has been unsurpassed in the scope and intensity of the oceanographic exploration and research. On December 7, 1872, *H.M.S Challenger,* a full-rigged spar-decked corvette of 2,306 tons with auxiliary steam power and a penchant for rolling like a barrel (46° one way and 52° the other), sailed out of the month of the Thomas. From then on, until May 24, 1876, she sailed around the globe, logging 68,890 nautical miles in the major oceans and gathering data and biological specimens from waters of all depths and at almost all latitudes. The end product was a vast collection of marine organisms such as the world had never seen and fifty large quarto volumes of multi-disciplinary data, some of which is still useful as reference works today. More directly, practical aspects of Oceanography was also developed. During this period it was because of this expedition that many new varieties of animals were located. Naturalists were able to identify 4717 new species and 750 new generas from the specimens brought back in this expedition. All of them were unrelated to the known contemporary forms. The *Challenger* data marked out a major current system and water temperature pattern.

The three-and-a-half year voyage of the *Challenger* still holds the records as the longest continuous scientific expedition. It also has been unsurpassed in the scope and intensity of its oceanographic probing. The success of the *Challenger* gave great impetus to many national oceanographic explorations from a number of other countries during the remaining part of 19th century. By the turn of the century, Oceanography was firmly established as a regorous Science, but the growth of it has been relatively slow after its 19th century beginning.

Modern study of Oceanography in India started nearly a century ago beginning with the first exploration of the fauna and flora of the Andamans

carried out by Dr. J. Wood Mason, an Officer of the Indian Museum. Soon after the great success of the *Challenger* expedition, British Government created the post of Surgeon-Naturalist to carry out a work in Indian waters similar to that of *Challenger.* The first Surgeon General, Dr. J. Armstrong started oceanographic studies by using the survey vessel *R.I.M.S Investigator I.* Subsequently a larger vessel *Investigator II*, with better scientific equipment, started making observations of salinity and temperature of seawater and of some atmospheric parameters like temperature, pressure, humidity, velocity and direction of winds. This data was published by the Royal Asiatic Society of Bengal. Subsequently, a wealth of useful oceanographic data was collected by Indian Research Vessels during Dana Expedition (1928-30). John Murray Expedition (1933) and Galathea Expedition (1950-52). These expeditions brought out a wealth of useful information regarding the physical and sociological wealth of the Indian Ocean.

After the country attained independence, efforts were directed towards enhancing the fishery resources from the sea. Keeping this in mind, the Central Marine Fisheries Research Institute was established in 1947 to carry out researches related to fisheries development. In the same year, the Indian Navy established the Naval Physical Oceanography Laboratory at Cochin for physical studies of the ocean and also problems cocnerning defence research. Andhra University at Weltair is one of the university which pioneered and carried out commendable work on physical oceanography and meteorology from 1952. In 1960, Government of India constituted the Indian National Committee of Ocean Research to plan and coordinate ocean research in the country.

Undoubtedly, Indian ocean is the least explored by ocean scientists and as such, UNESCO supported a multi-national project entitled "International Indian Ocean Expedition". This was the first major collaborative experiment carried out during 1960-65 using 40 ships and scientists praticipating from 20 countries. India, which contributed 4 ships for this expedition took an active part by assigning a competent group of scientists, well-trained to undertake this task. This work was mostly carried out under the leadership of late Dr. N. D Panikkar, who later became the Director of the National Institute of Oceanography which was established at Goa on 1 January, 1966 as a C.S.I.R Laboratory based on the recommendation of the Indian National Committee for Ocean Research. During the last one and half decades, this laboratory has expanded in all directions and has taken upon itself a variety of activities in the fields of physical, chemical, biological, geological, oceanography. One of the landmarks in Indian Oceanography research was the acquisition of the first oceanographic research vessel, *R. V. Gaveshani* on 31st December, in the country. Since then, *Gaveshani* has completed more than 100 cruises and collected data and information on all aspects of oceanography in Arabian Sea and Bay of Bengal. Another research vessel recently acquired by Central Marine Fisheries Research Institute at Cochin, will hopefully increase the opportunities and activities in the field of oceanographic research.

THE UNDERWATER LANDSCAPE

While viewing the major components of the earth's surface, one is struck by the fact that, beneath the ocean surface, there is a world of geography lying unexplored of which man is totally ignorant. He knows much less about the 70% of the earth's surface lying submerged under the ocean than the landscape on the near side of the moon. Soon after world war I an echo sounding device as SONAR was invented and used for measuring the ocean depth by finding the time of travel of the sound pulse from the surface to the ocean bed and back. When this remarkable invention is fitted to oceangoing vessels, every research expedition became a new voyage of discovery unfolding the mysteries of the ocean bed. Soon oceanographers discovered towering mountain ranges, deep canyons, active volcanoes and steep cliffs in the oceans of the world. Man could discover the wonders of the

hidden continents beneath the ocean having deep trenches, longest mountain chains, broadest deltas and mountains nearly as tall as Mt. Everest.

There major components of the earth's surface are the lithosphere (i.e. the thin outercrust of the land mass), the hydrosphere and the atmosphere. The ocean covers an area of 71 percent of the earth's surface with an average depth of 3.7 km and falls within the domain of hydrosphere. Comparatively, the average height of the land mass above the sea level which is 0.75 km is considerably less. If all the land mass on the earth is smoothened out both on land oceans, all land will be submerged to a depth of 2.5 km. Ocean is predominant in the southern hemisphere which is also known as marine hemisphere.

The five major oceans of the world are the Pacific, the Atlantic, the Indian, the Arctic and the Antarctic. The coldest, deepest and the largest is the Pacific ocean occupying more than half of the volume of the ocean basin. The ocean which received the largest amount of sediment from the Amazon, the Congo and the Mississippi is the Atlantic. The Indian Ocean is basically an ocean of the Southern hemisphere and is the smallest of the three major oceans.

Although scientists debate about the origin of the solar system which is still a mystery, the origin of the ocean is now fairly well-understood in terms of modern theories of sea-floor spreading, global plate tectonics and continental drift. The origin of seawater was explained in terms of following hypotheses :

1. Condensation
2. Weathering of volcanic rocks
3. Degassing of the Mantle

The last of these hypotheses, as propounded by W.W. Rubey, is now considered to be acceptable as it explains the total volume of water and also why the oceans are not saltier than they are. This hypotheses corraborates the evidence that oceans came into existence relatively late in the geological time.

Looking at the physical features of the ocean, the floor could be broadly divided into four major parts:

1. continental shelf
2. continental slope
3. continental rise and
4. Abyssal planes.

The continental shelf which is the area beneath the sea bordering the continent's skirts most of the earth's coasts gently sloping to a depth of 150-200 meters. Atlantic ocean has more shoreline and wider continental shelves than Pacific or the Indian ocean.

The land mass at the edge of the continental shelf abruptly plunges down into the sea forming a continental slope, which is a relatively steep slope ending at the bottom of the sea. These are the tallest and longest boundary walls between the land and the sea. In some parts of the coast such as that along Chile and Peru, the drop from the peak in the mountains to the bottom of the trenches is indeed spectacular reaching a figure of more than nine miles. Along many coasts, the continental slope is furrowed by deep gorges and canyons caused by earthquakes, undersea currents and thick cascade of silt rushing down the slope, Mariana's trench which is one of the famous deep trenches discovered in 1960 is 11 km deep.

At the edge of the continental slope, a continental rise begins gently ending in the Abyssal planes. Abyssal planes are areas of deep ocean floor generally found at depths of 300 to 6000 meters. Nearly half of the earth's surface is occupied by the Abyssal planes which are present in all the ocean and seas of the world. It was in this infinitely large Abyssal planes that scientists made the most startling discoveries about the earth's hidden surface. One of the spectacular observations is that many of the mountains, hills, cliffs projecting out of the Abyssal planes remained fresh and unaltered over several millions of years.

More than a century ago, the celebrated scientist Sir Charles Darwin explained that coral reefs are

formed on top of sinking volcanoes and still manage to be in the top 150 feet of the sea, which is the favourite level for the coral polyps, by growing at the same rate as the rate of subsidence of the sinking volcano. This brilliant hypotheses was only recently confirmed by US Navy Engineers, who dug out samples from coral topped sunken volcanic islands to reach the volcanic rock on an ancient coral Eniwetok Atoll after cutting 4000 feet of coral reef.

Geologists and Geophysicists all over the world have been trying to understand in a systematic fashion the structure, composition and origin of the earth's crust. The study of oceans revealed that the crustal layer of the earth is sufficiently thin particularly beneath the ocean bottom. Scientists have taken up a mammoth drilling operation for penetrating into the Mohorovicic discontinuity or 'Moho' which is the boundary between the crust of the earth and the enormous 1800 mile thick mantle layer underneath. During the early years of 1960's US Scientists undertook "Project Mohole" in order to obtain core samples from the mantle beneath the sea. Project Mohole had to be abandoned after cutting through 600 feet of sediment and rock without reaching the Mohorovicic discontinuity. Project Mohole successfully demonstrated the feasibility of deep sea drilling and generated several new and useful ideas for improving and advancing the deep-sea technology.

Putting this experience to good use in 1968, the Deep-Sea Drilling Project (DSDP) was undertaken by the Scrips Institution of Oceanography. For this project a 400 feet research ship *Glomar Challenger* was specially designed and commissioned. The Project was undertaken at a dept. of 20,000 feet below the sea-level to drill and obtain core samples beneath the ocean floor. With this highly sophisticated ship and modern facilities including satellite navigational system, digital computers, etc., it was possible to penetrate the earth's crust up to 2,500 ft. thickness. Though this project also could not succeed to penetrated the Mohorovicic discontinuity, it has added a wealth of knowledge in the field of Paleontology, magnetic properties of rocks, Geotectonics and confirmed the theory of continental drift which has an important bearing on the evolution of the ocean basin.

The greatest single geographical triumph of modern times is the recent discovery of Mid-Ocean range which is the single longest mountain range having the width of a hundred kilometers and extending over several thousand kilometers. Although the first clue of Mid-Atlantic Ridge came from *Challenger* expedition, use of sonars after world war II led to the charting out of many of the ridge under the oceans. While this study was going on, seismologists noticed that the epicentres of deep sea earthquakes exactly coincided with the location of the newly discovered ridges. Based on these observations, Ewing and Bruce C. Heezen made two hold predictions. First was that mid-ocean ridges were present where deep-sea earthquakes occurred. The second, which was a bold surmise, was that these deep-sea ridges would be one long interconnected mountain range. Subsequent surveys and seismic results confirmed both these predictions and showed that these ridges, which are also volcanically active, run right around the world. The Atlantic, the Pacific and the mid-Indian Ocean ridges are the major ridges in these oceans. The total length of Ocean ridge system (75,000 km) is long enough to girdle the earth twice over.

This is not the place for me to discuss the theory of continental drift propounded in 1855 by Edward Suess, a Swiss geologist who proposed that the contents of South Africa, Africa, Antarctica, Australia and India were once joined into a single large land mass called Gondwanaland. In his classic work "*On the Origin of Continents and Ocean Basins*", Alfred Wegener showed that all continents were once a part of a single super continent called Pangaea which was supposedly fragmented into two giant continents separated by the ancient sea called Tithys sea. The second part of this fragment called Laurasia encompassed North America and Eurasia whereas the southern part was the

Gondwanaland. Over millions of years, further fragmentation occurred thus forming the modern continents. It was estimated that Pangaea began to break up two hundred millions years ago, and that the second breakup began 135 million years ago into smaller plates. The entire theory is based on the similarity of the coast lines which fit into each other and also the similarity of the deposits of coal, of glacial deposits and of fossil plants and animals in the countries of the Gondwanaland. The theory of continental drifts is now well-established and it is generally accepted by all that the ocean basins are opening and closing ever since they were created during the 4-5 billion years of Earth's history. Very recently interest in this theory was revived by the discovery of sea floor spreading the Paleomagnetism. One of the interesting and convincing evidences in support of the theory, came from computerised continental drift reconstructions. They showed perfect fit between Africa and North and South America.

Paleomagnetic studies of rocks of different ridges in the ocean showed that the magnetic poles of the earth have been wandering in the geological past leading to the concept of Polar wandering. This is due to the continents and seas moving continuously rather than the pole itself changing its position. The crust of the earth has a high degree of mobility over the mantle resulting in a slow shifting of the solid lithosphere on the plastic asthenosphere beneath it leading to a change in the position of the poles. The modern theory of global plate tectonics assumes that the earth's crust is broken into several large and small irregular segments called "plates". These plates in the lithosphere ride on the relatively fluid-like asthenosphere causing the plates to move horizontally. There are six major plates identified. Each plate may contain a continent or an ocean or both. The boundaries where the two plates meet are subjected to enormous forces and are seats of intense activity as this is the region where considerable pressure is exerted by the two plates on each other. When plates diverge from each other, new material from the earth's mantle comes up and new crust is created continuously, as had happened along the major ocean ridges. On the other hand, when two plates collide, one is pushed beneath the other creating deep sea trenches and volcanoes releasing fantastic amounts of energy occasionally in the form of devastating earthquakes. One example of this is the collision of India with Asia bringing about a major continental upheaval resulting in lifting both continental and ocean floor rocks to form the majestic Himalayas which is the youngest mountain range still growing taller. Although to a lesser extent, earthquake energy is also released when two plates meet and move parallel to each other but in opposite direction. By a study of Plate Tectonics theory and its applications, scientists have come to the conclusion that modern ocean basins are relatively young (less than two millions years old). Ocean basins have been kept younger over ages. The Ocean basins are in a perpetual state of motion although at an imperceptible rate of the order of 1 to 16 cms per year. These rates are least in the mid-Atlantic ridges and highest in the East Pacific ridges. According to Sir Edward Buller the famous geologist the entire floor of the Pacific ocean and the Atlantic ocean were formed about 100 to 150 million years ago which is quite young compared to the 4.5 billion years of the age of the earth. The Indian Ocean was also formed in recent geological past when the Indian plate drifted away from the Gondwanaland and collided with the Eurasian plate in the North. At the present rate of motion of the plates, Atlantic and Indian oceans are expanding and Pacific ocean is shrinking, perhaps, to disappear in the future as many oceans have disappeared in the geological past, such as the Eurasian ocean which existed between Siberia and Western Russia in the geological past. The Eural mountains are formed as a result of the collision between Russian and Siberian plates. The plate theory of continental drifts is one of the most outstanding discoveries in modern times which not only explained the origin of the continents, mountains and ocean basins but will some day enable us to recreate the past history of the earth over several hundred million years ago.

Astrophysicists and geophysicists are deeply interested in the origin and evolution of the earth. In this task, they have very limited experimental evidence for recreating the history of the past. One such evidence has recently come to light when scientists tried to estimate the length of the day in the remote past. There is sufficient justification, on theoretical grounds, to say that the length of the day increased slowly in geological time as earth's rotation has been slowed down by tidal friction and also friction inside the mantle and core of earth. As a result of the increase in the length of the day, the number of days in the year decreased. Theoretical calculations indicated that at the beginning of Cambian period some 570 million years ago, there were 428 days in a year. Looking for a 'clock' in nature which had recorded the number of days in ancient geological period, scientists discovered the possibility of using the bands on ancient corals, representing daily growth, to precisely arrive at the number of days in a year in the geological past. Examining the hard shell of the corals of the past, distinct bands indicating annual and daily growth can be recorded to find out the number of days in a year and estimate the age of period by radioactive dating or stratigraphic evidence. It is indeed a triumph of the theory that the theoretical values of number of days in a year in the early ages of evolution of the earth agreed well with those estimate from coral "clocks".

Having reviewed the work on undersea landscape I cannot refrain from referring to continents of the vast Antarctica and its 14 million km area buried under a vast sea of ice. The average thickness of ice in Antarctica is 2.16 km and the volume is 30.11 cb. kilometers. If all the ice in the Antarctica melts the levels of the whole world will rise by 55 meters, submerging many of the coastal towns. It was captain Cook's adventures spirit which led him to cirumnavigate the Antarctica as early as 1773-74. However, systematic scientific study was started only during IGV (1957-58) when many nations undertook a well coordinated series of observations on this vast continent almost totally buried under ice with hardly one per cent of the land exposed for geologists to collect samples for their investigations.

Currently about a dozen countries have set up their research stations and pursuing a systematic programme of research for peaceful purpose confirming to the 30-years Antarctic Treatry ratified in 1961. Antarctica is a fascinating continent which contains 99% of the ice in the world and 90% of global fresh water reserves. It is therefore not surprising Antarctica plays a vital role on the climate, the ocean, the solid earth and the life of this planet. A new and powerful technique called the radio echo-sounding, which replaced the slow and cumbersome echo-sounding technique, is now extensively used not only to obtain the contour maps of Antarctica ice sheet but also the profile of the bed rock. Strangely, a number of lakes were discovered under the ice sheets of Antarctica, some of them more than 5 km wide. No one knows whether any life exists in these lakes as they are permanently burried under the sea. At best, they might be having minerals and gases.

The success of the Indian team under the leadership of S. Z. Dr. Qasim to land on Antarctic on 9th January, 1982 is a major landmark in Indian Oceanography. The team of meteorologists and geologists, geophysicists, communication and navigation experts has done a remarkable job in their 77 days expedition. This was the first exposure of the Indian scientists to the frozen continent and to carry out studies on rock magnetism, glaciology, meteorology and radio propagation. It also afforded an opportunity for geologists and geophysicists to make preliminary studies. The Indian team established an unmanned station appropriately named as "Dakshin Gangotry" for recording continuously the weather data. Right now, the second Indian Ocean expedition is already on its way and is likely to carry out in-depth studies for longer periods.

The last three decades is an epoch making period in the annals of the history of Earth Sciences,

as it witnessed revolutionary discoveries which led to a clear understanding of the origin and evolution of continents. A new field of study has just been opened up. This is the best opportunity for Indian geologists and geophysicists, to follow up the application of this theory to understand the Geology of our vast subcontinent particularly the technically unstable region along the junction of the Indian and Asian plate which was the seat of an ocean millions of years ago. They may endeavour to gain deeper insights to understand the driving mechanism of the plates, to refine the model and to investigate some of the side effects which will lead them to understand the process of erosion, rate of deposition and even the effect of climate in the past history of earth. May be such refined models of continental drift, paleoceanography and paleoclimatogy may provide important information guiding us in discovering rich deposits of hydrocarbons and major mineral deposits. An extrapolation of known resources available along continental margins could aid in search of mineral deposits along other continental margins which are yet to be explored.

UNDERWATER VEHICLES AND INSTRUMENTATION

To explore and exploit the rich resources of the ocean, it is not enough if we drop sophisticated scientific instruments, tools or cameras from the surface of vessels to acquire a wealth of data. However remarkable, these floating laboratories are like our Research vessel *"Gaveshini"*, there are many tasks which cannot be achieved unless man can go down into the ocean, however deep it may be and remain there at these great depths comfortably and travel long distances along the sea floor or collect mineral and biological samples for future studies in the laboratory and to carry out in *situ* studies of behavior of sea life in their natural habitat.

Japanese pearl divers are experts in deep sea diving and could remain for a long time underwater to collect oyster pearls. For well over a century, man have been able to work to a limited extent by having a divine suit and helmet connected by an air hose to the mothership. It is only after the development of Scuba (Self-contained underwater breathing apparatus), the aqualung that man could achieve complete independence from the mothership and greater mobility to explore the underwater world of the seas. This was made possible by designing a small compressed air cylinder on the back of the diver which feeds the proper amount of air regardless of his position. Soon Scuba diving become not only a popular sport for many amateur and professional divers, but also a key for exploring the underwater riches of the continental shelf. Scientists, particularly geologists, marine biologists and oceanographers learnt Scuba diving to gain first-hand knowledge of the undersea world. Mineral prospectors engaged Scuba divers for discovering new mineral deposits. Petroleum companies employed Scuba divers to repair offshore underwater oil wells. Scuba divers came in handy for many undersea exploits including salvage operations in ship wrecks. Remarkable and useful as the Scuba is, it has a serious drawback that, even at a depth of 100 feet man is subject to three times the atmospheric pressure and hence breathes three times as much oxygen leading to oxygen poisoning resulting in giddiness, nausea and convulsions. Remedy for this is to design a device that would regulate and control the intake of oxygen, whatever may be the ambient pressure. Krasberg, a young scientists from Harvard, developed an electronically controlled device.

Scuba diving has several handicaps when we have a deal with a detailed, prolonged study of underwater by a team of scientists. For extensive *in situ* studies involving more scientists, what is needed is a submersible vessel which can withstand the very high pressures at great depths and at the same time equipped well with the scientific instruments, cameras etc., for observation and recording. Although it was in late 1920, the American biologist, William Beebe who conceived the idea of penetrating the ocean depth, it was only during the last two decades that scientists and engineers started

designing and building varieties of modern submersible bathyscope vessels ranging from the Trieste I to the latest SEALAB series. Trieste was the brainchild of a Belgian scientist August Piccard. The voyage of Trieste to the bottom of the sea was considered a spectacular success. It has dispelled all doubts about the ability of man to reach the bottom of the ocean and even descend below the Abyssal planes to the bottom of the trenches. Under the leadership of Donald Walsh, Trisete made a historic voyage landing on the floor of Mariana Trench some 35,800 feet below the sea level. It was here, for the first time, new forms of life surviving on new forms of plankton unknown to mankind were discovered. In fact, it was with the help of Terieste that the dismembered remains of the first U. S. nuclear submarine Thrasher which sank on April 10, 1963 were discovered. For the first time it was demonstrated that, on the large ocean bed, small objects could be discovered by an equally small mobile submersible. One of the smaller deep-diving submersible Alvin could locate and retrieve the lost hydrogen bomb in 1965 of the coast of Spain.

Until the 19th century very crude methods were employed for measurement of the ocean depth. During the last few decades, in their efforts to probe deep into the sea and to tap their rich resources, oceanographers are employing a large variety of new and improved instruments. Almost all the sea-going vessels have invariably sonar systems which are used to measure the ocean depth, obtain the profile of the bottom of the sea in the form of charts showing the variation of the depth with distance. Sonar has undergone remarkable improvements using the modern techniques for signal processing for eliminating ambient sea noises in order to make it more sensitive and to extend the range of the instrument. Powerful sonars are even able to penetrate the sedimentary layer of the ocean bottom and delineate the structure of various layers above the hard rock. Sonar has been successfully used by geologists and geographers to map the bottom of the sea. During the world war, it has been used by worships to detect prowling enemy submarines. Submarines can communicate with each other through Sonar systems. In recent times, Sonar is extensively used for locating extensive fish shoals to help the fishing industry. Underwater sunken ships and oil rigs can be identified with good clarity using Sonar. Sonar has also been used select the route for laying under-sea cables for international communication and for fixing suitable location for construction of highways and tunnels under the sea-bed across narrow channels.

Among the techniques ocean scientists employ, seismic sounding is one of the most ingenuous and has been extensively used by oil prospectors for locating oil fields beneath the earth. Maurice Ewing who headed the famous Lamont-Doherty Geological Laboratory of Columbia University extended this technique to underwater exploration using two ships one to set off an explosive change in water to create a miniature earthquake-like wave which propagates horizontally in the bottom sediments and a second ship to receive and record the received signal. By measuring the arrival time of the sound pulse for different distances between the ships, it is possible to measure the thickness of the sediments on ocean floor. Seismic sounding has become a powerful tool not only to estimate the thickness but also to know composition of the sedimentary layers.

Underwater communication is an important area in which considerable work has yet to be carried out. There is a need for portable walkie-talkie for divers to communicate with each other using ultrasonic waves. Such portable devices have yet to be developed. Radio communication with submarines is another field which needs special attention from scientists and engineers. As sea water is a good conductor conventional radiowaves will get absorbed in the ocean and as such there is need for a powerful very low frequency (VLF) transmitter at frequencies below 10 Khz for underwater communication. Perhaps, some day scientists can control ionosphere at heights of 100 km and use it as natural antenna for communicating

with submarines by using extremely low frequency radio waves.

Under-sea photography has been in use for probing the sea nearly a century. During the last couple decades the Woodshole Oceanography Institution developed a technique for automatic underwater photography which reveals in minute detail and brilliant clarity the objects on the sea-floor. The major problem in underwater photography is to produce brilliant flashes of light which penetrate the thick dense muddy water on the bottom of the sea. This requires special illumination techniques for underwater photography. Both the underwater camera and television scan have been a great boon to modern biologists who could sit in their laboratories watch and study the behavior of fish in their natural habitat.

While all these techniques are of great value to observe understand the ocean and the life within it, scientists do need samples of the water and the earth and rock below the sea-bottom to analyse and understand the structure and composition in detail. For collecting water samples Nansen Bottle, named after the famous Arctic explorer Fridtz of Nansen, is used extensively. There are several varieties of coring devices used to collect the sample into a core pipe which bores through like a drill, cutting into the bottom of the ocean. Biologists collected sample of living creatures by many kinds of nets. Special devices like the Clark-bumpus sampler and Hardy Recorder were used to study the tiniest sea-creature, plants, microscopic plankton, etc. Such studies have been used to find out the riches of the sea food resources. A host of instruments such as magnetometers, gravimeters, subsurface current meters, bathythermographs, salinity meters and heat probes were developed to take measurements at great depths in the ocean.

Very recently scientists have developed a technique known as Ocean Acoustic Tomography, the basic principle of which was proposed in 1917 by the German mathematician Radon. This principle has been successfully used widely in medical diagnostics. The CAT (Computer Assisted Tomography) seen employing X-rays passing through any part of the body, especially brain, to form a three-dimensional image of ultrasound has been used successfully to give tomographic images of liver, kidneys etc. Motivated by a desire to study ocean currents, and following similar principal as CAT Scan,Walter Munk of Scripps Institute of Oceanography and Carl Wunch of Massachusetts Institute of Technology formulated the basic theory and design which crystallised as a practical measuring tool. This has now become an indispensable sophisticated instrument in the hands of the modern oceanographer and has been used in ocean current studies.

Development of marine instrumentation is still in its infancy in this country. In view of the need for specialized instrumentation for oil and mineral exploration, and for new research programes to be undertaken, there is an urgent need to encourage research and development and manufacture of modern sophisticated ocean instruments, if necessary, by adopting liberal and flexible policies.

PHYSICAL OCEANOGRAPHY

Having reviewed the structure and origin of the Ocean basins and the modern techniques designed and developed for exploration and scientific study of the ocean, it is appropriate to examine now some of the physical properties of the ocean and the part played by them in ocean currents, ocean energy, coastal erosion, marine life and marine ecosystem. The water wealth of the world is unevenly distributed with 97.3% in the ocean and the rest 2.7% on the land of which almost 85% is contributed by fresh water in glaciers and ice caps which are the largest fresh water resources on land. Undoubtedly, detailed studies of the spatial and temporal variations of the basic physical parameters, such as temperature, salinity, density, surface and physical parameters, such as a temperature, salinity, density surface and deep ocean currents will lead to a better understanding of the physical processes taking place at the interfaces between ocean water, ocean bottom, atmosphere and coastal land.

To the naked eye, it appears that only the surface of the ocean is distributed by waves and is in perpetual motion, but the fact of the matter is the mass of ocean water is far from being at rest. Indeed the gigantic mass of water in the ocean is in perpetual motion and constitutes a complex system with several physical and chemical variables changing rapidly in space and time. While ocean surface currents are mainly driven by wind at a surface, the origin of ocean currents at different depths can be traced to several sources such as rotation of earth, changes in position of moon and sun relative to earth, energy generated by solar radiation, and other additional sources of energy like earthquakes, tsunamies, volcanic eruptions, water and sediment transport from rivers etc.

The characteristic feature of the ocean is its high salinity which make it the richest source of numerous elements and minerals. Over millenia of years, ocean have accumulated salt from the land brought by rivers and became highly saline. Water is unique in the sense that it is a good solvent and as such many salts are present in it in a dissolved state. However, it is interesting to note that the relative concentrations of various salts remain surprisingly constant inspite of the systematic and rapid decrease of the total salinity with depth. The zone up to a depth of 500-1000 feet where there is a continuous decrease of salinity with depth is called halocline. Below this depth salinity remains practically constant. Estimates of salinity of seawater are make by chloride ion concentration which is easy to measure in the laboratory or on board ocean-going research vessels.

Salinity of the sea has a profound effect on physiology of marine organisms which depends on the nature of the biological members. By a process, known as osmosis the body fluid of the marine organism interacts with the saline water in the sea and attains an equilibrium, enabling the fish to survive the salt water environment. Unless adopted to the freshwater environment, salt water fish would not be able to survive in low salinity water or freshwater as it tends to inflate the animal with an inflow of freshwater in order to equalise the concentrations.

Sea surface receives enormous quantities of thermal energies of the sun which varies with latitude reaching maximum in the tropical waters. The average surface temperature variation with latitude shows that the sea in the northern hemisphere has generally higher surface temperatures than that in the southern hemisphere. This asymmetry is smaller in the northern hemisphere.

Oceans, constitute a huge reservoir for storing energy compared to the solid earth whose heat capacity is four times smaller. Consequently, the variation of temperature on the land is four times that on the sea. Examining the spectrum of light energy from the sun impinging on the ocean surface, it may be noted that most of the energy which is in the ocean. In particular, the amount of solar energy which penetrates below a depth of 100 metres is hardly one-fiftieth of the total incident energy. While the surface of the ocean absorbs and assimilates rapidly almost all the solar energy, but the mechanism of transfer of this heat into the depths of the ocean is relatively slow and complex. In fact, deep in the ocean, below a few metres depth, the diurnal variation of the temperature is relatively very small, unlike the relatively larger variation observed on the surface. Indeed, at depths below thousand metres, the temperature is of the order of 1–2°C, which is maintained through the deep ocean. Surprisingly the temperature at these depths even at the equator is largely determined by the water from the polar region which sinks and gets transported to the temperature and topical regions.

The surface of the sea is highly saline and hence has lesser surface tension which makes it easy for the formation of froth and foam when waves break up near the coast. The process of formation and breaking up of waves result in the formation of enormous quantities of foam and tiny droplets of water, containing dissolved salts and organic matter

from the surface of the surface of the sea. These are called aerosols. The wind and the general atmospheric circulating system carries the aerosols to high levels and disperses them till they condense into tiny crystalline ice particles. It is therefore obvious that rainfall in coastal areas contain substantial amount of sodium chloride.

One of the most interesting results of ocean science is the great abundance of carbon dioxide in the dissolved gases beneath the surface of the ocean, being nearly four times the concentration of nitrogen and nine times that of oxygen. Thus, even though, the atmosphere and ocean constantly interact with each other, strangely the composition of gases in the ocean is totally different from that in the atmosphere where nitrogen is four times oxygen and carbon dioxide is an insignificant minor constituent. Indeed, it is the predominance of carbon dioxide in the dissolved gases which explains the great abundance of biological life in the ocean as carbon dioxide is the most vital and essential ingredient for the growth of marine organisms. When this abundant quantity of carbon in the form of carbon dioxide in ocean waters is supplemented by a rich wealth of nutrients, and the entire volume is illuminated by radiation from the sun, marine plant life multiplies rapidly by photosynthesis and initiates the series of food chains leading to a rich harvest of higher forms of marine life. Oxygen, which is rich in the upper strata of the ocean is continuously depleted by marine organisms and as such the concentration reaches a minimum at a level where the biological life is in great abundance.

Man has always been fascinated by the innumerable variety of waves observed on ponds, streams and oceans. Little did we realise that all these waves have one common feature that they do not transport the water but only the energy. Atmospheric winds interacting with the surface of the ocean give rise to complex system of waves which propagate over long distances over the ocean surface with little loss of energy. Among the wide spectrum of waves thus generated, those with longer wavelengths travel faster and further than the shorter waves. Hence, the more complex and high amplitude waves generated in a thunderstorm arrive at the coast travelling several thousand of kilometers as a "swell" which contains mainly the long waves, the shorter ones having been dissipated on the ocean surface. Unfortunately, scientists have not yet unravelled the mechanism of the transfer of energy from the wind to the surface of the ocean and as such considerable theoretical and experimental works has yet to be done to be able to predict precisely the high of the "swell" which crosses the shore as a greater storm surge in a severe thunder storm or a cyclone causing collosal damage to life and property.

So far no reliable and simple method for measuring ocean wave heights was available particularly at large distances away from the coast. Recently, a new radio method of estimating the wave heights has been developed using high frequency radiowaves beamed towards the ocean surface from a high elevation on the coast. Such radiowaves reflected from the wave fronts reinforce each other to give a strong return signal when the wavelength of the radiowave is a multiple of half-wave length of the sea wave. One of the latest and improved versions of this technique, known as the sky-wave radar, enabled ocean scientists to send radiowaves bouned forward by the ionosphere to strike the ocean surface at a great distance of 2000-3000 km. These radio signals retrace their path and are received back after reflection from the ocean wavefronts with appreciable single strength at an appropriate frequency of the radiowave. The sky wave Radar has enormous potential is a powerful tool for scanning large areas of ocean at great distances and measure the ocean wavelengths. Indeed, this technique can also be used for measuring the wave heights in the cyclonic region on the ocean and send warning signals to be the lowlying coastal areas in case the wave heights are so high as to give rise to a devastating storm surge. Improved and sophisticated versions of this techinque could be used to detect and watch

movements of fleets of vessels which will be particularly valuable in defence applications.

Unlike the waves, which are purely surface phenomena, the wind on the surface also generates surface currents which involve literally the transport of ocean water unlike the waves. Ocean circulation is also influenced by the 24-hourly rotation of the earth and also by the gravitational pull of the sun and the moon. The Coriolis effect of the earth's rotation on the sub-surface currents in the ocean results in a clockwise deflection in the northern and anticlockwise in the southern hemispheres in the tropical zone.

While every one knows the difference between climate and weather very few, including scientists. realise that a similar distinction applies to ocean currents. As advanced techniques were not available till recently, we have known so far only the average features of the ocean movements which we may call "climate" circulation. With the modern techniques, it was shown that there is a fine structure superposed on this chlimate circulation which varies from day-to-day like the weather and which cannot be easily predicted. Synoptic charts of ocean currents are narrow, fast and winding, while the climatic maps are smooth, broad and slow. The later are used for long-term studies of the effect of ocean currents on coastal erosion and climatic conditons, whereas the synoptic maps are used to pilot ships and submarines to follow the currents to gain in speed. The current system in the ocean, like the wind system, tends to circulate and form gyres which follow generally the wind circulation. The theory of ocean circulation developed during last thirty years, explains reasonably well the experimental data. Model studies in the laboratory helped scientists to simulate the formation of currents like Gulf Stream in North Atlantic, Kuroshio in North Pacific and Agulhas in Indian Ocean. Some of the detailed studies on Gulf stream indicated that occasionally the main stream forms a smaller loop of a few hundred kilometers which breaks off and separates as an eddy and gradually weakens. The spectacular discovery involving sometimes transport of tens of millions of tons of water from North Atlantic to sub-tropical regions along with its living organisms is of considerable importance to the biology of the sea. Such eddies constituted the biggest natural transport of part of the ocean along with its marine organisms and econ-system. Another major finding is that the Gulf stream is not one single stream like a river but consists of 2–3 filaments each having its own speed of flow. It is like having three rivers in the ocean flowing at different speeds and carrying different volumes of water. The fine structure of the ocean weather is a new phenomenon which has no parallel in the atmospheric weather.

Deep sea circulation in the ocean is an important and interesting phenomenon. Basically the cold condensed water around the polar caps sinks downwards and propagates towards the lower latitudes along the ocean bottom. In fact, the cold and condensed water from the Antarctic flows towards the north and even crosses the equator to flow into the northern hemisphere. Such deep sea current systems are prominent in the Atlantic sea where they stretch from the north pole to south pole without being intercepted by any large land mass. On the other hand, the Pacific ocean is almost cut-off from the Arctic sea by North America and East Asia except for the narrow channel known as Bering Canal. This land mass acts as a barrier preventing the cold Arctic water moving southwards into the Pacific ocean.

One of the obvious effects of ocean currents noticed all along certain coastal areas is the erosion and accretion. Over years and perhaps over decades, we witness a continuous erosion of beaches on the shore as sea advances inland threatening the coastal towns. Such phenomena are noticed in many coastal towns like Visakhapatnam. A detailed study of the subsurface ocean currents with special reference to the speed, direction, volume of flow and diurnal and sessional changes may throw light on the origin and nature of ocean currents and their interaction with the coastal landmass. An in-depth study of these physical interactions by

oceanographers may ultimately lead to a solution to such problems of great national importance and result in the saving of valuable property, buildings, structures and even harbours along the coast. To cite an example, nearly half a centrury ago, engineers noticed rapid silting of the entrance channel of the natural at Visakhapatnam port and they were completely baffled by the gigantic problem of clearing the silt from the channel and the enoromous cost involved in the gigantic task. It was late Sir Mokshagundam Visweswarayya who gave an extremely simple solution to this problem by suggesting two condemned old ships to be sunk in the sea a little ahead of the entrance to the channel with a view to deflect and divert the current systems from entering the channel and blocking its passage with sand and silt. At a time when ocean currents and their behaviour was not well understood for want of data, it was the genius by Dr. Visweswarayya which found a practical solution thus saving crores of rupees of expenditure incurred on clearing almost continuously the harbour channel of the accumulating silt by special mechanised vessels.

OCEAN AND THE ATMOSPHERE

The climate of the earth is intimately connected to the ocean through the atmosphere which serves as the common canopy for both, thus transferring enormous quantities of water vapour, energy and momentum from the sea to the land. Extensive studies have been undertaken jointly by the meteorologists and oceanographers on the air-sea interaction with a view to improve our understanding of the world climatic conditions and even to make short-term weather forecasts. Such studies will ultimately enable scientists to predict climatic changes over longer periods thus enabling international organizations and different countries to face the challenge of disasters like droughts. Perhaps, the time is not far away when scientific studies over much longer periods will throw light on major climatic upheavals like ice ages.

It is now well-established that the ocean surface of 1 cm thickness known as surface micro-layer plays a crucial role in air-sea interaction. Detalied study of this layer is important in meteorology, agriculture and pollution. This micro-layer transfers not only energy and water vapour but also rich nutrients like nitrogen, phosphorous and potassium into the atmosphere. Oil spills and other pollutants over the ocean, concentrate in this micro-layer and finally enter into the food chain through marine organism which are eaten by the fish.

Ocean being a large reservoir of momentum and energy, the response of the ocean to inputs is much slower when compared to that in the atmosphere. Ocean is therefore referred to as the memory of the atmosphere. It is now generally accepted that the Somai current, flowing northwards along the coast of Kenya and Somali, initiates the summer monsoon one month later. Meteorologists and oceanographers have yet to unravel the cause for the delay. The Somali current however reverses and flows southward during northern winter. It is generally believed that the lowering of temperature over the Arabian Sea from 28° to 25°C resulting from Somali current triggers off the summer monsoon, as a significant correlation was observed between the drop in surface temperature of Arabian Sea and rainfall one month later during June-August period. A remarkable new observation by Sri Gilbert Walker revealed a world-wide southern oscillation, accompanied by high pressure over the Indian ocean associated with low pressure over Pacific and vice versa, the intensity changing from year to year markedly. This large global oscillation seemed to be linked with *El Nino*, a recurrent phenomenon involving replacement of cold upwelling nutrient rich current by hot tropical current off the coast of Peru, resulting in failure of normally bountiful fish harvest. It is not clear to what extent *El Nino* is related to the global oscillation, but it is certainly remarkable that the failure of monsoon in our country in 1972 coincided with the *El Nino* of 1972 indicating the possible connection between the two.

In any study of the ocean currents, one cannot ignore the complexity of the pattern of circulating currents which are widely varying from ocean to

ocean. It may be noted that the climate, marine organic life, coastal erosion and such other physical features are largely dependent on the surface currents as well as ocean bottom currents. A well-known example of surface current system is the Gulf Stream, which has its origin on the surface of warm tropical waters and converges along the Florida coast as a warm water current system. Proceeding further north, the Gulf Stream branches off into North Atlantic current along UK and western Europe and move southwards as Canary current along the coast of Spain and west Africa. It is well-known that the North Atlantic current which brings warm waters exerts considerable influence on the climate of western Europe, particularly Britain and Scandinavanian countries in the winter season. Oceans which are the giant reservoirs of water with all its rich biological and mineral wealth serve mankind by providing salubrious climate both in the hot tropical regions and cold north temperature zones by the massive transport of cold ocean bottom currents from poles to the equator and hot stream near the surface from equator to the poles. Indeed, nature has its own way of balancing the opposing forces and extremes of climate by a system of natural forces which tend to compensate extremities in climate. Let me express a word of caution that any attempt to disturb the natural ocean equilibrium by such grandiose schemes or projects proposed such as building a dam across the Bering strait to serve as a major source of energy, may lead to serious imbalances in the climate and ocean ecosystem.

One of the greatest challenges posed by the ocean is the devastating effects due to cyclones, storm surges and Tsunamis which have their origin in the ocean. Different parts of our country particularly adjoining the Bay of Bengal are devastated frequently by cyclones and consequent storm-surges at various locations on the sea coast. Similarly, every year all over the world hurricanes roaring Atlantic or Pacific Oceans invade the main land destroying life and property over extensive areas. The violent and whirling storms known as cyclones and hurricanes begin as a comparatively small storms at sea and gradually begin to grow to giant sizes of the order of 150 kms and move fast as roaring monsters. The world weather watch centres in various countries trace these events by recording and studying cloud pictures transmitted by weather satellites such as TIROS and NIMBUS. Thus cyclones and hurricanes brewing anywhere over the vast oceans are detected and early warning is given to all affeted countries. During the last two decades, cloud seeding attempts were also made successfully to precipitate the clouds in cyclones to minimize their fury. Much of the damage to coastal areas caused by cyclones is due to what is known as storm surges, giant waves which build up along shallow coastline areas to great height of 3–10 metres and moves like a wall of water inland devastating all life and property in its path. The worst storm surge struck the north coast of Bay of Bengal in 1970 killing 25,000 people. Recent Andhra cyclones in 1979 and 1981 involving storm surges of 3–4 meters, caused great havoc loss of life and property. All these storm surges were tracked by satellites, but timely warning could not be given to the affected areas.

Of all the ocean events the most destructive is the "Tsunami" (a Japanese word for harbor and wave) which is a giant wave of great height gernerated by an underwater earthquake. Tsunamis have caused great havoc in Japan and Hawaiin islands. Earthquakes associated with subduction zones on Pacific ocean floor make the incidence of Tsunamis highest there. Tsunami is a phantom at sea consisting of a giant wave, several miles long, which travels at great speeds of the order of 800 km per hour. Sailors in the ships and fishermen do not notice this even if it passes right under their sea craft. The destructive power of the Tsunamis is noted only when it reaches shallow water along the shore and travels inland as great wall of water 10-30 m high leaving death and destruction along its trail. Recorded evidence exists of Tsunamis of even 30 m travelling inland over several miles. Although seismic sounders give location of the epicentre of

the earthquake, this alone is not adequate. An ingenuous electronic wave-guage invented by Green was found to be extremely sensitive to detect changes in water level of 0.02 feet of water. A large network of such guages deployed near known Tsunami centres telemetres the data and warning signals to main control centres taking prompt action. Ionospheric physicists have also discovered a new technique for detecting and tracking the travelling ionospheric distrubances induced by the Tsunamis.

Far from the tropical seas Science has found a solution for another sea menace, namely, the large icebergs drifting slowly along shipping lanes causing disaster as it happened to *Titanic* on its maiden voyage in 1971. It is estimated that almost 7500 sizable iceberge breakoff, from Arctic glaciers along the coast of Greenland and start their menacing voyage down south. Today, International Ice Patrol keeps track of icebergs by Radar and dyeing it to watch its progress. Satellite imagery is also used to detect icebergs particularly during dense fog.

In any study of the ocean-atmosphere interaction, we can not ignore the role of carbon dioxide and its short and long range effects on the global climate. The total carbon dioxide in the earth's present atmosphere is 2300 billion tons which is 0.03 percent of its total mass. However, this quantity is also dependent on the amount of carbon dioxide withdrawn or supplied from the oceans, rocks and living organisms. The total carbon dioxide in the ocean is fifty times as much as in the air, but most of it is present in carbonate compounds. Being a rich reservoir, ocean acts as a damper for the fluctuations of carbon dioxide in air. When atmospheric concentration of carbon dioxide increases ocean tends to absorb the excess. When it falls, the ocean replenishes it. Also volcanoes in the ocean replenish it with more carbon dioxide whereas weathering of the rocks depletes it.

It may be of interest of note that ocean comes to the rescue of the atmosphere whenever there is an imbalance in carbon dioxide. In the last 620,000 years of current glaciation period, about ten distinct temperature cycles were observed in ocean sediments which can be explained on the basis of carbon dioxide exchange between ocean and air. If there is a lush growth of vegetation on land taking up large quantities of carbon dioxide, after sometime equilibrium with the ocean reduces the atmospheric concentration to nearly half its original value and the average temperature or earth falls by 6.9°F. This drop will cause glaciers to spread and oceans to shrink, resulting in slow release of the excess carbon dioxide from the ocean into the atmosphere. This will again raise the temperature and restore the carbon dioxide in the atmosphere to the original value. So long as the atmospheric carbon dioxide in the ocean–atomosphere system remains unaltered, these cycles repeat producing the well-established temperature cycles.

During the past century, activities of man involving burning of fossil fuels has seriously disturbed the carbon dioxide equilibrium of the earth. Annually six billion tons of carbon dioxide is added to the atmosphere by the fossil fuels and another 2 billion tons by agricultural operations. The eight billion tons increase in the carbon dioxide contributes to a large increase in plant life and is also partly absorbed by the oceans. Theoretical studies indicate that the carbon dioxide dissolved in the ocean establishes equilibrium with the carbon dioxide in the atmosphere in approximately 1000 years. During this long preiod oceans take up only half of the carbon dioxide added to the air. Over much longer period oceans can take up much larger additional quantities of carbon dioxide in the form of carbonate compounds before the ocean-air system attains equilibrium.

Estimates of the fossil fuels consumed in the world each year show that in the past 100 years man has added 360 billion tons of carbon dioxide to the atmosphere resulting in 13% increase in carbon dioxide to the atmosphere. Such an increase should raise the average temperatue of the earth by 1% F. This is exactly the average increase recorded all over the world during the past century. Extrapolating these figures to the year 2000 A.D.

the average temperature of the earth should raise by 3.6% F. If the consumption continues to increase at the current rate for another thousand years we would have exhausted all our known reserves of coal and oils and the carbon dioxide in the atmosphere would have increased 18 times. However, after ocean-atmosphere system attains equilibrium, there will be ten times carbon dioxide than it is today resulting in the earth being 22° warmer than at present. Such a large addition of carbon dioxide to the ocean will undoubtedly increase the acidity and pH of sea water. This may not disturb the future marine life, but certainly for man it will be most uncomfortable to live on this planet. During the next half a century, it should be possible to test conclusively the theories of climatic change and take remedial action if mankind has to survive the onslaught of this ecological crisis.

There are several international co-ordinated research programmes such as International Geophysical (IGY), International Quiet Sun Year (IQSY), Middle Atmosphere Programe (MAP), Global Atmospheric Research Programme (GARP) and Garp Atlantic Tropical Experiment (GATE) which undertook world-wide experimental programmes involving ocean-atmospheric interaction with world-wide coverage. The recent monsoon experiment (MONEX) in the Indian ocean involving participation by several countries succeeded in obtaining a vast wealth of data which is awaiting deatiled analysis and study. In most of these International coordinated experiments, besides research vessels which are fully equipped with modern scientific equipment, aircraft were also used increasingly to collect data at a faster rate.

CHEMISTRY OF THE OCEANS

The ocean as a chemical system is very complex as it has a very large number of chemicals in the form of salts. Cheimcal oceanographers have been studying the various chemical reactions with a view to understand and exploit these rich resources. In spite of the large number of elements and salts present, one of the important principles in chemical oceanography known as Forchammer's Law of Relative proportions establishes that ratio of all the major elements in the ocean remain same, irrespective of where the sample is collected from the sea. In recent times, chemical oceanographers are paying considerable attention to investigate ocean pollution with special reference to the levels of pollution, their origin and remedial measures.

At the outset, it will be relevant to outline briefly the techniques employed by chemical oceanographers. Most of the studies made by chemical oceanographers were carried out on sea water samples collected by the Nansen Bottle which has special valves at either end and contains themometres to record the temperature at which the sample is collected. Samples thus collected are analysed for their chemical composition in the laboratory in order to understand the chemistry of ocean waters. Chemists now-a-days use sophisticated instruments such as atomic absorption spectographs for measuring gaseous and organic content and amino acid analysers to detect and measure protein content. Currently chemical oceanographers have been able to use extensively radioactive isotopes to estimate the rate of deposition of marine sediments.

96.6% sea water is pure water and only the remaining 3.4% contains dissolved salts. The bulk of dissolved salts in sea water consist of six major elements—chlorine, sodium, magnesium, sulphur, calcium and potassium. Seawater contains also other elements in minute quantities, the levels of concentration being 1–100 parts per million. Strontium, bromine, boron, iron and silicon are some of the minor elements present in sea water. Trace elements of less than one part per million are controlled significantly by biological activity. A remarkable property of marine organisms is their ability to attract, absorb and assimilate many of the trace elements in the sea-waters. For example, plankton absorb several trace elements. Some varieties of sopnges have the ability to concentrate nickel in their body.

Elements, such as carbon, oxygen, nitrogen and phosphorus are indeed essential for the survival and growth of living organisms as they form the basic nutrient elements. In fact, these elements are available in the form of compounds such as bicarbonates, phosphates and nitrates dissolved in water. At shallow depths, where there is abundant light, the basic elements carbon, nitrogen and phosphorus are removed from these compounds by photosynthesis. In very deep waters, where the amount of light available is negligible, the bacterial activity comes into play to destroy organic matter which is brought back into ionic sea water. In this way, there is a closed cycle of photosynthetic activity, followed by bacterial degradation which essentially maintains the basic ingredient for the survival of life in the ocean. No wonder, the organic matter in the ocean has low concentrations at the surface and increases with depth.

In view of the continuous contact of the atmosphere with the sea surface, sea water contains several gases, especially oxygen, carbon dioxide, nitrogen and noble gases such as argon, helium, neon and radon. Near volcanoes under the sea, hydrogen sulphide is present in abundance. Oxygen dissolved in sea water is made available chemically by photosynthesis of plants in water at or near the surface. Oxygen is also consumed rapidly for the decomposition of organic wastes, plants and animal life that tends to sink to the sea floor. Ocean is the richest source of oxygen for replenishing the atmosphere. On the other hand, nitrogen in the sea plays a vital role as it helps to synthesise complex protein molecules which are vital for the growth and reproduction of all organisms. Marine organisms also excrete complex nitrogen compounds which eventually decompose under the action of bacteria into simpler chemical compounds. Of all the dissolved gases in the ocean, carbon dioxide plays a very prominent role in the sustenance of life in the ocean. The oceans contain 130 trillion tons of carbon dioxide, of which only a small fraction is dissolved in sea waters, the rest being present in the form of lime stone, lime sediments, etc. There is a continuous exchange of carbon dioxide between the atmosphere and the oceans at the air-sea boundary. Living organisms in the oceans need enormous quantities of carbon dioxide of their survival and growth. It was estimated that annually about 200 billion tons of carbon dioxide is extracted from the atmosphere by the oceans. It is well-known that carbon dioxide is continuously absorbed by the plants in the sea in photosynthesis, while its concentration increases by exchange with the atmosphere and gases released from the volcanoes. While, no doubt 100 million tons of carbon dioxide is depleted from the ocean by the formation of fossil fuels, this is a very small fraction (0.2%) of the annual production of carbon by photo-synthesis. Scientists have estimated that several hundred million years ago, extensive deposits of oil and coal were formed in the ocean which depleted thousand trillion tons of carbon dioxide from the atmosphere-ocean system.

A new branch of study called the Isotope Oceanography has come to the forefront in recent times. Using radioactive elements such as C 14 as a radioactive tracer, oceanographers developed an interesting method of determining the rate of deep sea circulation. Ocean circulation studies have thus become possible by using C 14 as radioactive tracer to estimate the time of traverse. By following such techniques it was found that water at the bottom of the Antarctic which is very cold has taken nearly 600 years to complete this journey from 60° South latitude to 30° North latitude. Similarly studies have indicated that the average speed at deep waters as Pacific is very smalll and is of the order of 1.8 meters per hour which is comparatively a very slow speed.

In ocean waters, the distribution of isotopes varies widely depending on the depth and the latitude. To illustrate this, we shall consider the concentration of deuterium which is an isotope of hydrogen and is present as heavy water in the sea. In the equatorial region, where the surface temperature are higher, the rate of evaporation of

water from the surface is more. The heavy water, being slightly heavier than normal water, there is greater evaporation of normal water on the surface in the equatoral regions. This results in enrichment of heavy water in the surface. Comparatively, the temperature and polar regions are poorer in heavy water. There is similar accumulation on concentration of an isotope of Oxygen (O^{18}), relative to (O^{16}). Indeed the ratio (O^{18}/O^{16}) in ancient sediments in pre-historic ages could be used to study the fluctuation of temperature during the last three hundred thousand years.

One of the most successful applications of radioactive isotopes is in the age-determination of deep sea sediments and also of the rate of sedimentation. In this estimation of the deep sea sediments, isotopes such as proactinum (Pa^{231}) and lonium (Th^{230}) are used.

LIFE IN THE OCEAN

The *Beagle* expedition of Charles Darwin and the *Challenger* expedition in the late 19th century were historic expeditions to collect thousands of marine organisms. Based on these fabulous collections a systematic description and classification of marine plant and animal life was made. In the past, marine biologists were largely interested in taxonomic studies, but, of late, they turned their attention to an in-depth study of the marine organisms, their biology and behaviour.

The Marine environment can be broadly divided into two principal regions—pelagic and benthic. Those fish which emerge occasionally on the surface are called Pelagic fish and those which live in the deep sea are called Demerish fish. The Benthic region is divided into littoral, bathyl, abyssal and hadal zones. The littoral region covers the coastal environment from the shore up to a water depth of about 200 meters. The rest of the huge mass of the ocean is divided into three horizontal zones, the bathyl from 200 m to 2000 m the abyssal from 2000 to 6000 m and hadal below 6000 m to even the bottom of deep trenches. In general the population of marine organisms decreases with depth with practically very few carnivores in the hadal region where sunlight cannot penetrate. Strangely carnivores in this region survive on dead organisms sinking to the bottom and oxygen and nutrients brought from great distances by deep-ocean currents.

One method of classification of marine organisms is based on locomotion and habitat :

1. Plankton
2. Benthos
3. Nekton.

The first group the plankton are floaters or wanderers and have no means of locomotion or self-propulsion. Usually they are carried by the ocean current system. In terms of numbers, the Plankton constitute the major population of marine organisms. Plankton generally live in shallow waters absorbing sunlight and mineral nutrients. With the exception of jelly fish and brown algae, plankton are usually microscopic organisms. Planktons, are broadly classified into Phytoplankton and Zooplankton. The phytoplankton which include microscopic diatoms, live generally in cooler waters and contain a lot of silicon dioxide. Where there is a dense population of phytoplankton in the ocean, the ocean, appears slimy and large quantities of calcium carbonate is deposited. Plankton multiply at a phenomenal rate of 10–1000 million tones per day even in a small sea like the Sargasso Sea.

Zooplankton being a much more evolved species are larger and are more complex in structure, feeding habits and behaviour than Phytoplankton. They have a remarkable ability to adopt themselves to different environmental conditions of temperature, salinity, currents, illumination and nutrients. Leaving aside the microscopic varieties, there are two major groups called copepods (0.3–10 mm) and crustaceans which are larger and are commonly known as krills (up to 50 mm). The latter serve as food for certain species of whales.

There are three varieties of bottom dwelling organisms (Benthos) : Sessile, creeping and

burrowing. All varieties of sea weeds belong to the first category. Corals, barnacles and oysters which attach themselves to some objects belong to this class. The commonly known crabs, lobsters and snails are creeping variety whereas clams and worms are burrowing type of benthos. All the evolved species of fish, small and big including dolphins, porpoises and whales are Nektons.

One of the earliest classifications of sea life was that due to a Swedish naturalist, Corolus Linnaeus, who evolved a remarkable new scheme of classification of animals and plants, based on similarities of structure which is well established and known to all students of Biology.

The most abundant of the ocean plant life is the primitive form known as algae which generally survive near the surface in ocean waters. Except for one variety of plant called eelgrass, ocean has no advanced form of plant life. Blue-green algae observed in the Indian Ocean are rich in nutrients and have been successfully used not only in extracting chemicals but also in enriching soil fertility by agricultural scientists working in Indian Agricultural Research Institute. Green algae usually confined to shallow waters are responsible for rich limestone deposits in ocean. Red algae occur in varieties of beautiful shapes and colours and is used as the raw material for extracting agar-agar, a substance used in food industry particularly for jellies and ice creams. Of all the algae, the most advanced is brown algae, familiarly known as kelp which settles down on the sea floor in shallow waters. It is one of the richest sources for iodine and phosphorus.

Diatoms are well known unicellular algae protected by bivalved silica shells having a glassy appearance and innumerable perforations through which they absorb gases and nutrients. The silica box contains chloroplast pigments that absorb the sunlight to convert carbon dioxide and water to organic matter. Diatoms, which are asexual, multiply at a fast rate by cell division. There is a continuous division followed by progressive growth in a healthy environment. Interestingly their life is short and millions of them sink to the bottom, consolidate in due course to give diatom ooze which is a useful natural filtering material.

Animal life in the sea is very varied and diversified than plants in terms of shape, size, form and weight. They also live at different depths in the ocean. Strangely, some species of marine animals can survive at great depths where there is total darkness. The variety of animal species in the ocean is indeed staggering as the total number of 25,000 species range from the extremely small microscopic animals like sarcodina to the giant size whales. I shall not attempt to describe such a large and diverse range of animal species in the ocean. However, I would briefly refer to the crucial role of bacteria which is one of the earliest forms of life known at dawn of evolution of the earth and play a crucial role in marine ecology not only because of its ability to adapt and survive but also because of its capacity of bring about chemical and physical transformations in oceans and in deep sea sediments. Perpahs, bacteria are the oldest organisms which are most extensively distributed all over the world. It is one of nature's greatest wonders that bacteria can survive even at the deep sea floor where the pressure goes up to thousands of atmospheres. Perhaps, the key to the understanding of the oil wealth in deep sea sediments lies in studying the role of bacteria in the formation of petroleum. They can do wonders like producing petrol, limestone, silicate rock and even iron deposits. Mankind's future perhaps will be mainly dependent on the understanding and successful utilisation of bacteria in the various development needs.

Recorded evidence of unusual sonar observations during last war of unidentified layers at sea bottom moving up during day and down during night, could be now interpreted by scientists as due to huge shoals of small fish and crustaceans etc. Which move up and down seeking light at the lowest limit of penetration of sunlight penetrating this layer by using submersibles like Alvin, marine

scientists discovered new forms of marine life some carrying their own headlights and some having luminescent organs. Thus, in deep sea, we find many fish which have the capacity for self-illumination.

In recent years, several expeditions of marine scientists exploring the deep V-shaped valley of Mid-Atlantic Ridge, East-Pacific Ridge and Galapagos Rift, led to the discovery of many new forms of marine life surviving in the dark depths of the ocean by a totally new biological process unknown to man. Setting foot on these unexplored hot volcanic surfaces for the first time, marine biologists discovered sea life similar to clams, crabs, mussels and unusually long carnivorous tube-worms which constitute an entirely new system of life perhaps belonging to a new Phylum. In the warm waters above the ridge hydrogen sulphide gas released from the volcanic rocked supports an entirely new species of bacteria which evolve and multiply by a process called chemosynthesis process totally different from photosynthesis. The higher forms of sea life is evolved by a food chain which starts from this new species of microscopic bacteria. Although, there were speculations on the existence of such new forms of life in other planets having a totally different atmosphere, such a possibility is not even predicted as a possibility on the face of this planet. The "Oasis"expedition in April–May, 1982, on the East-Pacific ridge off the coast Baja—California, gave ample opportunities to scientists from USA, France and Mexico to extend these investigations and discover many more such new species of marine life.

BIOLOGICAL RESOURCES

It may be recapitulated that the earth which has been so lavishly gifted with the most precious natural resources is finding it difficult to support even the existing population, while the world population continues to grow and is likely to touch a staggering figure of 11 billion by the year 2100 as estimated by the United Nations. Moreover, the people of developed societies have exploited some of the natural resources so indiscriminately that they are on the verge of being completely depleted.

In such a situtation, can the sea help mankind for its biological survival and provide him the life's essentials so that he can lead a full and rewarding life. From this standpoint, the importance of ocean in providing food and protein can hardly be over-estimated. If, with the application of Science the Technology we could usher in an era of green revolution and slove the food problem to a great extent in the Indian context, why can't we harness the potential biological resources of the sea, perhaps with less financial power inputs but with careful planning, for providing rich food to millions of people who are still living below the poverty line. Let us not forget that fish protein has a favourable balance of amino acids and as such is well-suited for human diet.

In analysis of the food problem of the human race, one should not overlook the fundamental fact that over three-fourths of human settlements are along the banks of the rivers or the coastline of the ocean. Yet it could not harness adequately the ocean resources for its food purposes. It is estimated that oceans are contributing only to three percent of the world's food consumption. Fish form an important constituent of our food, rich in protein and we have known the art of catching fish from times immemoral. However, even with all the advances in methods of locating, harvesting and catching of fish, fish contribute hardly to 10% of protein to our diet. The remarkable feature of fishery resources in that they are renewable, available in abundance and are easily accessible in that part of the sea in continetial shelf and other shallow waters which occupies only 8% of the total oceanic area. Available data of fish harvest indicate that approximately three-fourths of the world's fish catch come from the continental shelf. In addition, twenty-four percent of total fish catch comes from narrow select regions off the coast where the phenomenon of coastal upwelling is found. Coastal upwelling is a major contributing factor for bountiful

harvest of fish, but occasionally events like *El Nino* lead to the failure of fish harvest. The Somali Cold current upwelling, off the north-east coast of Africa, has similar effect of bountiful harvest occasionally punctuated by a sharp fall. It is striking to note that recent experimental studies have established that, by pumping nutrient-rich cold deep water to the surface, an artificial upwelling can be created for intensifying the fish productivity. By using such new scientific techniques, recurrent failure of fish harvest in the well-known upwelling areas could easily be avoided or mitigated.

There is a Chinese proverb which says : "If you give a person a fish a day, you are giving him a meal for the day, but if you teach him how to fish, you provide him meals for the rest of his life". This clearly underlines the significance of the art of fish farming for intensifying the productivity of fish. The singular factor involving fish farming relates of the identification of their locational aspect. The oceans are endowed with about twenty-five thousand varieties of fish and their number is estimated to be several billions. A number of studies conducted on the different varieties of fish in the context of the following variables : movement feeding and spawning habits and their response to the stimulus by various electrical currents and sound waves, have revealed that it is possible to develop scientific techniques and devices for havresting them. While developing the scientific methods and tools for fish harvesting, we must consider the parameter of cost-benefit analysis and ensure the conservation and maintenance of our ecosystems. The sound produced by each species in the ocean, if scientifically understood and perfected could perhaps become one of the major variable in the process of identification of the fish zones. Scientists have discovered that sea is literally filled with sound produced by the wide variety of marine species. Experiments in marine laboratories established that almost 80–90% of marine fish produce detectable sounds in many ways which can be deciphered in order to understand the language of the fish. When scientists succeed in understanding these sounds produced by each species, he can put this knowledge to use in order to attract or drive the fish into fishing boats.

Modern Science had developed special techniques using sonars fitted to fishing trawlers for detecting large shoals of fish to collect a big haul. According to a well-known observation some varieties of fish will swim along a course of strong currents and are irresistibly drawn towards the current electrode. Fish generally tend to follow warm water currents and as such infra-red detectors could be used as a handy tool for indicating the path of fish shoals. In future, it may be possible to use satellites from outer space for locating the fish concentration in the sea. Researches carried out in the Woods Hole Oceanographic Institution revealed that a variety of sounds could be employed during the fish catching operations. Say, for example, the sounds which frighten fish especially of predators can drive whole shoals of fish towards fishing craft awaiting with their nets. Chemicals could also be used successfully to guide salmon fish to their spawning grounds in a river. Fish are found to be allergic to air bubbles and this device was used successfully by many oceanographers to keep millions of fish in confinement with the aid of an artificial closed curtain of air bubbles. Such air bubble enclosures could be formed even on high seas by floating platforms off the shore.

Scientists, using ultrasonic signals sent through underwater sources, have succeeded in establishing communication process with the porpoises, dolphins and even whales. This device has proved to be immensely useful in the fish catching operations. It is well-known that dolphins were trained to help in rescue missions to transport tools to divers at work under sea. Porpoises have been successfully trained to do acrobatics better than man. Although scientists have not get perfected such high level training to command the services of these mammals, there is great scope for research work in this field. Futurologists are speculating on the enoromous future potential of ocean ranching of fish of 200-

300 species, which are presently caught for food, by using dolphins as "aqua-cowboys" to herd shoals of fish to fertile grazing grounds in the same manner as well-trained dogs were used on land-based ranches. There are enough evidences to indicate that man has yet to learn the scientific methods and devices for harvesting the fish in a healthy fashion. Any attempt on our part to over-exploit them would be likely to endanger the reproduction and ecology of fish species. In such a situation, it is necessary to explore and employ appropriate technologies which are ecologically oriented to maximizing the fish-farming.

There is another dimension to the problem which should not be overlooked in the developmental process of fish-farming. The problem stems from the fact that the mortality rate of fish is highest in any living species. To take an example, the survival rate of fish from the moment of spawning till they reach the size of 2″ in the case of mackerel fish is as 4 in a million. This extraordinarily high mortality is due to the lack of protection from predators, incidence of disease, non-availability of food and inclement weather on the high seas.

Of all the countries in the world, Japan is the most advanced country in the matter of modernized fish-farming. It would be appropriate to look at briefly the mariculture, which has been defined as a technique of cultivation of sea life in confinement protected from predators and inclement weather. The Japanese and Chinese have used this technique for cultivating pearl oysters over several centuries. Mariculture has also been employed extensively to cultivate mussels, scalps, shrimp and a small number of fish including carp, salmon, trout, catfish, tuna and others. In spite of the new technology, mariculture has not been adopted widely all over the world. The total worldwide mariculture production is only two million tons which is 4% of the total world catch. In recent years, the Central Fishery Research Institute at Cochin and the Central Institute of Fisheries education at Bombay have successfully reared prawns in salt water tanks. In Australia, oysters are grown on wooden sticks. In Spain, the mussels are reared on ropes which are hooked and lowered in to the water. It is Interesting to note that given the same kind of care and planning a brackish pond yields three times as large a yield as an acre of land in agriculture.

In all fishing operations, there are innumerable varieties of trash fish (50%) which are thrown as useless although they are edible. Scientists have developed a method of making this trash fish into fish protein concentrate (F.P.C.) which is the hope for the protein-hungry world. This concentrate could be in the form of colourless and odourless white power-like wheat flour and can be produced at a cost of almost one rupee per pound.

In a world faced with a shortage of 20 million tons of protein, it is possible to produce large surplus of vital protein which is twenty times the present yield by application of scientific methods. The world's resources of smaller and larger fish will be approximately 200 million tons. It was estimated that at the end of the last world war, the world's annual catch was 20 million tons which increased to nearly 70 million tons by 1970. Thereafter the increase had been gradual. According to UN indicative world plan the annual fish catch by 1985 could be 100–200 million tons. However, the exploitation of fishery resources of our oceans, without taking care of their replenishment should not be overlooked. The artificial hormone treatment and other methods of fish spawning and pisciculture are imperative not merely for the steady supply of fish food but also for the maintenance of a natural equilibrium in the ecosystem.

The most important fishing areas of the world are North American waters, North Sea between UK and Europe, South American waters, Indian Ocean and East Asian waters. Of these Waddel sea in Scandinavian region, waters off the coasts of Peru and Chile and parts of the Indian ocean are extremely rich in fishery wealth. East Asian waters are the most intensively fished in the world. The proportionate fish catch in various oceans of the

world was : Pacific Ocean 53%, Atlantic Ocean 40%, Indian Ocean 5% and Mediterranean 2%. Thus, within the total world catch, the major Oceans Pacific and Atlantic together contribute 93% Although, fortunately, India has a large coastline, the total production of fish in 1981 was only 2.4 million tons of which 1.4 million tons is from the sea and 1.0 million tons is from inland waters. Our export earnings for the same year is around 290 crores for 75,000 tons of fish exported.

Seaweeds which are generally considered a nuisance could offer a solution for the hungry millions as an alternative for food because of their high nutritional value. Seaweeds could be used in a variety of ways for food, pharmaceuticals, textile purposes. For example, Algin, Carrageenin and agar are three major substances which are extracted from seaweed and are used in a variety of ways in food preparation, such as icecream, malted milk, cheese, chocolates, puddings and salad dressing such as mayonnaise. Apart from these, there are many other varieties of seaweeds which can be used as food, fertiliser and even biomass. At present, the cost of harvesting and processing seaweeds is high but scientists could find out ways and means to cut down the cost and increase the availability of seaweeds. The future of seaweed farming is very bright. Japanese scientists have successfully pioneered sea-weed cultivation extensively using simple designs and could harvest as many as six crops per year.

It is estimated that the total annual yield of seaweed in the country is 50,000 tons and may reach one lakh tons if all the seaweed resources along the coastline are explored and utilised. Considerable work has been done on seaweed in the Central Salt and Marine Chemical Research Institute and Central Marine Fisheries Research Institute and National Institute of Oceanography and Andhra University on various aspects of economically useful seaweeds. Scientists in our country should take up urgently development of fast-growing, high-yielding and protein rich varieties of seaweeds suitable for aquaculture. Efforts should be made to prevent pollution of low-lying seaweed growing areas. Seaweed industry should be encouraged and be treated as a part of rural development programme for poor people living along the coast.

Apart from the sewweeds, there is a far richer source of seafood namely plankton, the microscopic plants and animals that abound in sea water in millions turning it into a rich nutritious soup. There are two varieties of plankton—phyto plankton and zooplankton. The most numerous type of this zooplankton are called copepods. The wide diversity of animal life among the zooplankton is staggering, as such a diversity is not seen in any realm of life. They are enormous in their numbers. The total number of copepods in the world in much more than all multi-celled creatures combined, including insects. These copepods feed on phytoplankton which is the first food chain of the sea. The next chain is created when small fish eat the zooplankton. The final food chain is the one in which larger fish like tuna, shark etc. consume smaller fish. There is a colossal loss of food almost 90% at each stage with, the result a thousand pounds of diatoms will ultimately lead to 1/10 pound of tuna.

Detailed and quantitative study of the data in each stage is useful in estimating regional and global food resources. Scientists are now deeply concerned about cutting short these heavy losses in the food chain by evolving methods of directly turning the plankton into food so that the vorld's food supplies may be considerably enhanced and utilised for the grossly over-populated world of today. This involves extensive studies in the laboratory to convert the plankton powder to hamburger-like meat, which may be very tasty. At the present stage of progress in plankton-food technology, the cost of such products is high mainly due to high cost of filtering plankton from sea water. To illustrate, it would be necessary to filter about 15 million tons of water to get 50 tons of plankton which is not a cost-effective process.

Scientists are trying to tackle this problem following nature's own system of filtering as it exists, for instance, the blue whale which needs a million calories a day, all of which comes from plankton which she picks up as it moves through the water. Perhaps by the end of the decade techniques will be developed and perfected to collect a steady stream of plankton as the ships move along on high seas. By the end of this century, hopefully, scientists will be able to perfect these techniques to make plankton the greatest addition to world's food supply for man as it is estimated that the mass of phytoplankton in the ocean is approximately 0.2 million billion tons which is the largest quantity of living species in the ocean.

A remarkable feature of the living species in the ocean is the vast diversity in the nature of species and the wide range of size, from the microscropic phytoplankton to the giant whale. Whales are sea-mammals widely differing in size, shape, structure and weight. There are about 90 different species of whales in the ocean and the adjoining seas. Known as the largest animal, the size of the whales vary from 2 to 35 metres and weight from 1 to 120 tons. While, on the one hand, killer whales are the most dreaded marine animals, majority of whales are vlunerable and harmless because of their slow movements. During the last few decades man began hunting whales as a source of edible oils and fats for his personal gain. The ruthless exploitations and greedy destruction of the whales for selfish ends by whale hunters has led to a rapid depletion of these species. There has been a growing concern about this rapid depletion of these species. These has been a growing concern about this rapid depletion of certain whale species and near extinction of eight species of whales which led to a world-wide awakening among the nature conservation and it has become a world-wide ecological concern of mankind. The United Nation's Conference on Human Environment held in Stockholm in 1972, unanimously recommended a ten-year moratorium in world whale hunting. With the emergence of a world-wide consciousness and international controls many countries have stopped all whaling activities.

A similar situation holds good for porpoises and turtles which are facing ruthless exploitation. As such, stringent measures must be taken against the complete elimination of these species. Large scale use of crocodile skin industry has also attracted attention and steps must be taken for artificial rearing.

In any analysis of the ocean biological resources and their development, we should not overlook that, apart from the source of food, the oceans can become rich repositories of our pharmaceutical industry. Considering the significance of oceanic resources for the pharmacological purposes a good deal of investment is being made by the national and international governments. Indeed the marine pharmacology is emerging as an important area of ocean science. Several marine organisms and plants have been used for medical purposes from times immemorial, According to ancient history, water crabs properly treated were used as antidotes for most poisons. Chinese have used sea weeds for treatment of throat diseases. Modern pharmacologists are currently investigating many marine organisms for pharmacological studies. Sea-cucumber is known to be capable of freezing nerves without damaging them and the extract from this is an indispensable toxin for post-operative treatment Barnacles possess a cement which is used as dental glue because it is water-proof and strong. The venon produced by man-of-war fish is used or preventing heart attacks. Certain varieties of horse-shoe crabs, one of the endangered species at present restricted to eastern part of Bay of Bengal, contains a unique substance called lysate which has enormous medical applications, as it serves as an index for the bacterial endotoxin in vaccines and serums. A remarkable observation that sharks can withstand more brain damage and are also immune to cancer may pave the way for discovering a drug to fight this deadly disease. Detailed scientific investigations must be undertaken or marine pharmacology in

various universities and national laboratories to discover new drugs which will be of paramount importance to the health of our people.

PHYSICAL RESOURCES

In any analysis of the rich resources of the oceans of the world, one is struck by the vast renewable biological wealth, but it is striking to note that the physical resources of the oceans are equally staggering. No doubt the majority of the physical resources barring energy of the waves, wind tide and temperature are non-renewable and as such this would call for a planned and cautious approach in exploiting them. The vast mineral wealth in ocean sediments and ocean basins is indeed enormous but the most valuable mobile ore of the oceans is the vast volume of water holding enoromous quantities of salt, chemicals and gases. Oceans hold 350 millions of cubic miles of water. Each cubic mile of sea water weighing 4.7 billion tons contains 165 million tons of dissolved solids of which common salt is the most abundant, followed by magnesium, calcium, potassium and bromine. Oceans, as a whole have vast mineral resources to the extent of 50 million billions tons. Besides, the sea floor is covered by manganese nodules which are awaiting to be exploited. The last few decades witnessed phenomenal progress in the exploration and exploitation of oil and natural gas. As more and more of the land resources are getting depleted, greater attention is now paid to extracting of several scarce elements and chemicals from sea water and mining of minerals in the manganese nodules on the sea floor and mines at different depths in the sediments of the sea floor.

In a world, facing serious shortage of petroleum for its various developmental needs, it is necessary to look for new sources of petroleum using modern geological and geophysical techniques. It is now well-established that organic matter subjected to high pressure and chemical actions is responsible for the formation of petroleum and other gas products. Scientists have not yet unravelled the mechanism of the formation of petroleum, but an approximate estimate indicates that it takes nearly million years or so to form petroleum from such organic matter. Geological and geophysical studies revealed that the petroleum products consisting of petroleum and natural gas, usually associated with water, get trapped in dome-shaped structures or at a junction of a major fault in the earth's crust.

Deep sea drilling for oil is comparatively recent. Right from the year 1930, geologists and geophysicists felt certain that there was oil under the sea, but they felt that in may not be feasible to drill for it because of major technological hurdles. Enterprising engineers, aware of the potential of the oil in the offshore, started designing giant mobile and even floating platforms in the sea by ingenuous methods in order to conduct deep-sea drilling operations.

With the rapid depletion of resources of petroleum on land and with the advancement in modern techniques of exploring and exploiting offshore petroleum, there was a global awakening among many countries to start exploring for petroleum in their offshore waters. It was estimated that offshore waters, all over the world, have reserves of 85 billion barrel of petroleum. Foremost amongst the countries which started offshore drillings are USA, UK, Norway and a few other European countries. It is estimated that nearly 20% of the world's known oil reserves come from offshore reserves of oil and gas. Even a modest estimate indicates that the total potential of petroleum products in the sea are atleast equal to those on the land. Recently extensive petroleum reserves were found in the North Sea area between Britain and Scandinavian countries. Current estimates of the reserves indicate that this is one of the richest offshore oil fields of the world. Although the offshore platforms are currently located in shallow depths but futures technological developments will certainly enable the exploitation of petroleum available at depths of even 2000 metres.

India is one of the developing countries which has started sufficiently early to explore offshore

areas, for oil prospecting. The success achieved in 1980 in Bombay High has opened up a new chapter in the exploration of offshore oil resources to feed the petrol refineries in our country. It is indeed remarkable that within a period of two years, Bombay High Oil Fields increased their capacity to reach production level of 80 thousand barrels a day which is worth about 30 crores of foreign exchange per year and nearly 10 percent of the present cost of import to crude oil. Besides these rich resources of oil in the Bombay High, the country is fortunate to have discovered natural gas offshore at Andaman Nicobar islands, Godavari and Cauvery basins.

With the explosion in human population, man will be compelled to turn to the sea for his future needs of water. Even a country bountifully blessed as USA with all its large rivers and lakes cannot increase its water resources without turning to the sea. Out of the water resources estimated to be 400,000 million gallons a day, U.S. is using around 70% for its daily requirement of agriculutre, industry and domestic use. In India, the total resources of water is 177.5 million hectametres of which only 26.4 million hectametres is used. Nearly 50% of our population has no potable water supply.

The three basic ways of separating salt from sea water are distillation, reverse osmosis and freezing. On the high seas, many ships use distillation for meeting its freshwater need, but this is a most expensive method for freshwater. The Central Salt and Marine Chemical Research Institute at Bhavnagar has set up an experimental solar distillation plant producing a few hundred gallons per day which is serving the requirements of a small village. Although inexpensive, in recurring costs the initial capital cost to set up such a unit is high and vast land areas are needed for setting up the plant. Reverse osmosis is a cheaper and compact method for separating salt from sea water using a specially treated membrane that allows water only to pass through. Central Salt and Marine Chemicals institute has also perfected this technique which is commercially viable. Drought prone areas, located on the sea coast which have a serious water shortage could well use this new technique for supply of potable drinking water.

A grandiose plan of tugging an iceberg from the arctic region was suggested by John Issac of the Scripps institution. It is estimated that in two months time an ocean-going vessel can tug a 10 mile long and half mile wide iceberg and tow it into a floating dam to supply 250 million gallons of freshwater. The cost will workout at one-third of a cent, per thousand gallons, a minute fraction of what we pay for our drinking water. This idea would be still more valid for arid zones and vast desert lands in various countries, particularly in Africa and Australia.

In any analysis of the rich non-renewable resources which man can exploit in the sea, the brightest and the most commonly useful for the present and the future needs of our economy are the chemicals from the sea water. Since historic times, man has been using sea water for extraction of common salt which is a vital ingredient of man's diet. The techniques of preparing common salt by salt pans on the sea-shore are know to mankind perhaps for over thousands of years. Today, almost all countries are extracting varieties of chemicals on a commercial scale from sea water.

Out of 92 naturally occurring elements in the earth, nearly sixty elements can be extracted from the sea water which highlights the variety and the wealth of minerals dissolved in the sea water. Unfortunately, most of these elements are present in infinitesimal amounts which can only be extracted by expensive methods on a very limited scale.

Chemical analysis of the composition of sea water is bound to lead to estimates of the sea water mineral potential which will be high at least in the case of major constituents considering the fact that volume of sea water resource is gigantic. However on economic considerations, very few of the minerals are extracted from sea water commercially. Common salt is the most important and abundant

of all chemical constitutes being 0.3% of the sea water. The total quantity of salt in the sea is 50 trillion tons and if this quantity is spread out dry on the land, it will cover the globe to a height of 502 ft. burying everything on the land in a sea of salt. Looking back at the preindustrial period, salt from the sea was used only for human consumption. With the rapid industrialization all over the world, major use of common salt in industries for production of chlorine, sodium hydroxide, several magnesium salts, bromine and a few other compounds. Apart from the use of common salt for extracting other elements and minerals, it is used directly in many industries like paper, plastic and textile industries. Magnesium which is a scarce metal on earth is found in sea water in sufficient quantity, to be a commercially viable proposition for extraction.

Wayback in 1879, the British oceanographic ship *H.M.S. challenger,* first brought up from the sea floor curious potato-sized lumps of stone now known as manganese nodules. Years later, several oceanographic expeditions dredged more and more of this rich manganese nodules spread on the surface of the sea floor in countless millions in almost all the oceans. Irregular shaped and varying in size from 1–6 cms they consist of manganese and iron oxides in percentages varying from 10–40% deposited in concentric layers around a nucleus. This discovery is important not so much for its manganese and iron content but the ability of these nodules to scavenge other relatively rare metals like copper, nickel and cobalt. Till recently, scientists concentrated the efforts in understanding the origin, growth, composition and structure of these nodules as a subject of great scientific curiosity. The remarkable feature of these nodules is their ability to grow at an average rate of 1–2 millimetre per thousand years. Estimates of the concentrations of these nodules vary widely from place to place. According to one oceanographer Dr. John Mero, the aggregate deposits of the nodules would be around 1–7 trillion tons containing 400 billion tons of manganese, 16 billion tons of cobalt. Such vast and rich deposits of nodules contain metals like copper, cobalt and nickel whose total ocean resources by far exceed the estimated world's total land resource. While these figures indicate enormous and almost unlimited reserves lying to be exploited on the surface of the ocean, but their distribution over a large area of the ocean bottom makes it economically non-viable except in those regions where there is an excessive concentration. Scientists, technologists, economists and planners predict that it is possible to commercially exploit these, only when the land resources get exhausted but it should be stressed that it it not economical to exploit them as most of them are located at great depth. However, extensive studies carried out in recent times, revealed thick solid deposits of over 50 million tons all along the axial deep trenches in the Red sea which can be economically exploited in view of their high concentration.

Sea floor is indeed a treasure house of exclusive mineral resources which nations can exploit. However, the distribution of these various minerals various widely from region to region among the various minerals available in the ocean, one of the most promising are the large beds of phosphate rock, conveniently situated in shallow areas near the shore, which is a vital material in the manufacture of chemical fertilizers currently in great demand all over the world. Phosphorite deposit were discovered off the coast of several island in the Indian Ocean. Continental self of Australia is richly endowed with phosphorite which is being minded for its domestic and export potential. While the world reserves of phosphorite in sea are estimated to be 300 billion tons, the present world reserves of phosphates are 50 millions tons of which 98% is held by four countries, namely U.S.A., U.S.S.R., Tunisia and Morocco.

Another element extensively used in chemical industry is sulphur which lies buried within the continental shelf and sea floor sediments. This element is usually recovered by pumping hot water which melts the sulphur and brings it to the surface.

Tin is another industrially useful element whose land resources are dwindling. Malaysia has large tin deposits and is one of the Asian countries exporting tin in large quantities. Very recently extensive prospecting by foreign firms led to a few sites offshore Thailand, Laving rich deposits. Iron is certainly one of the most important elements sought after by many industrial countries. Nearly a decade ago, Japan which has a large internal consumption of iron discovered a fabulously rich mine, estimated at 2 billion metric tons, off the coast off Kyushu which is one of the southern-most islands. In addition to these abundant, commonly used and industrially potential metals, ocean geologists estimate the availability of enough copper and aluminium in 40 million and odd square miles of ocean bed which will continuously supply the needs of man for the next million years at the present rate of consumption.

From times immemorial, explores are lured and tempted by bright prospects and exciting possibilities of undersea gold and diamond prospecting. Perhaps the greatest and the most abundant gold mines will be found underneath the sea in the present and next century, as thereare enough scientific evidences of gold mines obtained by a new technique of surveying the sea bed for ancient river channels which are likely to have rich deposits of gold dust and grains. Diamond prospecting was first initiated by Keeble who believed diamonds could be found in sands near the mouth of the river. He started a pioneering venture using a ship *Barge 77* and succeeded in bringing ashore significant qualities of diamonds off the shore of South-west Africa. Indeed, the diamond wealth of the sea is so high that every thousand pounds of sand was bringing as many carats of diamond as are million pounds of material on earth.

ENERGY FROM THE OCEAN

The ocean receives energy from the sun in the form of solar radiation. It also receives the gavitation energy due to attraction of the sun and the moon on the earth. In addition, there is a perennial supply of heat from the molten mass in the interior of the earth. The total energy is accumulated in the ocean in the form of temperature and the kinetic energy of the moving water in the waves, tides and currents in the ocean. The most spectacular and conspicuous features of the ocean are the waves of varying height and length. Waves on the ocean have always impressed artists, poets and scientists. One of the earliest studies of the waves by German Scientist Franz Gerstner revealed that water particles in a wave move in circular orbits. The study of the wave and surf movements is essential for naval operations particularly during war time. Although the waves on the surface of the ocean carry enormous amounts of energy, it has not yet been possible to develop techniques to exploit this source economically.

While scientists have not been able to develop a simple and efficient machine to extract the wave energy which was so obvious to the naked eye, energy of the tides could be fully exploited by building giant power stations. The periodic rise and fall of sea level due to the gravitational attraction exerted by the moon on the sea and to a lesser extent by the sun is called the tide. Tides are complex phenomena which depend on the positions of the moon and sun, the uneven distribution of the water on the earth's surface and the irregular configuration of the ocean base. The complex interaction of these features results in tides which vary from place to place, ranging from a few inches to about 12 meters height. Tidal gauges are usually installed in most of the harbours to record continuously tidal data which help in navigation.

Tidal motions have so far attracted much attention from scientists and engineers because power generation is possible following the conventional hydro-electric power systems. Normally the tidal range does not exceed 2 to 3 meters. However, there are special locations where tidal range can be as large as 15 metres. There are about 25 sites all over the world where the tidal range exceeds 5 metres which is the minimum

height required for setting up tidal hydro-electric power stations. The first country which has exploited tidal power is France which has set up the Rance river power plant near St. Malo which is the first commercially successful tidal power plant. The tidal height in this area ranges from 9 to 14 metres. The plant completed at a cost of 100 million dollars, generates a total of 2,40,000 k. W. of power using 24 reversible turbines. In India, the gulf of Kutch and the Gulf of Cambay on the west Coast in the State of Gujarat are the only two places having the potential for setting up tidal hydro-elelctric power stations, which can generate a total tidal power of a few thousands of megawatts.

In recent times considerable interest has been evinced by scientists and engineers to utilize the vast and almost unlimited ocean thermal energy available in the upper layers of the ocean which is constantly receiving the energy from the sun. The temperature of the sea water which is of the order 25°C at the surface goes down to 8°C at a depth of 450 metres. This difference in temperature between the surface of the ocean and the deep water can be utilized to obtain electric energy by using a technique which is exactly opposite to the principle of a refrigerator. Designs are well under way to generate a 1,60,000 k.W. power plant by using the Ocean Thermal Energy Conversion (OTEC) Principle near Laccadive islands. It will probably take several years of research, design and development before this new and perennial power supply system could be perfected. Scientists have predicted that with OTEC electric generators it is possible to provide continuous energy supply to mankind which is 200 times as great as the estimates of world's power requirement in the year 2000.

New methods of generating power are contemplated by using the salinity gradient when freshwater from the rivers flow into and meets the salt water of the sea particularly in the estuaries of large rivers, as scientists have shown in laboratory experiments, that considerable amounts of electric power can be generated when freshwater meets salt water.

OCEAN ENVIRONMENT

In the present climate of opinion, a good deal of awareness is being reflected by the national governments and international agencies including the United Nations system, about the conservation and the maintenance of our environmental equilibrium. This awareness has arisen after the damage has been caused during the process of our development strives made with the application of Science and technology. A wide variety of byproducts and disposable material extremely harmful to the human system and the biological world as a whole has been discharged into the environment and dislocated our natural equilibrium. Most of the environmentalists and ecologists are now articulating on the top of their voices that man must learn to live in harmony with laws of nature, but unfortunately what they are missing is of more importance. In fact, they are not viewing environment in its totality. While studying our environment, we must consider it as the total fluid system comprising both of water and air which envelopes the earth. It may not be overlooked that the interaction of the ocean and atmosphere is so thorough and complete that any deterioration of the ocean environment will lead deterioration of the total environment. The marine environment to a large extent dominate that of land. It nourishes and supports its life which evolved from the sea. Air, water and temperature are necessary conditions for the evolution and progression of life on this planet. The ocean holds untapped energy resources and mineral deposits of staggering magnitude and also supports a global food chain. It is true that the ocean has always offered benefit to the mankind in reverse ways and has been a crucial input to our economy, defence and aesthetic sensibilities, and yet it is threatened by man's misuse of his environment.

Perhaps, it is our inability to perceive oceans in terms of living organism that we went on disturbing their ecosystem and treate them as dumping grounds for our wasted and disposable materials of every kind from seawage to radioactive waves. It was our

mistaken belief that they had the capacity to absorb them, but on the contrary, what has happened should not surprise us. This process has contributed to a significant level of pollution not only on the coastal areas but also in the mid-ocean. There has been a continual deterioration of the ocean environment induced largely by man-made processes and occasionally by sporadic natural processes such as volcanoes and earthquakes. While studying the oceanic environment, it is necessary to understand about the Physics, Chemistry, Biology and Geology of the oceans, so that we can reliably assess what happens to the substances we dispose off daily, in ever-increasing amounts, into the oceans. Let us not forget that the mechanics of dissemination of pollutants causing damage to the oceanic environment are of complex and manifold character, not yet fully understood.

Massive oil pollution of coastal waters is one of today's most alarming sources of hazards. Although there is some pollution danger from offshore drilling operations, the greatest threat is posed by the huge oil tankers needed to satisfy our demands for energy. Sewage sludge from secondary treatment plants can have damaging effects through the accumulation of petrochemicals and of heavy metals in the sludge is discharged at sea, the toxic materials may be harmful to bottom populations and inhibit the bacterial breakdown of the organic pollutants. Domestic sewage contains fertilizing elements such as phosphorus and nitrogen which can increase productivity in the sea, but when added in excess, they stimulate growth of undesirable phytoplankton and tend to eliminate species beneficial as food for higher organisms. Insecticides, such as DDT, used in agriculture and polychlorinated biphenyls, (PCB's), used in manufacturing processes, are both carried to the sea by the atmosphere or by land runoff. While concentrations are lower in the open ocean than in coastal waters near rivers, scientists have found them to be surprisingly high, given the tremendous area and volume of the ocean. Heavy metals are being recycled by man at rates several times faster than natural weathering or erosion processes. The oceans are being polluted through rivers and atmosphere by these waste products of man's civilization and technology.

Amongst the different pollutants affecting our oceanic environment, perhaps the discharge of outflow of oil into the ocean seems to be the major pollutant. The agricultural, domestic and industrial activities are also threatening our marine environment and the rate of pollution has reached an alarming degree specially in countries bordering on sea. We do not know the extent of marine pollution in India at the Peninsular Belt, especially in the coastal region, Visakhapatnam, Trivandrum, Cochin, Goa and Bombay, but then monitored, perhaps the rate would be quite alarming.

Before considering important pollutants like synthetic organic compounds, heavy metal halogenated hydrocarbons, carbondioxide, radio-active wastes, it would be relevant to look at briefly the pollution caused by oil to our oceanic environment somewhat in depth. It would be relevant to recall that oil pollution hit the global news headlines as one of the major constituents of pollution to the oceanic environment, with the discharge of 34 million gallons of oil on the surface of the ocean near Cornwall coast by Liberion ship Torrey Canyon in 1967. Considering the importance of the oil in the present era, the operational activity of oil tankers has increased considerably. It is estimated that over 3500 oil tankers with an intake capacity of 1000 millions tons or more are operating and they are dumping over 5 million tons of oil into the ocean annually.

Looking at the dynamics of oil pollution in marine environment, one is struck by the fact that oil has been indentified as a major threat to the existence of the fish community. It causes a high incidence of severe neurological disorders followed by death. It indirectly affects the human life and other mammals inhabiting that region. It is understandable because once the inhabitants of that region take contaminated fish, they fall a prey to various physical and mental disorders. In any

analysis of the oil spills in the ocean, we should not forget that oil is highly toxic and it can endanger the life of sea birds and lump back whales, and others. Assuming that some forms of oil spills would appear to be inevitable as the demand for petroleum continues to increase in the coming decades, can we explore ways and means to minimize them, especially the offshore spills? We should give top priority to improve our coastal navigation systems and introduce strict regulations of marine traffic. The obsolete tankers should be banned and the new tankers equipped with all the safety measures should only be permitted to operate in the ocean. The International Maritime Consultative Organisation and other International agencies should address themselves to this question seriously and evolve improved standards for the preservation of healthy oceanic environment which should be made mandatory for all involved in the navigational and transportation activities in the sea.

Another significant pollutant to the ocean environment has been identified as radioactivity. The artificial radiation emanating from radioactive nuclei, are manifested in the ocean, following discharge of radioactive wastes. The impact of the radioactive hazards to the oceanic environment came to the notice of public when two atom bombs were dropped in Japanese cities of Hiroshima and Nagasaki in 1945. Since then, we have witnessed a proliferation of nuclear experiments, which have been carried out in the atmosphere, underground and undersea.

The major sources of ocean contamination by radioactive material are fall-outs from nuclear explosions, effluents and waste products from nuclear power plants and nuclear driven ships. Since oceans are enormous in the size, volume and depth, it is taken for granted that they are the safest repositories for radioactive wastes. Radioactive substances from nuclear plants enter the ocean chiefly in packaged disposal dumped to the deep seafloor. Nuclear driven ships discharge radioactive material in the ocean through various leakages. In fact the radioactive material goes to the sea through various channels and contaminate the ocean significantly. It is difficult to say with any degree of a authenticity about the impact of radioactive material on the marine life but the available data is a clear index of their significant impact on mutational changes and as such change in the genetic spectrum.

Another significant variable which is contributing to the pollution of oceanic environment are heavy metals. Heavy metals such as lead, copper, zinc, cadmium, nickel, chromium, mercury are responsible for degrading the quality of environment and extinguishing a number of marine organisms. It is interesting to observe that worst type of marine pollution due to heavy metals was observed amongst the inhabitants on the shore of Minamata Bay in 1953 and Niigata Island in 1965, due to the release or mercury through inland channels. Many organisms absorbed heavy metals in their bodies and later passed these through the food chain to man. Metals are often associated with chlorinated hydrocarbons. Finally, heavy metals are also supplied to the ocean from mine residues, which are carried by streams and rivers. Some heavy metals may come from the crude or heavy fuel oil leaks (or spills) from ships, pipelines, offshore wells, and refineries. Vanadium, manganese, cobalt and nickel are found in crude oils as non-volatile porphyrins. Oceanic pollution is more concentrated along coastal zone primarly because of high population concentration and heavy density of industrial complexes. It is along the coastal zone, that factories, power stations, refineries, harbour installations are established, which discharge highly toxic materials contributing to the degradation of the oceanic environment. The major sources of this degradation are the municipal wastes and industrial effluents. Methyl mercury chloride had been identified as the causal toxin, which contributes to pollution in the marine organism. It is byproduct of the manufacture of polyvinyl chloride resin, octanol dioctiol pthalate with acetaldehyde as the initial material.

It may be recalled that the chemical pesticides which are being used extensively for accelerating the pace of agricultural production are proving dangerous to the health of ocean. DDT which was found to be a useful compound for controlling malaria has adversely affected the marine life, say for example, the residues of DDT in the sea environment are selectively absorbed by planktons which in turn are taken by small fish, thus eventually it gets transferred to higher organism including the man.

Though all the chlorinated hydrocarbons, synthetic organic chemical compounds are discharged into the sea all along the industrial coastalline all over the world, the process by which they can be removed from the seawater are not well understood. We need more information of potential toxic matters in successive levels of food webs to avoid any future disasters to organic life in the ocean.

The effect of pollution on marine organisms cannot be evaluated unless normal functioning of the healthy organisms is known. This requires a large amount of basic research work about the marine organisms and their response to marine environmental changes and chemical pollutants. Such experiments have to be carried out in their natural habitat encircling portions of the sea water rather than in the laboratory.

Assuming that much of the pollution to the oceanic environment is the result of our industrial development, the solution to the problem does not lie, in calling for a moratorium on the industrial developments. In fact, we cannot afford to slow down the pace of our development task and also cannot wait any longer from harnessing the resources of the ocean for developmental purposes, to satisfy the needs and requirements of our explosive population living in impoverished conditions.

Perhaps, we have to evolve a coherent environmental policy for conserving and maintaining the marine ecosystem without causing any dislocation to our industrial and agricultural developmental activities. It is possible to control the oceanic pollution by promoting multi-disciplinary studies and working out operational strategies and modalities of action through which we can efficiently and effectively control the pollution. The first task would be to identify various pathways by which pollutants enter the ocean and later an analysis of the behaviour of the individual pollutants. These are essential for recommending remedial measures against hazards in the oceanic system. Once we realize that oceans are repositories and the necessary pre-requisite conditions for the maintenance and the sustenance of life in this planet, then our task would be to treat them in such a fashion that the equilibrium in the oceanic environment is not dislocated

RESEARCH, TRAINING AND MANPOWER PLANNING

Implicit in the preceding analysis is the general assumption that ocean development is crucial for human and social development and as it is absolutely necessary to accelerate the pace of education, training, research and development activities in various areas of ocean Science and technology. Educational activity is a vital input in any developmental process and must be organized in the context of social, political, economic, cultural, environmental and technological demands of any society for facilitating an integrated development of man and society. As such there is an urgent need for promoting an efficient and effective educational training programme linked to a coherent policy for manpower planning for identification and development of ocean resources.

Though India has a long and rich coastline, we have not been able to exploit our ocean resources for our development due to various factors. We have not succeeded in our efforts to establish the necessary infrastructure, collect data and build the manpower needed for carrying out this task. Very little has been attempted on the survey front for collecting the basic knowledge and information about the sea and the sea bed. The data on ocean

dynamics, currents, coastal upwellings, waves, marine chemicals, biological and physical resources, mineral mapping, their delineation and assessment is totally inadequate for taking up any meaningful programme of development. It is rather unfortunate that we have not been able to prepare realistic man-power projections and to train skilled personnel in various priority areas of ocean development due to lack of a realistic plan of ocean development based on data of our resources. To cite a few examples, we have a serious shortage of ocean engineers urgently needed for our offshore oil installations. In the area of marine pharmacology, physical oceanography, monsoon dynamics, ocean pollution and ocean mining, we do not have adequately trained staff both for developmental and research activities.

It may be recapitulated that the United Nations Convention on the Law of the Sea has recognized India as a "pioneer" investor in ocean mining and perhaps this imposes a heavy responsibility on us for organizing an efficient educational and research infrastructure in the area of oceanography for the preparation of highly skilled manpower to meet the demands of the country as well as of the developing societies which might have to draw upon our resources in the forseable future.

The picture that emerges of our universities in regard to the training and man-power facilities in the area of oceanography does not seem to be satisfactory. Andhra, Annamalai, Cochin universities and I.I.T. Madras are offering educational programmes in marine science and engineering. The courses offered no doubt need to be updated in the context of various scientific and technological breakthroughs in the different disciplines of knowledge. Marine science being an inter-disciplinary subject, it has to be organized in a coordinated fashion involving scientists having in inter-disciplinary approach.

The vastness and complexities of the ocean environment calls for a coordinated, centralized and highly sophisticated research programmes. This should be also based on adequate knowledge of all commercially exploitable ocean resources. The main thrust of such a programme should be on the optimum utilization of living resources like fish and seaweeds, exploitation or non-living resources such as marine chemicals, oil, manganese nodules and harnessing of renewable resources like thermal wave and tidal energies. This is not the place of identify the frontier areas on which we should concentrate—the issues have been specified and identified in each of the preceding section but the point which I intend to make is that the basic research is of utmost importance in any scientific area and perhaps more important than the applied one. It is the basic research which provides support to the applied research. The knowledge which we are applying to some of the most urgent problems of marine environment is applied from the basic research work done during the past.

At the same time, let us not overlook the fundamental fact, that marine development is heavily dependent on technological achievements. Much more needs to be done for the development of indigeneous technology for the exploitation of various development resources from the ocean. In fact, the technologies, which need to be developed should be ecologically balanced, self-reliant and employment-oriented.

There is another direction to the problem which should not be overlooked in any process of teaching, training and research particularly in Ocean Science. Paracelsus once remarked "No man can find a teacher in the class room nor his master by the fireside". Ocean Science being largely a field-oriented subject, no man can be a good oceanographer by learning in the classroom or library. It would be wrong for an ocean scientist to believe that he can do advanced research without adequate training and experience on a research vessel. Many of our Ocean Science training programmes in our universities and national laboratories suffer from lack of training on board a research vessel equipped well for all types of ocean

studies. If our ocean scientists have to carry out advanced research as well as train our young researchers, adequate infrastructure and support in the form of ocean-going research vessels has to be provided particulary to the university sector.

If our oceans have to become potential sources of food, energy and chemicals and to provide an alternative source to our land resources which are depleting fast, there is no way out, but to train our scientists in this area in a big way. While training our scientists in this area we should not forget that the problem of the ocean development is of a global character and it needs a global solution, and therefore we must work out a global marine policy and ocean management programmes while keeping in mind our national interests.

MANAGEMENT AND CONSERVATION OF THE OCEAN RESOURCES

The issue of management and conservation of the ocean resources — food, minerals, energy and marine environment — for the developmental tasks has assumed considerable importance in the present climate of opinion. This is a staggering problem and beset with a set of challenges. The major difficulty stems from the fact that the size of the oceans is so vast, covering roughly two-thirds of the earth's surface and touching the boundaries of approximately one hundred and fifty countries which are independent nations.

Considering the importance of oceans for the development of their economy, most of these independent countries are putting forth their claims for portions of the ocean as part of their territorial jurisdictions. The difficulty is further compounded by the fact that over 85 percent of oceanic territory falls outside the jurisdiction of all nations. In such a situation, who should have the legitimate right to exploit the resources of the ocean is a problem of problems which only the United Nations system can tackle with some degree of firmness and foresight.

The complex programme that ocean development entails will require well designed management, institutional infrastructure, basic knowledge and information about all aspects of the ocean including its resources. It would also involved a detailed survey and sampling in the regions of exclusive Economic Zone and the adjacent ocean to locate and evaluate the rich and economically viable resources. The integrated management of ocean resources would call for the new technological capabilities which must be continuously revised and updated. Preserving simultaneously the marine environment to avoid the undesirable consequences of hasty decisions made on the basic of inadequate understanding and to proceed in an effective way, it is imperative that we improve our communications system, global cooperation and coordination.

It is essential that ocean-oriented lawyers, economists, business experts, sociologists and others should be involved in the decision making process. To put the issue a little explicitly, the entire process of development will involve the blending of oceanography with public policy which could be viewed from the two perspectives : the first concerns with the decision making process and the second concerns with the substance or the issues now devolving in oceanography. The integrated management of the ocean resources will also call for a clearer and coherent legislation on the part of national government's and international bodies. What is really needed in a statutory dedication of national government and international bodies for evolving a rational and just legal political framework for exploring the minerals and others resources underlying the high seas.

This is not the place to examine, in historical perspectives, the conflicts amangst various countries which took place during the different periods of history, but the point which I intend to make is that issues relating to ownership of resources, territorial claims and marine environment are being debated currently in the international Laws of the sea. The United Nations Laws of the sea convention which has been the subject of great debate and controversy is likely to open a new chapter in the foreseeable

future in the international law and global cooperation. In 1958, over 81 countries took part in the Geneva conference, and four important conventions, which have since been ratified by several other nations, adopted :

1. the convention on the Territorial Sea and Contiguous Zone;
2. the Convention on the Continental Shelf;
3. the Convention on the High Seas; and
4. the Convention of Fishing and Conservation of the Living Resources of the High Seas.

If would be relevant to examine each of them briefly.

TERRITORIAL SEA AND CONTIGUOUS ZONE

According to the convention on the territorial sea and the contiguous zone, each nation will have the sovereign power to a band of sea adjacent to its coast (the territorial sea) and to the air space over the territorial sea as well as to its bed and subsoil.

Opinions were divided about the width of the territorial sea. The zone exists within the twelve miles from the baseline that makes the point from which the extent of territorial sea is to be measured. The convention also stipulates that each coastal nation would have a right within its contiguous zone to carry out immigration, customs, and sanitary policies.

THE CONTINENTAL SHELF

The convention on the continental shelf envisages that shelf is defined as "the sea bed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea to a depth of 200 metres or beyond that limit, to where the depth of the super adjacent water admits of the exploitation of the natural resources of the said areas, as well as the sea bed and subsoil of similar submarine areas adjacent to the coasts of islands." The convention provides to each coastal nation sovereign right over the continental shelf for the purposes of exploration and exploitation of its natural resources.

THE HIGH SEAS

According to the convention on the high seas, the high seas encompasses all portions of the sea outside territorial seas or the internal waters of a nation. The high seas belong to all nations and are therefore under no jurisdiction of an individual nation. Naturally, every coastal and non-coastal nation has got an access to the high sea. The convention guarantees freedom of navigation, fishing, construction of submarine cables and pipelines and flight.

FISHING AND CONSERVATION

The convention on fishing and conservation of the living resources of the high seas provides that all states have the duty to adopt or to cooperate with other states in adopting such measures for their respective nationals as may be necessary for the conservation of the living resources of the high seas.

While assessing the contributions of the United Nations towards the establishment of an international legalist framework for harnessing the rich potentials of the oceans resources, we must, consider, in detail, the historic Malta Resolution which was geared to give the United Nations a greater role in managing the world's oceans, particularly the resources of sea bed and subsoil which fall beyond national jurisdiction. Another related development occurred almost simultaneously. In August 1967, the United Nations was confronted with an imaginative proposal by the government of Malta of turning over to the United Nations all the mineral resources of the deep sea. This proposal immediately raised the legal question of who owns the sea bed. The United States was surprised at Malta's initiative. Ambassador Arthur Goldberg went to the United Nations in October 1967 with a three-part proposal; first, to re-enunciate a concept the government has adopted, that there be no colonial race with regard to the sovereignty of the deep sea bed; second, that the United Nations establish a committee on the oceans; and third that the nations of the world work together to find out resources are in the oceans.

Space and time does not permit to discuses, in detail, about finding of various conferences, seminars and symposia organized under the auspices of national and international agencies, especially by the United Nations for working out a global policy and an international legal and political framework for exploring the vast potential resources of the oceans. However, I would like to focus on the United Nations Law of the Sea convention which was signed on December 10th, 1982 by India and 116 other countries at Montego Bay in Jamaica. This convention unfolds a new chapter in the evolution of any growth of international law and global cooperation.

It gives special recognition to the leading role of India in exploiting deep sea bed resources. The nations and the international consortia with pioneer status are to be given priority being allocated are for sea bed mining under the convention and they in turn will have to share their technology with an international body, to be known as Enterprise, which will exploit the resources as a common heritage of mankind.

Indian Law Minister Jagannath Kaushal, who attended the final session of the nine years long U.N. Law of the sea conference at which the convention was signed, had said, that India was grateful for the recognition as a pioneer. This, he said would boost the morale of the other developing countries as well. Mr. Kaushal also said that India had fulfilled the conditions, such as the carrying out of surveys and making a minimum investment for exploiting the sea bed resources to qualify for this status. The president of the conference, Mr. Tommy Koh of Singapore warned the countries boycotting the convention; 'any attempt by any state to mine the resources convention will earn the universal condemnation of the international community and will incur the gravest political and legal consequences'.

The lengthy detailed document of the convention lays down the law for virtually all aspects pertaining to the sea. It allows a 12 nautical miles-wild territorial zone along the coast and a 200 miles wide exclusive economic zone in which coastal states control all resources, such as fish and petroleum. The treaty also demarcates the delineation of sea boundaries and provides for peaceful international navigation. The United States and other developed nations accepts this provisions. The controversy, however, centres around the recognized by the convention that all countries have a right to the natural resources in the waters beyond the exclusive economic zone. The convention provides for setting up an International sea bed authority to regulate the mining and other economic exploitation of the resources with "Enterprise".

The adoption, by an overwhelming majority of nations of the convention of the UN conference on the law of the seas will unfold a new opportunity in the realization of the goal of a new international economic order, and global co-operation.

It is heartening to note that our country has been recognized as a pioneer investor in ocean mining by the United Nations and has thus been entrusted with a heavy responsibility for the development of necessary technological infrastructure and capability for the exploitation of the resources of the ocean which belong to the entire population on the globe. This is unique challenge and a rewarding opportunity for us.

Considering the crucial importance of the ocean resources for development in an ecological fashion by developing appropriate technology and capability, the Government of India has set up the Department of Ocean Development (DOD) to carry out the manifold broad objectives of policy-planning, coordinating with various agencies and monitoring and implementing various developmental programmes on the ocean Science and technology. It is one of the major governmental agency entrusted with the overall management of ocean and relating matters. It is also coordinating its activities with other federal agencies including the Department of Science and Technology, CSIR and its laboratories,

the Department of Environment and the University Grants Commission for carrying out both basic and applied research and developmental activities.

THE FUTURE SCENERIO

While presenting an overview on new developmental advances in oceanography, within the national, international, legalistic, political and socio-economic frameworks, I was primarily moved by one consideration as to how oceans can transform the face of this planet by eliminating hunger, squalor, disease, imbalances and grim poverty in the emerging and foreseeable future. Whether one admits it or not, they are the last frontiers of knowledge and human and social developments, holding a rich promise for the establishment of an ecologically balanced human a rich promise for the establishment of an ecologically balanced human environment and rich quality of life. To put the issue little explicitly; for me, the human development and ocean development at this critical hour of our history are interlinked and we should endeavour to accelerate the pace of their development in an integrated fashion.

A close look at the literature on various developmental activities reveals that rarely our experts in various disciplines of knowledge endeavour to provide objective projections into the future. But what does the futurologists tell us? It is interesting to observe that, in the sixties, most of the futurologists presented a picture, a vision of the future of an unending explosion of knowledge and accomplishments in diversified developmental areas. Surprisingly, these very prophets of optimism are currently predicting a global crisis, a highly technological and nightmarish society animated by human and artificial robots. It is not an exaggerated statement, if I am permitted to say, that these prophets of gloom and doom are presenting the future scenerio in terms of total despair and even the extinction of human life on this planet. Some of the indications are

1. explosion of population;
2. imbalanced development amongst the developed and developing societies;
3. impairment of the biosphere;
4. stagnation and inflation eroding the world economy;
5. military expenditure reaching a new appalling record of 450 billion per year;
6. rampant social ills of poverty, injustice and intolerance; and
7. an absence of meaningful dialogue between east and west.

Granted that we are passing through crucial times, I have a firm faith in the human will and its capacity to meet these challenges with determination. The very fact that our present situation is likely to end in global disaster should provide us with new opportunities and an new commitment to transform it is so that it may become an exceptional opportunity. Let us not forget that there is a close co-relation between crisis and creativity and this could be amply substantiated from the study of the lives of great men.

There are enough evidences, based on scientific researches and speculative thinking, which clearly substantiate that the following are frontier are as where major breakthroughs in oceanography are possible in the foreseeable future. These are

1. revolutionary developments in the area of remote sensing technology for prospecting oil and material and biological resources of the sea with the use of satellites, special aircraft, and research vessels;
2. development and deployment of ocean monitoring equipment extensively for collecting, analyzing data on the marine environment;
3. innovative developments in the frontier area of underwater archeology;
4. exploration into the behaviour pattern of sea life with the help of underwater acoustical techniques;
5. a foreseeable possibility of revolutionary breakthroughs in the areas of marine pharmacology;

6. understanding of the genetic behavior of sea life relation to their immunity to fatal diseases like cancer;
7. a new possibility of understanding the evolution of life in other planets, based on the discovery of entirely new marine life, surviving on toxic volcanic effluents in the bottom of the sea;
8. establishing innovative technologies for underwater communication system and linking it with the land-based communication network;
9. building a new complex and sophisticated system of transportation which will be self-sufficient and immune from disasters; and
10. an emerging possibility of colonization on the sea floor by human population living on floating or submergible vehicles with an access to modern facilities.

Considering the strategic importance and urgency of exploiting the vast ocean resources, scientists and technologists would be working on newer and more sophisticated electronic remote sensing techniques for locating, identifying and estimating the vast reserves of oil well, mineral deposits and biological wealth of the oceans, particularly in the shallow zones of the continental shelf. Satellites have already been put to use to locate and follow oceans currents like gulf stream, ocean bottom profiles showing the path of rivers flowing into the sea. Acoustical and radio sounding techniques would undoubtedly be improved and perfected to identify and delineate the large oil wells besides vast deposits of natural gas, manganese nodules, precious gold and diamond and rate elements like nickel and chromium, etc.

To ensure a balanced development of the marine environment, it is absolutely necessary that we should give top priority to monitor the ecological characteristics of the ocean by an extensive use of highly sophisticated instrument packages located on floating buoys deployed at specific points on the oceans for collecting scientific data. This process will also involve the establishment and the use of highly sophisticated computer systems which will be located in the world ocean data center to consolidate the wealth of data, store and analyse and present the results in the form of weather profile map. Apart from yielding meaningful results in the various dynamics of the oceans, this process would enable us to produce and publish ocean weather maps along with the meteorological maps in the dailies. They would aim at enhancing the accuracy of prediction of our weather, both on the land and in the ocean.

Another unique and an exciting possibility which needs to be exploited at an optimum level relates to the development of underwater archeology. The establishment of an underwater, archeology is likely to bring about a major breakthrough in the identification of many new cities, towns and civilization which existed and flourished during the pre-historic times. At the same time, we will be able to develop innovative methods and techniques to be employed by historians for understanding the historical processes and developments of human civilizations.

A new understanding of the extraordinary capabilities of the ocean life may enable mankind to design and develop new instruments. Say for example, the discovery of radar was based on the auditory capability of bats to fly in total darkness avoiding all obstacles. In a similar way, we could visualise the possibility of several breakthroughs in the area of instrumentations during the process of our study of the behaviour characteristics of the sea life.

The marine pharmacology is another vital area in which we are likely to witness several breakthroughs. In any analysis of the development of oceanic resources, we should not overlook the fundamental fact that the ocean biological wealth abounds in innumerable species which are totally resistant to fatal diseases like cancer, epilepsy and heartattacks, etc. An analysis and understanding of their genetic and other characteristics may unravel the new and exciting possibilities of developing

new diagnostic and treatment methods. It may be added that very little work has been done on the genetic studies of marine organism. We can envisage the possibility of relating genes structure of sea life with its behavourial characteristics and to special capacity of resistance to various diseases which are afflicting mankind. These new discoveries will advance the frontier of knowledge in the areas of medical sciences and improve the diagnostic and curative aspects of various ailments.

A new possibility of understanding the evolution and development of life in our neighbouring planets, based on the recent discovery of a new form of life, surving on toxic effluents in volcanic regions at the bottom of sea could be visualized. It is interesting to observe that the recent discovery of new forms of life without having any access to oxygen and carbon dioxide in the volcanic regions at the bottom of the ocean, — which is nourished by the new type of bacteria fed on hydrogen — might enable us to identify and understand the evolution of various types of life in our neighbouring planets. The study of these new forms of life has to be pursued relentlessly from a changing perspective. Such studies will produce meaningful results in our biological knowledge.

We are on the verge of witnessing a revolutionary breakthrough in the area of underwater communication systems. While we have the sonar systems for communication between ships and submarines, it is almost impossible for two submersible or two diverse vessels to communicate with each other in view of the ineffectiveness of radio communication and constraints in sound communication systems. If mankind has to realize the dream of colonization on the ocean bottom, it is absolutely necessary to accelerate the pace of research and development in this area.

While mankind has been using the seacraft for adventuring and commercial purposes for over several centuries, we have not yet witnessed any major breakthrough in the area of ocean transportation. This is an area where revolutionary designs of new transportation system are likely to be evolved which will be highly stable and dynamic. These large ocean–going vessels will have the intrinsic merit of being self-sufficient in terms of food, energy, communication and other physical and recreational amenities, etc.

Looking at the phenomenal explosion of global population, mankind may have to look for colonization of the ocean areas by building towns and cities under the sea. It should be noted that the environment on the sea bottom is more congenial as the temperature is moderate and does not undergo an appreciable daily or seasonal changes. The greatest obstacle for man is to find the enormous resources of oxygen necessary for living under the sea and also to move from place to place. Man's exploration of the sea has always been limited by lack of oxygen which he has always to carry on his back in the form of a tiny cylinder. Is it possible to make a synthetic gill imitating what the living tissues of fishes gill do? Scientists have experimented on many materials and perhaps are nearer the solution to have a thin membrane of polyestrine and rubber silico, which will permit oxygen to prevent the water to flow in. While air has 200 c.cs. of oxygen for every litre, sea has only 9 c. cs. of dissolved oxygen. Although this amount is small, it is enough to supply man's needs. The future possibility of extracting oxygen from sea-water through special membranes must be explored.

Hopefully, these possibilities would soon become realities with the advancement of our knowledge in oceanography in the near future and ultimately would enable mankind to survive in the oceans. Granted that with the exploration of moon, we could not succeed in migrating our expanding population to the moon but I am confident that a colonization of oceans by the people of the earth is an emerging possibility in the near future.

Meeting of such creative minds in the city of Lord Venkateshwara—the seat of knowledge—for looking forward towards the solution of manifold problems, which are making the human race

uncomfortable, reminds me that most of our creative works have been accomplished at sacred places. In fact, the birth of our scientific knowledge can be located in our philosophical and spiritual traditions

It is fascinating to note that during the post-Newtonian period we have witnessed the fragmentation of knowledge in diverse disciplines, leading to the emergence of the Cartesian division and the mechanistic world view. They have been extremely successful in the advancement of Classical Physics and technology but had many other implications on the development of man and society. The twentieth century Science which originated in the Cartesian division and the mechanistic world view is now trying to overcome the fragmentation and leading us back to the idea of unity expressed in the Greek and Eastern philosophies. One runs into many statements by the distinguished physicists of our century about the radical transformation of our whole world view, based on ecological ideas of interconnections and interdependence. Here is an insight from Julius Robert Oppenheimer.

The general notions about human understanding ... which are illustrated by discoveries in Atomic Physics are not in the nature of things wholly unfamiliar, wholly unheard of, or new. Even in our own culture they have a history, and in Buddhist and Hindu thought a more considerable and central place. What we shall find is an examplification, an encouragement, and a refinement of old wisdom.

What Neils Bohr had to say on the subject is equally relevant for our purpose. He writes.

For a parallel to the lesson atomic theory ... (we must turn) to those kinds of epistemological problems with which already thinkers like the Buddha and Lao Tzu have been confronted, when trying to harmonize our positions as spectators and actors in the great drama of existence.

Please permit me to invoke Lord Venkateswara's blessings that he should provide us a creative spark and guide us during the deliberations in the next few days. Hopefully, the deliberations will generate ideas on diversified areas of development and foster the spirit of cooperation and collaboration amongst various countries on many experimental areas for a quantum leap forward in the area of oceanography.

I express my sincerest thanks to our distinguished Prime Minister for inaugurating the Science congress and for continuously providing us a dynamic leadership in the development of Science and technology in general, and Ocean Science in particular. The creation of the department of the Ocean Development clearly indicates her commitment to the advancement of the last frontiers of knowledge.

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BIOLOGICAL RAIN - A NEW WINDOW FOR HARVESTING ATMOSPHERIC MOISTURE

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Recurrent droughts in several regions of the world and its disastrous impacts on survival of life have necessitated to look for a viable option for harvesting atmospheric moisture. Human efforts have been made to make rain artifically through physical and chemicals means. Recently, in addition to these two, biological agents are also being exploited at experimental levels for harvesting atmospheric moisture. The biological alternative specifically termed as "Bioprecipitation" proved to be economically feasible and practically viable.

INTRODUCTION

Water/moisture is the foremost necessary clause for existence of life on any planet. Earth and its atmosphere have enough water/ moisture to support life, but still there is severe scarcity of water in several regions and due to which habitat suffers a lot. Ways and means have been exploited from time immortal by a number of creatures including human in search of water/ moisture to sustain their life. Establishment of many ancient cities on the bank of rivers to have easy and economic access of water exemplifited the human efforts in the history. Consequent upon industrial revolution and intensive agriculture, demand of water has increased exponentially that made the scenario for natural rainfall as insufficient to fulfill this demand. All these led to put pressure on human to invent methods to harvest available atmospheric moisture or create rain artifically.

The harvesting of atmospheric moisture/water has been a major challenge in arid and semi-arid regions of the world where water level is abnormally low on account of scanty rainfall. Therefore, an easier and less expensive way has to be ascertained to get moisture/water. During the last two decades, a number of atmospheric moisture harvesting experiments has been tried and attempts were demonstrated to sustain the habitats' life. These experiments mainly encompassed use of chemical nucleators and other machines and biologically active microorganisms and plants. Chemicals such as Silver Iodide, finely powdered Sodium Chloride, solid CO_2 mediated artifical rain experiments and were successfully demonstrated the possibility of harvesting atmospheric moisture, but proved to be quite expensive and have some harmful consequences to human and environment also, therefore not much preferred. Many plant pathogens and plant surfaces have cutting edge over chemical means owing to their economical and eco-friendly approach. Numerous plant pathogens and plant surfaces have super-hydrophilic or hygroscopic properties and are thus likely to be able to absorb water from atmosphere. The bacteria *Pseudomonas syringae* and *Pseudomonas fluroescens migla* (plant pathogen) and the bromeliads (plants of Bromeliaceae family) are among the best known examples. These biological classes that make rain given way to a novel concept of Bioprecipitation.

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PHYSICS OF PRECIPITATION

Clouds are aggregate of minute water droplets suspended in the atmosphere. Droplets produced by the condensation process are indeed very small in size, averaging less than 10 micrometer in diameter, seem to float in the air. Rain drops have diameters ranging from about 200 microns upto 700 microns. The drops larger than this upper limit (500 microns) have capability to fall against air updraft motion. The cloud droplets to join together to from large rain drops capable of failling to earth as precipitation. In certain type of clouds, the water droplets do not tend to coalesce and all the time they are kept floating in the air and no precipitation is released from them. On the contrary, in certain cloud froms, the droplets have a tendency to join together and big size rain drops develop and they are producers of precipitation. Two mechanisms have been proposed to explain these processes namely ice-crystal theory of Bergeron (for clod clouds) and Collision-coalescence theory of Bowen (for warm clouds). Either to condense, to grow or to coalescence, a hygroscopic nuclei is required to be present in the atmosphere.

RAINFALL AND ICE CREATING BACTERIA

Atmospheric moisture vary between 0.2 to 4 per cent and harvesting it through experiments other than chemical means viz; water house, wind turbine and bacterial use are some of the recent development in the field of research aiming to achieve artifical rain. Looking to the severity of demand and its eco-viable vista, research efforts leading to microbes mediated artificial rain or very specifically bioprecipitation has fetched wider global attention. The first ever concept of bioprecipitation was enunciated by David Sands *et al*[1].

The concept of biological rain through bacteria materialized from the basic natural phenomenon that, before a cloud can produce rain or snow, rain drops or ice particles must form. This requires the presence of tiny particles that serve as the nuclei for condensation. Traditionally minerals were thought to be the dominant ice nucleators in the atmosphere, however, airborne microbes like bacteria, fungi or tiny algae can do the job just as well[2]. Unlike mineral aerosols, living organisms can catalyse ice formation even at temperatures close to 0°C. The new research finding also support that a large variety of macroorganisms including bacteria, fungi, diatoms and algae, persist in the clouds can be used as precipitation starters.

A few physiologically distinct groups of bacteria associated with plants are reported to be capable of ice nucleation "*in vitro*" and "cause" frost injury of plants[3]. Some of the Bacteria like *Pseudomonas syringae, P. fluorescens migla* and *Erwinia herbicola* serve as effective ice nucleators even at relatively high temperatures of -1 to -2 degree Celsius. There is also a remarkable fact that, most known ice-nucleating bacteria are plant pathogens. A recent study confirmed that the rain making bacteria that live in clouds might have evolved the ability to impel showers as a way to disperse them worldwide.

Some very potent ice nucleators in decaying plant matter were found that made the surprising discovery that they came from microbes[4]. A few years later, the bacteria *Pseudomonas syringae* was identified as the source of these nucleators[5]; parallelly, Deane Arny discovered that more frost formed on plants infected with *P. syringae*.

The rain making potential of bacteria lies on a mechanism that the bacteria produce a special protein, InaZ, which can act as an ice nucleus at the relatively warm temperature of -2°C, probably because its repetitive shape is just right for coaxing water molecules into a crystalline arrangement. Air, including clouds, is usually full of micro-organisms like bacteria and fungi, some of which produce ice-nucleators. Ice crystals which form in clouds will grow until they are big enough to fall as either rain or snow depending on whether they melt on

the way down. Researchers have detected *P. syringae* in fresh rain, snow and ice from a wide range of locations including Louisiana, the French Alps and even Antarctica. Another team of researches found that one-third of the ice crystals in clouds over Wyoming had formed around biological particles.

MICROBE WATER CYCLE AND BIO-PRECIPITATION

Like natural water cycle there exists microbe water cycle also, but in this cycle microbes (Bacteria, Fungi) do not change their physical status. These bacteria and fungi are found as high as 30,000 feet in the atmosphere. The researchers found air mass and hurricanes that spew these bacteria from water and land surfaces into atmosphere. It was observed that mostly marine bacteria, and terrestrial bacteria were originated over water and land. These bacteria were dynamically mixed with other particles and in terms of distribution, there were about 144 bacteria cells found in every cubic foot of air. Reported information suggests that the bacteria gets out of clouds and back to Earth and on plants through rain and thus complete the cycle.

Similar to the natural phenomenon, bioprecipitation also requires a source of nucleation; such sources exist both outside and within plants. Outside sources of nucleation include dust particles, organic matter, bacteria and even gas bubbles. These bacteria populate on the surface of many plants species, and frost formation on such plant surfaces bears a logarithmic relationship to the number of ice nucleating bacteria on the plant surface. A reduction in number of such bacteria on plant surfaces reduces the threshold temperature for frost formation. The same bacteria that cause frost damage on plants can help clouds to produce rain and snow. Studies on freshly fallen snow suggest that 'bio-precipitation' might be much more common than was suspected.

HARVESTING MOISTURE THROUGH PLANT BREEDING AND LAND MANAGEMENT

Plants harbor large numbers of microogranisms on their surfaces. Cultivated plants, in particular, are considered to be a major source of the microorganisms – and especially the bacteria. Canopies of snap bean, for example, harbor INA strain of bacteria *Pseudomonas syringae* in strength of about 30 bacteria/m^2/Sec in the air. Sands and colleagues proposed the existence of a biological cycle whereby colonization of plants by INA bacteria contributes to enhanced precipitations which in turn augment plant and microbial growth and contributes to the dissemination of bacteria to new plants[1]. Thus plants could be considered to be cloud seeders. Attempts must be made to widen the host range of the crops suitable for bacterial colonization by specific strain. Future selective breeding followed by effective selection would offer the potential for plant evolution to support high numbers of INA bacteria. For maximizing INA bacteria anchorage on plant surface, selection for specific canopy properties may be one possible avenue. It will of course be important to establish that newly introduced or selected crop cultivars with increased harboring efficiency should at least maintain yields of existing varieties and ideally be resistant to the pathogenicity of INA bacteria. Plant breeding and agronomic strategies that enhance these forms could be investigated to reduce the spread of plant pathogenic INA bacteria. A considerable knowledge base integrating research in agronomy, microbiology, meteorology, physics, sociology and economics will be needed to bring us to the point of such choices.

ENVIRONMENTAL EFFECTS OF HARVESTING RAIN THROUGH BACTERIA

Artificial rain produced by several chemical *viz*; Silver Iodide (costly) or solid carbon dioxide or even finely powdered Sodium Chloride (cheaper) leads to accumulation of these chemicals in plant

and animal bodies which could create argyria, anaemia, weakness and loss of weight. Similarly adverse health implications were also reported from the study conducted at the "Bangalore University which revealed that the first rains of summer encompassed high level of pathogens including *Streptococcus spp, Staphylococcus aureus, Enterococcus spp, Actinomyces spp, Bacillus subtilis, Neisseria spp*, and *Mycobacterium sp* in addition to *E coli*." These fungal species can cause infectious disease, have acute toxic effects, and give rise to allergies and cancers. However, there seem viable preventive as well as remedial alternatives available for microbial borne diseases as compared to that of chemically induced. Therefore, despite to the risk involved in bioprecipitation, the option is quite preferable considering economical, environmental and remedial aspects.

CONCLUSION

Demand of water has increased tremendously and in some regions natural precipitation is not enough to sustain lives. The artificial rain making is a tool and possesses the potential to fulfill, to some extent, the demand of water, but is quite expensive and has limited applicability due to its environmental effects. Bio-precipitation emerged out as a new hope for water harvesting, though it's pro and cons have not been fully evaluated, but seems to be economically feasible and practically viable for water harvesting. However, before materializing the concept, a scientifically sound risk-benefit assessment must be executed leading to an explicit prospect of Bioprecipitation.

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DIABETES AND MEDICINAL PLANTS

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Diabetes mellitus is a metabolic disorder characterized by chronic hyperglycemia or increased blood glucose levels, resulting from insufficient or inefficient insulin secretion, with alterations in carbohydrate, protein and lipid metabolism. Type 2 diabetes is the most prevalent form, of the total diabetics about 90% have type 2 diabetes, which is characterized by post-prandial hyperglycaemia (increase in blood sugar level after a meal). Many medicinal plants are reported to have insulin-mimetic effect, modulation of insulin secretion and inhibition of carbohydrate digesting enzymes.

INTRODUCTION

Since ancient times, plants have been an exemplary source of medicine. Ayurveda and other Indian literature mentioned the use of plants in treatment of various human ailments. In India, indigenous plant remedies have been used in the treatment of *Diabetes mellitus* since the time of Charaka and Sushruta (6th century BC)[1]. Plants have always been an exemplary source of drugs and more than 80% of the currently available drugs have been derived directly or indirectly from them. Medicinal plants have the advantage of having no or only few side effects. Some of them are being used in traditional systems of medicine from hundreds of years in many countries of the world. Metformin is an oral antidiabetic drug used for the treatment of non-insulin-dependent diabetes mellitus (NIDDM) patients. Metformin is now believed to be the most widely prescribed antidiabetic drug in the world; it was first derived from a medicinal plant *Galega officinalis*, which was historically used for treatment of diabetes in medieval Europe[2]. There are many antidiabetic plants which might provide useful sources for the development of drugs which can be used in the treatment of diabetes mellitus. The literature on medicinal plants with antidiabetic activity is vast, so a few commonly used plants have been discussed here.

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WHAT IS DIABETES ?

Diabetes mellitus is a complex metabolic disorder resulting from either insulin insufficiency or insulin dysfunction. The disease is primarily classified into insulin-dependent diabetes mellitus (type 1 dabetes, IDDM), non-insulin-dependent diabetes mellitus (type 2 diabetes, NIDDM) and Gestational diabetes mellitus (GDM). The prevalence of NIDDM is increasing globally. Of the total diabetics, about 90% have NIDDM[3], which is characterized by post-prandial hyperglycaemia (PPHG) and associated with post-prandial oxidative stress. PPHG (increase in blood sugar level after a meal) plays an important role in the development of NIDDM, as well as in complications associated with the condition, including micro-vascular and macro-vascular diseases.

Most of the food we eat is broken down into simple sugar glucose, which is the main source of fuel to get energy for the body. After digestion the glucose reaches our blood stream where it is available for the cells to utilize for energy, but

insulin is needed for the uptake of glucose into the cells. Insulin is a hormone secreted by the pancreas, it has to be secreted in adequate amount to transport glucose from blood into different cells of the body. If the insulin is not produced sufficiently or the produced insulin does not work efficiently, the glucose is not taken into the body, remains in the blood. This makes rise in blood sugar level causes hyperglycaemia. If a diabetic person has high blood sugar, either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced. This high blood sugar produces the classical symptoms of polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger)[4].

Pancreatic α-amylase is a key enzyme in the digestive system and catalyses the initial step in hydrolysis of starch to a mixture of smaller oligosaccharides. These are then acted on by α-glucosidases and further degraded to glucose which on absorption enters the blood-stream. Degradation of this dietary starch proceeds rapidly and leads to elevated PPHG (post-prandial hyperglycemia). PPHG can be controlled by delaying the absorption of carbohydrates from the gastrointestinal tract by inhibiting digestive enzymes. Foodstuffs which are rich in phenolic compounds are known to inhibit digestive enzymes, most of the phenolics of millets (finger millet or ragi) and grains are concentrated in the seed coat[5]. Many plants (Indian gooseberry, guava, and pomegranate), vegetables (cauliflower, garlic, onion) and leafy vegetables (amaranth, punarnava) are reported to have hypoglycaemic activities. An herbal formulation containing the three medicinal fruits *Phyllanthus emblica* (Amla), *Terminalia belerica* (Bibhitaki) and *Terminalia chebula* (Haritaki) named Triphala (Sanskrit, tri = three and phala = fruits), is traditionally used medicine for the treatment of diabetes.

TYPES OF DIABETES[6]

Type 1 diabetes is called as insulin-dependent diabetes mellitus (IDDM), immune-mediated or juvenile-onset diabetes. It is caused by an auto-immune reaction where the body's defense system attacks the insulin-producing cells. This disease can affect people of any age, but usually occurs in children or young adults. People with this form of diabetes need injections of insulin every day in order to control the levels of glucose in their blood.

Type 2 diabetes is called as non-insulin-dependent diabetes mellitus (NIDDM), and accounts for at least 90% of all cases of diabetes. It is characterized by insulin resistance and relative insulin deficiency, either of which may be present at the time that diabetes becomes clinically manifest. The diagnosis of NIDDM usually occurs after the age of 40 but can occur earlier, especially in populations with high diabetes prevalence. It is characterized by insulin resistance and impaired beta cell function.

Gestational diabetes (GDM) is a form of diabetes consisting of high blood glucose levels during pregnancy. It develops in one among 25 pregnancies worldwide and is associated with complications in the period immediately before and after birth. GDM usually disappears after pregnancy but women with GDM and their offspring are at an increased risk of developing NIDDM later in life. Approximately half of women with a history of GDM go on to develop type 2 diabetes within five to ten years after delivery.

DIABETES COMPLICATIONS[4,5]

One of the long-term complications of NIDDM is hypertension or high blood pressure. Hypertension and NIDDM are interrelated metabolic disorders. Persistent hypertension is one of the risk factors for strokes, heart attacks, heart failure and is a leading cause of chronic renal failure. Though pathophysiology of diabetes remains to be fully understood, experimental evidences suggest the involvement of free radicals in the pathogenesis of diabetes and more importantly in the development of diabetic complications. Free radicals are capable of damaging cellular molecules, DNA, proteins and

lipids leading to altered cellular functions. Many recent studies reveal that antioxidants capable of neutralizing free radicals are effective in preventing experimentally induced diabetes in animal models as well as reducing the severity of diabetic complications. For the development of diabetic complications, the abnormalities produced in lipids and proteins are the major etiologic factors. In diabetic patients, extra-cellular and long lived proteins, such as elastin, laminin, and collagen are the major targets of free radicals. These proteins are modified to form glycoproteins due to hyperglycemia. The modification of these proteins present in tissues such as lens, vascular wall and basement membranes are associated with the development of complications of diabetes such as cataracts, microangiopathy, atherosclerosis and nephropathy. During diabetes, lipoproteins are oxidized by free radicals. As diabetes is a multifactorial disease leading to several complications, and therefore demands a multiple therapeutic approach.

DIABETES AND INSULIN

Even insulin therapy does not reinstate a permanent normal pattern of glucose homeostasis, and carries an increased risk of atherogenesis and hypoglycemia[1]. Regardless of the type of diabetes, patients are required to control their blood glucose with medications and/or by adhering to an exercise program and a dietary plan. Insulin therapy by injection is given to those with IDDM and also to some patients with NIDDM when oral hypoglycaemic drugs fail to lower blood glucose. Due to modernization of lifestyle, NIDDM is becoming a major health problem in developing countries. Patients with NIDDM are usually placed on a restricted diet and are instructed to exercise, the purpose of which primarily is weight control. If diet and exercise fail to control blood glucose at the desired level, oral antidiabetic medication is prescribed. Several plants have been reported for their insulin stimulation and mimetic activities (Table 1).

Table-1
Some important medicinal plants with antidiabetic properties[6,8,9]

S. No.	Botanical name	Common names	Family	Beneficial effects
1.	*Aloe vera*	True aloe, Ghritakumari	Liliaceae	Hypoglycemic, wound healing in diabetics
2.	*Amaranthus caudatus*	Amaranth tender, Chaulai sag	Amaranthaceae	Hypoglycaemic activity
3.	*Boerhaavia diffusa*	Hogweed, Punarnava	Nyctaginaceae	Increases plasma insulin concentration and insulin sensitivity
4.	*Azadirachta indica*	Neem	Meliaceae	Hypoglycemic, reduces peripheral utilization of glucose and glycogenolytic effect
5.	*Caesalpinia bonducella*	Yellow nicker, Kantkarej	Caesalpiniaceae	Hypoglycemic, insulin secretagogue, hypolipidemic activity
6.	*Ficus benghalensis*	Indian banyan, Indian fig, Bengal fig	Moraceae	Hypoglycemic, hypolipidemic, inhibits insulinase activity from liver and kidney, Insulin mimetic activity
7.	*Glycyrrhizae radix*	Liquorice root, Mulethi	Fabaceae	Hypoglycemic activity
8.	*Gymnema sylvestre*	Gudmar, Madhunashini	Asclepidaceae	Stimulation of repair or regeneration of beta cells, anti-hyperglycemic effect, hypolipidemic

S. No.	Botanical name	Common names	Family	Beneficial effects
9.	*Momordica charantia*	Bitter melon, Bitter gourd	Cucurbitaceae	Insulin mimetic activity
10.	*Phyllanthus emblica*	Indian gooseberry, Amla	Phyllanthaceae	Decreases lipid peroxidation, antioxidant, hypoglycemic
11.	*Punica granatum*	Pomegranate	Lythraceae	Antioxidant, anti-hyperglycemic effect
12.	*Pterocarpus marsupium*	Indian kino tree, Indian Malabar, Vijaysar	Fabaceae	Hypoglycemic, insulinogenic-enhance insulin release
13.	*Syzigium cumini*	Jambul, Jamun	Myrtaceae	Hypoglycemic, anti-oxidant activityty, α-glucosidase inhibitory activity
14.	*Swertia chirayita*	Indian gentian, Chirayata	Gentianaceae	Stimulates insulin release from islets
15.	*Terminalia bellerica*	Bahera, bastard myrobalan, Bibhitaki	Combretaceae	Hypoglycemic, antioxidant, hypolipidemic activity
16.	*Terminalia chebula*	Myrobalan, Harra, Haritaki	Combretaceae	Hypoglycemic, antioxidant, hypolipidemic activity
17.	*Tinospora cordifolia*	Amrita, Guduci	Menispermaceae	Anti-hyperglycemic, stimulates insulin release from islets
18.	*Trigonella foenum-graecum*	Fenugreek, Methi	Leguminosae	Hypoglycemic activity, stimulates insulin release by islet cells

SYNTHETIC DRUGS AND HERBAL MEDICINE

Oral antidiabetic agents exert their effects by various mechanisms: (1) stimulation of β-cells in the pancreas to produce more insulin (sulfonylureas and meglitinides), (2) increasing the sensitivity of muscles and other tissues to insulin (thiazolidinediones), (3) decreasing gluconeogenesis by the liver (biguanides), and (4) delaying the absorption of carbohydrates from the gastrointestinal tract (α-glycosidase inhibitors)[6].

A major effort was directed toward discovery of novel antidiabetic agents, which resulted in the discovery of several patented compounds: cryptolepine, maprouneacin, 3β, 30-dihydroxylupen-20(29)-en-2-one, harunganin, vismin, and quinines[7]. Galegine was isolated as an active antihyperglycemic agent from the plant *Galega officinalis* L. used ethnomedically for the treatment of diabetes. Galegine provided the template for the synthesis of metformin and opened up interest in the synthesis of other biguanidine-type antidiabetic drugs[2].

Since the hydrolysis of dietary carbohydrates such as starch is the major source of blood glucose, it is believed that the inhibition of the carbohydrate hydrolytic enzymes may be a promising strategy for the management of NIDDM. Phytochemicals such as phenolics with strong antioxidant properties have been reported to be good inhibitors of the enzymes linked to NIDDM. Phenolic extracts of plants were found to be effective inhibitors of intestinal α-glucosidase and are being used to control NIDDM. Some polyphenolic compounds from plants are known to cause insulin like effects in glucose utilization in mammals. *Aloe vera*, bitter gourd, guduchi, *Gymnema sylvestre* (gudmar), neem, methi, *Syzygium cumini* (jamun) and pomegranate etc. are some most commonly used plants which have antidiabetic properties[7,8]. Several mechanisms have been investigated to explain the antihyperglycemic action of medicinal plants, which include modulation of insulin secretion, insulin-mimetic effect and inhibition of intestinal glucosidase activity[7,9]. Some important commonly used medicinal plants having antidiabetic properties and their beneficial effects are presented in Table 1.

DIABETES AND DIET

The uncontrolled diabetes can lead to long-term organ damage, resulting sometimes in heart disease, stroke, vision loss, kidney failure, foot amputation or death, studies show. The diet frequently recommended for people who suffer from diabetes is one that is high in dietary fibre, especially soluble fibre, but low in fat (especially saturated fat) and sugar. Highly processed, calorie-dense, nutrient depleted diet leads to exaggerated increase in blood glucose and lipids that induces immediate oxidative stress[5,10].

A statement of American Diabetes Association recommended the medical nutrition therapy (MNT) for diabetics. MNT is important in preventing diabetes, managing existing diabetes, and preventing, or at least slowing, the rate of development of diabetes complications. MNT is an integral component of diabetes self-management at all levels of diabetes prevention[4].

The MNT recommendations include[4]

(a) Energy balance, overweight, and obesity:

- In overweight and obese insulin resistant individuals, modest weight loss has been shown to reduce insulin resistance. Thus, weight loss is recommended for all overweight or obese individuals who have or are at risk for diabetes.
- For weight loss, either low-carbohydrate or low-fat calorie-restricted diets may be effective in the short-term (up to 1 year).
- For patients on low-carbohydrate diets, monitor lipid profiles, renal function, and protein intake (in those with nephropathy) and adjust hypoglycaemic therapy as needed.
- Physical activity and behavior modification are important components of weight loss programs and are most helpful in maintenance of weight loss.

(b) Primary prevention of diabetes

- Among individuals at high risk for developing NIDDM, structured programs emphasizing lifestyle changes that include moderate weight loss (7% body weight) and regular physical activity (150 min/week) with dietary strategies including reduced calories and reduced intake of dietary fat can reduce the risk for developing diabetes and are therefore recommended.
- Individuals at high risk for NIDDM should be encouraged to use dietary fiber (14 g fiber/1,000 kcal) and foods containing whole grains (one-half of grain intake).

Inhibition of pancreatic α-amylase could result in the abnormal bacterial fermentation of undigested carbohydrates in the colon and therefore mild α-amylase inhibition activity is useful. Plant derived compounds are reported to have strong inhibitory activity against α-glucosidase and mild α-amylase inhibition. High fibre content may further improve the satiating effect of the diet and a diet rich in soluble fibre, including oat bran, legumes, barley and most fruits and vegetables, has the most beneficial effect on blood lipids and blood pressure levels[10]. Pulses are important in the diet as their effect on blood glucose is less than that of most other carbohydrate containing foods. Green leafy vegetables rich in fiber help to lowering down the blood sugar levels and thus are healthy.

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FORMATION AND IMPORTANCE OF BIOFILM

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Biofilm can be defined as microbial communities attached to a surface. Biofilm-associated cells are differentiated from their planktonic (free-swimming or suspended) counterparts by generation of an extracellular polymeric substance (EPS) matrix, reduced growth rates, and the up- and down-regulation of specific genes. An established biofilm provide an optimal environment for the exchange of genetic material between cells. They also show greater resistance to antibiotics since they present penetration barrier to such agents. Biofilms affect public health because of their role in certain infectious or chronic diseases and in a variety of medical device-related infections. This review focuses on the process of biofilm formation, their distribution, along with their industrial and clinical significance. A greater understanding of biofilm processes would lead to novel, effective biofilm-control strategies and a resulting improvement in patient management.

INTRODUCTION

A biofilm is a complex aggregation of microorganisms growing on a solid substrate, varying in thickness from a mono cell layer to 6-8 cm thick, but mostly on an average of about 100 μm in thickness. Biofilms are characterized by structural heterogeneity, genetic diversity, complex community interactions and a hydrated extracellular matrix (ECM) of polymeric substances[1]. The first colonists facilitate the arrival of other cells by providing more diverse adhesion sites and building the matrix that holds the biofilm together. Only some species are able to attach to a surface on their own. Others usually anchor themselves to the matrix or directly to the earlier colonists. Once colonization has begun, the biofilm grows through cell division[2]. A single bacterial species can form a biofilm, but in natural environment, it often comprises various species of bacteria, fungi, algae, protozoa and debris along with corrosion products[2].

BACTERIAL BIOFILM

In their natural environment, biofilm commonly consists of aggregates of bacteria, encased in a mucoid polysaccharide structure, often growing as populations attached to surfaces. It represents microbial societies with their own defense and communication systems. It may be a pure culture derived from a single type of microorganism or more often, a mixed culture of multiple microorganisms[3]. Bacterial biofilms formed by *Pseudomonas aeruginosa, P. fluorescens, Escherichia coli, Staphylococcus* and *Vibrio cholerae* have been studied in some details. In some hardy microbial communities, bacteria like nontuberculous mycobacteria, *Pseudomonas aeruginosa*, *Legionella pneumophila* etc. not only survive but proliferate and wait for susceptible hosts[4]. A number of mechanisms, including drug

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efflux pumps, drug diffusion and penetration through the ECM, have been proposed as mechanism for the resistance of bacteria, growing as biofilm[5]. However, none of these mechanisms alone can explain the phenomenon of increased resistance associated with biofilm. Other studies have identified genetic components required to form single-species bacterial biofilm or quorum sensing signals (acyl-homoserine lactone) in *P. aeruginosa* biofilm[6].

DISTRIBUTION OF BIOFILM

Biofilms are common in nature and appear in our everyday life in more than one form, since bacteria commonly have mechanisms by which they can adhere to surfaces and to each other[1]. Recent advancements in technology have brought to use a plethora of devices, so that many humans will host a biomaterial, and will therefore be at risk of biofilm infection. The surfaces for biofilm growth include rocks in water, food stuff, teeth and various biomedical implants like artificial hearts, joint replacements, orthopedic implants and other prosthetic devices, contact lenses, heart valves, vascular prostheses, dental implants, intrauterine devices, temporary-indwelling, intravascular catheters and reverse osmosis membrane filters[1,7]. These devices are mostly made of inert metals, vitallium (cobalt-chromemolybdenum), titanium, stainless steel, plastics and other synthetic products like polyethylene, polyethylene terepthalate (dacron), polymethyl methacrylate, silicone rubber, polytetra fluoroethylene (teflon) and polyvinylchloride. After the biomaterial is implanted, either tissue cells or microorganisms will begin to colonize it. If the tissue cells colonize first, the implant will most likely be successful. If the bacteria colonize first, many microorganisms can adhere to the surface of the implant, leading to colonization[8]. Microbial infections can form on biomaterials that are totally inside the human body or partially exposed to the outside. In industrial environment, biofilms are encountered on the interior of slime-clogging drainpipes[9].

BIOFILM FORMATION: FACTORS AND MECHANISM

Biofilm development is conceived as a developmental process in which free swimming cells attach to a surface, first transiently and then permanently, as a single layer. This monolayer of immobilized cells gives rise to larger cell clusters that eventually develop into a three-dimensional structure, consisting of large pillars of bacteria, interspersed with water channels[10]. Comprehensive studies in recent times have been made with respect to *V. cholerae*. The *V. cholerae* monolayer, a distinct stage in biofilm development, requires a combination of pili, flagella and exopolysaccharide. The environmental signals, bacterial structures and transcription profiles that induce and stabilize the monolayer state are unique. The cells in a monolayer are specialized to maintain their attachment to a surface. The surface itself activates mannose-sensitive haemagglutinin type IV pilus (MSHA)-mediated attachment, which is accompanied by the repression of flagellar gene transcription[11]. In contrast, the cells in a biofilm are specialized to maintain intercellular contacts. The progression to this stage occurs when exopolysaccharide synthesis is induced by environmental monosaccharides. Thus, the proposed model for biofilm development in natural environment is (i) cells form a stable monolayer on a surface, (ii) when biotic surfaces are degraded with the subsequent release of carbohydrates, the monolayer develops into a biofilm[12].

Regarding the biofilm production in the laboratory, the pioneering studies were made by Cholodny, Henrici and Zo Bell, more than 50-60 years ago. Usually the methodology involved was unmersion of glass slides into natural environments and observing the biofilm developed, under microscope. The adhesion and attraction of the bacteria to the surface may be brought about by different mechanisms, including surface charge, gravity, Brownian motion and chemo attraction, provided

the surface has nutrients. After attraction, the attachment of bacteria to the surface occurs by a two-step process, comprised of reversible binding[13]. The reversible binding is usually brought about by weak Van der Waals forces to hold the bacterium close to the surface, before a stronger attachment can arise by a combination of both physical and chemical forces. The production of exogenous polysaccharides, containing the material exuded by bacteria, is one of such chemical substances implicated, also called as the glycocalyx. The bacteria divide and grow freely within this glycocalyx to form microcolonies, eventually forming a biofilm[3]. The biofilm formation is partially controlled by quorum sensing, an interbacterial communication mechanism dependent on population density.

The adhesion capability of the invading microbe(s) depends on the nature and type of surface/environment, surface-shape/homogeneity, charge/lack of surface charges, electrolyte concentration, hydrophobicity, flux materials, hydrodynamics/flow characteristics, nutrient availability at the surface, nutrient concentration, proper pH and temperature availability etc[14]. The usual surface types that facilitate biofilm formation include high surface energy materials (for instance, negatively charged hydrophilic materials like glass, metal or minerals) or low surface energy materials (low positively- or low negatively- charged hydrophobic materials like plastics made up of organic polymers)[15]. A higher surface energy denotes higher activity, leading to more adsorption of dissolved solutes or nutrients, which in turn, affects the rate of bacterial colonization of the surface[16]. On the other hand, the rate of biofilm growth is governed by factors like rate-limiting nutrient penetration (culture and environment-dependent), nature of anaerobic and aerobic areas within the biofilm and heterogeneous versus homogeneous populations[17].

The sequences of events that occur during biofilm formation can be summarized as follows: (i) one or more bacterial organisms are attracted to a surface, influenced by the factors as mentioned above, (ii) The primary colonizing bacteria attaches to the surface and multiplies, producing an altered microenvironment around the established micro colony by its metabolic activity, (iii) homogeneous environment is converted to a heterogeneous one, which, in turn, attracts other bacterial species, (iv) A succession of colonizing bacteria attach on to the surface, resulting in the formation of a biofilm, until a series of complex communities result[2,13].

BIOFILM FORMATION OFFERS SELECTIVE ADVANTAGE TO THE CONSTITUENT MICROBES

The adhesion to the surfaces provides considerable advantages for the sessile biofilm-forming bacteria, as compared to the planktonic growth. These advantages include innate protection from antimicrobial agents and exchange of nutrients, metabolites or genetic material between the microorganisms. Such syntrophism actually benefits the growth and survival of the participating bacteria[18]. Each bacterial community either helps the other with metabolic by-products or being helped in return, since they are held together by the glycocalyx.

(i) Protection from antimicrobial agents : The antimicrobial agents are capable of easily eradicating planktonic population of bacteria, as compared to the sessile forms. Previously, the exopolysaccharide glycocalyx was considered to be the physical barrier, not allowing the antimicrobial agents to reach the microcolonies of sessile bacteria. However, analysis by confocal scanning laser microscopy (CSLM) and Fourier transmission infrared spectroscopy (FTIR) have helped to develop a variant concept of biofilm and sessile bacteria. At the University of Calgory, a FTIR study undertaken by Jana Jass and colleagues showed that although the antibiotics are able to penetrate the biofilm rapidly and reach the

surface below the film, they are incapable to penetrate effectively the sessile cells located in clumps or microcolonies[3]. The antibiotics being effective against the planktonic population and a few sessile cells on the outer edges of microcolonies; the inner cells remain viable after cessation of the antibacterial treatment. Biofilm-sessile organisms can require 50 to 600 times the planktonic minimal bactericidial concentrations (MBC) to control an infection[19]. An earlier observation has clearly shown that the biofilm inhibitory concentrations (BICs) were much higher than the corresponding conventionally determined minimal inhibitory concentration (MICs) for the beta-lactam antibiotics[20]. The repeated use of antimicrobial agents can cause bacteria within the biofilm to develop an increased resistance to biocides. As a rule, slow growing or dormant microorganisms are far less susceptible to antimicrobial agents, as compared to viable, log-stage growth cycles, found usually in liquid culture of free cells[19]. In the latter case, the cells experience uniform exposure to or physical contact with the antibiotics. The drastically enhanced resistance of *Candida* biofilm against most antifungal agents (with the exception of echinocandins and lipid formulations of amphotericin B) contributes to the persistence of this fungus, despite antifungal therapy[21]. However, countering the theory of impaired antibiotic access, alternative explanations have been offered by other scientists, on the basis of possible physiological differences between sessile and planktonic bacteria, such as growth rates and adherence-dependent differential gene expression. In fact, researchers have now shown that a bacterium which attaches to a surface "turns on" an altogether different set of an array of genes, which makes it effectively a significantly different organism to deal with[22].

(ii) Nutrient exchange : The concentration of available nutrients in the biofilm directly affects the growing cells within it. The polyanionic exopolysaccharide matrix, surrounding the microcolonies of sessile bacteria, serves as an ion-exchange column, concentrating nutrients and ions, especially cations, from the surrounding fluid, leading to an increased availability of nutrients for growth[23]. The presence of concentrated nutrients in the biofilm helps the sessile bacteria to tide over adverse bulk fluid conditions which directly hamper planktonic growth. The multispecies microconsortia facilitate interspecies substrate exchange or removal and allocation of metabolic products.

(iii) Dehydration-free : The presence of highly hydrated glycocalyx, which binds water molecules, protects the sessile bacterial cells within it from the effects of desiccation[23]. The same safeguard is unavailable to the planktonic bacteria, which are directly dependent on the availability of water in the immediate surrounding.

(iv) Higher metabolic activity : It was demonstrated by M. Fletcher at the University of Maryland that bacteria attached to a surface are more metabolically active than planktonic bacteria. A consortium of bacterial species within the biofilm interact with each other in several ways, such as removal of toxins produced by one species, degradation of complex substrates or compounds like cellulose to be utilized as an energy or carbon sources, recycling of substances produced on lysis or death of cells etc[24]. Close proximity of different microbial colonies ensures combined metabolic capabilities in bringing about rapid substrate degradation, leading to the enhancement of previously mentioned advantages of a sessile mode of growth. It also warrants transfer of plasmid DNA and acquisition of new genetic trait, thereby conferring beneficial capabilities to the recipient. The altered gene expression and increased opportunities for horizontal gene transfer are recognized as consequences of the association of microbes with surfaces[25].

SIGNIFICANCE OF BIOFILM

A. Positive effects : Although biofilm normally cause infection, they can sometimes be beneficial.

For example, biofilm can be used for water treatment, in that they can break down undesirable compounds, thereby purifying the water[26]. Many sewage treatment plants include a treatment stage, in which waste water passes over biofilm grown on filters, which extract and digest harmful organic compounds. A biofilter is one of several air pollution control technologies that use microorganisms to treat odorous air. The biofilter has fans, ducts, media support, air plenum and biofilter media. The ventilation wall and pit fans blow air from the building and pit through ducts into the plenum below the biofilter media[27]. The air passes from the plenum through the biofilter media where the microorganisms treat it before it exhausts to the atmosphere[28]. A well-managed biofilter can reduce odor emissions by 85%, hydrogen sulfide by 90% and ammonia by around 60%. The emission reductions can vary widely from 20% to nearly 100%[29]. The biofilter media moisture content and residence time (the time required for the air to pass through the biofilter media) are the key factors that regulate effectiveness.

B. Negative effects :

i. Industrial problems : As already mentioned earlier, the physical presence of biofilm either damages surfaces or causes obstruction so that the efficiency of the surface is reduced. This kind of surface damage is collectively termed as "biofouling". It causes corrosion or deterioration of the interior of metal pipelines, storage tanks or vessels, computer chips, contamination of food, pharmaceutical and medical products, equipment failure, energy loss through inefficient energy transfer and decreased productivity[27,30]. The biofilms on floors and counters can make sanitation difficult in food preparation areas. Biofouling is also commonly found in the shipping industry. The microorganisms like bacteria or algae can form a microfilm on the hull of a ship. This biofilm can then serve as an attractive substrate for the attachment of macroorganisms like seaweed or barnacles. This macrocoating fouls the hull, and can retard the efficiency of the vessel[31].

(ii) Clinical disasters : Transitioning from acute to chronic infection is frequently associated with biofilm formation. Biofilm colonizing and spreading along implanted tubes can lead to pernicious infections in patients. Due to resistance to antimicrobial agents, biofilm often cannot be removed from biomedical devices, causing significant morbidity or occasional mortality[32]. In a medical set-up, a range of apparatuses, which are in contact with water, find several applications. The common examples can be water filter systems, used in dialysis units or elsewhere, dental units, section apparatuses, artificial ventilator pipes, gas tubes etc. The usual spectrum of problems, which bacterial biofilm present in the above mentioned systems, include insulation against heat exchange, reduction of fluid/water flow and harboring water-borne potential pathogenic microorganisms. Such processes are seen to occur in most of the systems where the ambient physical conditions favor the growth of microorganisms. An additional problem is the development of encrustation and consecutive obstruction in the biomaterials like central venous catheters[33]. The body surfaces, especially skin, have a wide range of microbial flora, being dominated by *Staphylococcous epidermidis*. Such bacteria quickly invade the implants and form extensive biofilm. Occasionally, the infection may reach grevious proportions and cause severe complications, such as *Staphylococcus aureus* infection of intravascular catheter, leading to heart wall colonization and endocarditis[34]. This colonization may present the need for additional operations, amputation, or it may even lead to death. *Pseudomonas aeruginosa* or *S. aureus* biofilms are the predominant cause of chronic airway infection in cystic fibrosis[18]. The dental plaques or dental diseases are another common clinical sign of the occurrence of biofilm.

The modification of the biomaterial surface seems to be the most promising prevention strategy for bacterial biofilm. The factors governing the eradication of a biofilm is a function of the organisms in the biofilm, biofilm age, the antimicrobial agent used and the dwell/duration of the treatment[35]. The most effective antimicrobial agents are those (i) that are less affected by the EPS matrix of the biofilm, (ii) that have a more rapid bactericidal effect, or (iii) for which the mechanism of action is not dependent upon the growth rates of the organisms[19]. The prophylactic use of antibiotics at the time of insertion of such implants is indicated to reduce the rate of infection and limit the secondary infection arising out of the prosthesis or eliminate any contaminating bacteria at the time of insertional surgery. The current antibiotic therapies are reported to have limited effectiveness in resolving biofilm infection. Strategies such as the antimicrobial lock treatment (ALT) have often been used for treatment. This approach involves the instillation of high concentrations of the antimicrobial agent directly into the biofilm-containing catheter, allowing sufficient exposure (i.e., dwell) time to eradicate the biofilm[36]. However, fungal biofilms have proven to be much more difficult to treat using the ALT, though newer fungicidal drugs such as the echinocandins hold promise in this regard[37]. Another serious drawback with the ALT is the potential for the development of resistance. The promising technologies that incorporate novel approaches such as ultrasound, bacteriophage, quorum-sensing inhibitors, or enzymes may provide useful approaches in future. Model systems should be developed and used to study biofilm processes on several indwelling medical devices. A comprehensive study of the cell signaling process or molecular responses, at the level of gene regulation might also provide better knowledge of the mechanism of biofilm formation, enabling more efficient prevention in future.

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SURFACE STRUCTURE OF PLANETARY BODIES—THE MOON

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Excepting the planet earth, which has been studied primarily by the geologists and geophysicists, for explaining surface characteristics of all other planetary bodies, including the pock-marked structures prominently preserved over the surface of the Moon, mostly astrophysicists have so far taken the leading role for explaining the relevant features. Most scientists consider that the pock-marked structures over planetary bodies are formed due to impact of external objects like meteorites of various shapes and sizes. The impact theory has been considered to be more convincing because of the fact that meteorites do strike over the surface of the earth, as well as, other planets and planetary bodies, sometimes in the form of showers. Despite the fact that meteorites sometimes strike the planetary surfaces, such phenomenon cannot be taken for granted for producing pock-marks for the simple reason that the impacted objects, under such circumstances, would be pulverized and, also, in most cases, would thoroughly deform the surrounding zones around the point of impact. In this paper formation of perfectly circular depression, often with a peak formed precisely at the geometrical central point of the depressed circles of various sizes, have been considered to be the impression of a silicate melt undergoing rapid cooling at the penultimate stage of solidification.

INTRODUCTION

In contrast to the pock-marked Moon-like surface, the surface features of the planet earth, investigated in detail by geologists, show completely dissimilar characteristics. While earth-like crustal features have also been detected in some of the inner or terrestrial group of planets, the solid crusts of the outer planets in general have remained concealed under the thick veil of dusty or cloudy matter. The outer planets, also known as giant or gas planets are, nevertheless, additionally endowed with a spectacular ring system around their equatorial plane. Besides, planets and planetary moons, which are basically of spherical shape, large number of objects of smaller dimension and of irregular shape that revolve around the Sun, occur in the asteroid belt. These are usually characterized by smooth surface invariably associated with potholes or pitted structures. It has been taken for granted by most scientists that the pock-marks observed on the surface of the Moon has been caused by impact of meteorites of various shapes and sizes. The evidences in support of such impacts that resulted in formation of the pock-marks are considered to be impact melt pools and breccias, complex morphology of the structures associated with a central peak and malty-ring basins etc. The author argues that the evidences that have so far been put forward in support of impact phenomenon are in fact caused due to solidification of the of the surface of the Moon from its original stage when it was a silicate melt and cannot be formed due to impact of meteorites.

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POCK-MARKED PLANETARY SURFACES

Presence of numerous circular pock marks are visible over the surface of the terrestrial Moon and many other planetary objects of the Solar System. These features, commonly observed over the satellites of planets or small-sized planetary bodies, have been considered by most scientists to be caused due to impact of external objects or meteorites falling over the surface of the relevant planetary bodies. This theory has been considered to be more convincing because of the fact that meteorites do strike on earth and other planets, sometimes in the form of showers. Despite the fact that every now and then meteorites strike the planetary surfaces, such phenomena cannot be taken for granted to be responsible for producing all pock-marked surfaces[1,2]. It is reasonable to think that very large size circular marks - which are common in many planetary bodies - cannot be caused by bombardment of very large size meteors for the simple reason that such events would either pulverize the striking planetary object or thoroughly deform it. In support of these views example of the planetary satellite Mimas, one of the large moons

Figure 1, Typical pock-marked structures exhibited on the surface of the Moon (Credit NASA). Note the perfectly circular outline with raised circular ring forming the boundary in all pock marks. Such marks cannot be caused due to impact of meteorites.

of the planet Saturn which is, in most cases, pitted with relatively small pock marks although an exceptionally large crater is also found on the satellite's surface, which has been named Herschel, after the distinguished scientist. Compared to 394 km diameter of Mimas, Herschel crater's diameter is 130 km while its depth is 10 km. If the impact crater theory is correct, how the satellite Mimas can retain its perfect spherical shape, despite a meteor of such gigantic dimension fell over it? Further, it is also unreasonable to think that under such circumstances all impact marks would essentially show perfectly circular outline as has been found in Mimas.

CRUST FORMATION OF PLANETARY BODIES – FLUID TO SOLID STATE

To a geologist for studying structural features of the crust, in addition to the associated characteristics, the sequence of events that have taken place since their formative stage are also significant. Analysis of such events gives a completely new turn in our understanding on the pock-marked surfaces of planetary bodies. The planetary bodies are considered to have passed through a boiling state before attaining its present condition characterized by solid crustal surface. For example, in case of the terrestrial Moon it is reasonable to consider that it too had to pass through a boiling condition before attaining its present state. Under such condition of passing phases from liquid to solid, innumerable marks with perfectly circular outline would be produced over the magma surface. These marks are caused by boiling of the magma in a rapidly cooling environment associated with widespread degassing or escape of volatiles. Many interpreters on origin of planets, especially the earlier ones, considered that in the formative stage, the planets were in a fluid and super-heated state. Because of cooling due to loss of heat from the initial gaseous condition, the planetary bodies gradually passed in to a liquid stage, eventually turning into solid units. These changes, manifested mainly on the rocky planets, appear to be particularly relevant to the upper-most crustal parts and mantle. In the penultimate and final stages of boiling and gas emission, the medium would become semi-fluid with production of large

numbers of perfectly circular marks over it which would be preserved when its surface finally turned into solid, retaining the perfectly circular outer wall as well as a minute peak or blob at the geometrical centre of these circular structures. It can be interpreted that the boiling marks were initially cropped up as minute blobs but with time, facilitated by escape of volatiles, their dimension continued to grow outwardly keeping their circular outline intact. The emission of volatiles would significantly accelerate due to the gravitational force exerted by an external object which in case of Moon was obviously the planet earth.

The pock-marked Moon surface, shown in figure 1, reveals that :

(1) There are innumerable numbers of pock-marks over the surface of the Moon. These are found to occur in diverse dimensions, varying between the sizes of very small orifice and large epicontinental or inland sea which are known as maria.

(2) All these openings over the planetary bodies are perfectly circular in shape.

(3) Close observation reveals that relatively smaller pock marks are occurring over the bigger ones while the reverse is not true.

(4) Smaller the marks, their circular shape are better preserved. With increase in size of the pock-marks, the circular shape are retained although not as sharply as in the smaller ones.

(5) Smaller the size of the circular basins, their relative depths are more in comparison to the bigger ones and are generally conical in shape.

(5) The floors of the bigger basins are flat, relatively shallow and appears to be raised.

(7) Overlapping of the smaller pock marks over the peripheral border of larger ones has been observed whereas the smaller ones cut by the bigger marks is totally absent.

(8) Large size depressions or marias are marked by indistinct and distorted borders, within which smaller pock-marks and small protruded hillocks are occasionally present.

(9) The hillocks are located closer to the periphery of the mare and appear to be broken and disjointed parts of peripheral border of maria.

(10) Typical geological structures, as observed over the surface of the earth, such as, folds and faults are generally absent over the pock-marked surface of the Moon and other planetary bodies.

CONCLUSION

The above mentioned characteristics of the pock-marked surfaces can be interpreted in the following manner :

These structures appear to mark the concluding and penultimate stages of solidification of the thick semi-fluid magma that formed the crustal layer of the Moon and can be considered to be formed by somewhat similar process like boiling of fluid objects, fluid food or similar items. With the process of boiling of the semi-fluid magma, when it reaches the final stage of solidification, a number of small orifices started to pop up over their surfaces and tend to enlarge in dimension keeping their circular shape intact. Through these orifices volatiles readily escaped enhancing the process of solidification. In case of planetary bodies, it is most likely that the process of ejection of volatiles was greatly facilitated by the gravitational attraction of external planetary sources which also enhanced the dimension of the circular orifices or basins. The lava emission would continue to extrude or rise up through the orifice of the large-sized basins, thereby raising the basin floor, in consequence of which it attained a flat

appearance. In case of very large basins of the size of epicontinental sea, their peripheral walls may be weakened and broken down due to outwardly directed pressure exerted in consequence of increase of size of the circular depression. The detached broken parts would be embedded in the interior parts of the circular basin to form hillock-like structures while their original wall-like circular fence, would continue to widen with some gaps formed due to detachment of the broken parts of their wall. With complete solidification of the upper most crustal part of the planetary bodies, the above-mentioned structures would be perfectly retained over their surface.

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KNOW THY INSTITUTIONS

NATIONAL INSTITUTE OF INTERDISCIPLINRY SCIENCE & TECHNOLOGY, THIRUVANATHAPURAM

National Institute for Interdisciplinary Science & Technology (NIIST) located at Industrial Estate, Pappanamcode, Thiruvanathapuram, Kerala is one of the major research laboratories of Council of Scientific Industrial Research (CSIR), which undertakes R&D projects of both basic and applied nature in a number of areas of fundamental importance to the country. Founded as a Regional Research Laboratory, the Institute acquired excellence in may frontier areas of research and gained multi-disciplinary expertise and infrastructure. The institute has accomplished national visibility and international presence justifying its diverse mandates, which include development of technologies for the effective utilisation of regional resources, generation of scientific knowledge pertaining to basic and applied sciences, dissemination of information and human resource development. Scientists of the institute have bagged many national and international awards also.

It got renamed as National Institute for Interdisciplinary Science & Technology (NIIST) in 2007 in view of its orientation towards interdisciplinary character. At present, the institute is well poised to meet the challenges of globalized economy, while continuing to cater the regional needs in agro products, materials and energy. NIIST is in the path of becoming a 'Centre of Excellence' of international standard, piloted by a vision-enabled strategic plan under the dynamic leadership of the present Director.

The institute was established as CSIR - Trivandrum Complex in October 1975 based on a request from Kerala Chief Minister, Shri C. Achutha Menon in 1971. As suggested by the Chief Minister,

Erstwhile Industrial Testing and Research Laboratory (ITRL) at Thiruvananthapuram was taken up by CSIR to establish the complex. Later, based on the recommendations of the Executive Committee of the CSIR -Trivandrum complex, the Governing Body of CSIR approved renaming the complex as Regional Research Laboratory, Trivandrum (RRL-T) on 6th October 1978. RRL, Trivandrum in its infancy had four Divisions namely Materials, Glass & Ceramics, Food & Spices and System Planning and Research Management and the Laboratory took up research in areas based on mineral, agricultural, forest and marine resources of Kerala, which were not receiving adequate attention in the other existing laboratories of CSIR. RRL, Trivandrum scaled new peaks under the able leaderships of its Former Directors Prof. P. K. Rohatgi, Dr. A. D. Damodaran, Dr. G. Vijay Nair and Prof. T.K. Chandrashekhar.

The Laboratory has five major divisions namely Agro-processing & Natural products, Biotechnology, Chemical Sciences & Technology, Material Sciences & Technology, Process Engineering & Environmental Technology. NIIST takes up Contract Projects (Sponsored, Collaborative/Consultancy) as well as testing and analysis from industries. NIIST has several national and International linkages bonded through R&D, Academia and industry chains. The Laboratory has many high impact Publications, Potential Patents and illustrious Technology Transfers to its credit. It also plays a significant role in the Human Resource Development arena by training Post Graduate students and generating PhD Personnel.

SOCIETAL PROGRAMMES

The institute has an active programme targeting societal development. Recently CSIR has identified CSIR-800 as a thrust area with a vision of inclusive growth and improvement in the quality of life of the 800 million people at the bottom of economic pyramid, through S & T interventions. Under this scheme NIIST has taken up a project named Green Enterprises for Micro-Sector (GEMS). A number of technologies that have the potential to crate green micro-enterprises that generate income and employment for low income groups and are at the same time beneficial to the environment, have been identified, namely (i) environment friendly extraction of natural fibers, (ii) natural fiber based biodegradable household articles, (iii) value addition of under-exploited and underutilized agro products, (iv) agro-technologies for cultivation and post harvest management of medicinal, aromatic plants and (v) development of green household sanitation devices. Linkages are being built up with NGOs and appropriate Governmental bodies for delivery of the technologies in a way that would benefit large number of people in the low income group The institute has also been supporting in Kerala Tile Sector in modernization of infrastructure, training manpower and setting up quality control laboratories. Studies on industrial feasibility for preparation of coir and banana fiber reinforced polymer composite panels and building components have also been conducted.

AGROPROCESSING AND NATURAL PRODUCTS DIVISION

The mission of Agroprocessing and Natural Products Division is to provide innovative high quality Scientific and technical solutions in the field of process and product development and knowledge generation in the areas related to lipid science, spices & flavors and natural products .The division's core competence is on process and product development and on the transformation of such processes into fully engineered technology packages for commercial exploitation for the benefit of society. The division has set up large number of commercial plants in many states and extended technical expertise in making policy decisions in relevant areas by governmental and non-governmental agencies. More recently the division has been focusing on exploitation of the herbal wealth of the region. Concerted effects are on to

create the required infrastructural facilities and strengthen intellectual capabilities for undertaking chemo and bio-evaluation of herbs and natural products in order to develop neutraceuticals, phytochemicals and functional food products. The division has well trained manpower, pilot plant facilities and sophisticated instrument to undertake research programmes in partnership with industries.

BIOTECHNOLOGY DIVISION

The mandate of the Division is to conduct high quality R & D in specific frontier areas of Biotechnology. Significant emphasis is put in exploration and value addition of regional bioresources while ensuring environmental sustainability. The divisional R & D and industrial consultancy activities are linked with programmes of national importance through networking with national and international organizations. Collaborative research and linkages with reputed national and international institutions is a major strength of division. The current focus areas of the division are (i) bioprocess and product development (ii) energy and environment and (iii) health and genomics, which are well aligned with priority sectors of CSIR such as Affordable health care, Energy and Chemistry & Environment. In the area of bioprocess and bioproducts, the division's emphasis is on production of industrial enzymes, biopolymers and amino acids. Considerable success has been achieved in developing microbial-based eco-friendly process for production of bioethanol from lignocellulose feed stocks. Under the energy sector, the main focus is on developing microbial based polymers such as PLA and PHB using agro residues as feed-stocks available in the country, which focus on multi feed based processes. A pilot plant is being established for the lignocelluloses bioethanol programme. Microbes have been isolated from the Western Ghats in Kerala and deposited in the NII Culture Collection, which is a registered depository for the culture collection having ~1200 actinomycetes, Yeast, bacterial and fungal cultures.

CHEMICAL SCIENCES AND TECHNOLOGY DIVISION

The vision of the division is to be internationally recognized for excellence in discovering new knowledge on functional materials and natural products/bioactive molecules and to develop such molecules/materials for industrial applications using innovative cost competitive and environmentally acceptable processing technologies. This division has the following sections : Photo sciences and Photonics, Inorganic and Polymeric Materials and Organic Chemistry. The activities of the Division are related to (i) working on fundamental and applied aspects of Photochemistry and related areas with the purpose of developing photonic materials for applications in solar energy harvesting, electro optical devices and photo medicine, (ii) design and develop inorganic materials and polymers for applications in areas relate to energy storage, lightning and molecular sensing for imaging and diagnostics and (iii) to isolate/synthesize new bioactive molecules and to develop state of the art synthetic organic methodologies for the fine chemical industry.

MATERIALS SCIENCES AND TECHNOLOGY DIVISION

The mandate of the materials Division is development of materials for strategic and societal applications. The division has activities related to nano-ceramics, electronic materials, super conducting and magnetic materials, alloys and composites. Under the nano-ceramics activity, sol-gel based processes have been developed for production of nano-rare earths phosphates and oxides, based on which a pilot plant has been set up at M/s Indian Rare Earths Ltd. Kollam (Kerala). Processes for fly ash, red mud and new clay mixes have been successfully transferred to various industries. Nano-lithium dioxide coated ceramic tiles with self cleaning and anti algal activities have been prepared based on which a plant has been set up by BHEL in Bangalore for preparation of Water

treatment membranes. The electronic materials activity lays emphasis on communication and energy. The super conducting and magnetic materials group has fabricated long length high Tc wires and tapes for cryogen free magnets and fusion magnets. The division has successfully developed materials and components for space, defence and for societal applications such as high strength aluminum and magnesium alloys with considerable grain refinement. Under the minerals area an environmentally safe process of synthetic rutile was developed and transferred to industry.

PROCESS ENGINEERING AND ENVIRONMENTAL TECHNOLOGY

This division has four sections viz, (i) Environmental Technology (ii) Computational Modeling and Simulation (iii) Chemical and Process Engineering and (iv) Dioxin Research. The environment technology group is engaged in the development of processes for odour control, anaerobic treatment for solid waste treatment, industrial water purification and activities related to Environment Impact Assessment (EIA) etc. The Computational Modeling and Simulation group carries out research work for developing software tools for casting in foundries, modelling of chemical reactions, rotary klin reactors and works related to rational design of molecules and materials. The Chemical and process Engineering group is engaged in the development of mineral beneficiation flow sheets and also reverse flow dryers for the rural sector. The Dioxin Research Unit is focusing on the monitoring, control and phase out of persistent Organic Pollutants (POPs) with special reference to dioxins and furans from various industrial and non-industrial activities in Southern states of the country. Some recent R & D achievements of this Division are : (i) Setting up of odour control plants in rubber and fish meal factories using gas biofilter technology & anaerobic leach bed technology for production of white pepper (ii) software for casting simulation 'virtual casting' and simulation of micro porosity in Aluminium castings for General Motors, USA (iii) Simulation for rotary klin for manufacture of synthetic rutile, (iv) Investigation of industrial and non-industrial sources of Dioxin and furans in southern states as a first step for the implementation of Stockholm convention in India (v) Process and flow sheet development for KCCP China clay, Guda clay, GMDC clay and silica sand etc. and development of reverse flow dryers for copra, ground nut, pappad etc.

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S & T ACROSS THE WORLD

STUDY SAID TO EXPLAIN GIANT UNDERWATER WAVES

You can't see them on a turbulent ocean surface, where they produce a rise of just inches. But internal waves, hidden totally within the ocean, can tower as high as skyscrapers, with profound effects on climate and on ocean ecosystems, scientists say.

Now new research, both in the ocean and in the largest-ever laboratory experiments to investigate them, is said to solve a longstanding mystery about just how the largest known internal waves, in the South China Sea, form, They're shaped like surface waves. But instead of forming where water meets air, they form where different layers of water meet. The difference between an underwater wave and the water around it is its density, due to temperature or salinity differences that cause ocean water to form layers.

Instruments can detect the boundary between colder, saltier water below and warmer, less-salty water above. That boundary can resemble the ocean's surface, producing waves that reach towering heights, travel vast distances, and can play a key role in the mixing of ocean waters, helping drive warm surface waters downward and drawing heat from the atmosphere, scientists say.

The new findings come from a team involving the Massachusetts Institute of Technology and other institutions, and coordinated by the U.S. Office of Naval Research. Because internal waves are hard to detect, it's often hard to study them directly in the ocean. Thomas Peacock, a mechanical engineer at MIT, joined other researchers in the study, published in the journal *Geophysical Research Letters.* They did laboratory experiments to study the production of internal waves in the Luzon Strait, between Taiwan and the Philippines. "These are the most powerful internal waves discovered thus far in the ocean," Peacock said. "These are skyscraper-scale waves."

The solitary waves have been measured to reach heights of 170 meters (more than 550 feet) and can travel at a leisurely pace of a few centimeters per second. "They are the lumbering giants of the ocean," Peacock said.

The large-scale laboratory experiments on the generation of such waves used a detailed model of the Luzon Strait's seafloor, mounted in a 50-foot-wide rotating tank in Grenoble, France, the largest such facility in the world. The tests indicated the waves are generated by the entire ridge system on that area of seafloor, and not a localized hotspot within the ridge.

The last major field program of research on internal-wave generation took place off the coast of Hawaii in 1999. In the years since, Peacock said, scientists have come to a greater appreciation of the significance of these giant waves in the mixing of ocean water—and therefore in global climate. "It's an important missing piece of the puzzle in climate modeling," Peacock said. "Right now, global climate models are not able to capture these processes," he said, but it's important to do so: "You get a different answer ... if you don't account for these waves." To help incorporate the new findings into these models, the researchers plan to meet this month with a climate-modeling team as part of an effort sponsored by the National Science Foundation to improve climate modeling. These waves may be "the key mechanism for transferring heat from the upper ocean to the depths," Peacock said.

Internal waves have been known for well over a century, Peacock said, but remained poorly understood because of the difficulty of observations. Among the new techniques that have helped is the use of satellite data: While the submerged waves raise the water surface by less than an inch, long-

term satellite data can clearly discern this difference. "From 15 years of data, you can filter out the noise," Peacock explains: Many locations, such as the Luzon Strait, generate these waves in a steady, predictable way as tides flow over submerged ridges and through narrow channels. A resulting 12-hour cycle is clearly visible in satellite data, he added. Internal waves can also play a significant role in sustaining coral-reef ecosystems, by bringing nutrients up from ocean depths, Peacock said.

SCIENTISTS DECODE OLDEST DNA OF EXTINCT HUMAN

Researchers say they have decoded a key part of the DNA for a 400,000-year-old extinct human related to a species of ancestral humans called Denisovans. The scientists were able to study DNA so old that previous samples of similar age could only be retrieved from permanently frozen ground. This sample instead came from a cave in Northern Spain.

The researchers said they determined the almost complete "mitochondrial genome," a large section of human DNA which isn't enclosed in the cell nucleus like most of the rest. Mitochondrial DNA is maternally transmitted and commonly used for ancestry studies. The Spanish cave, known as the "bone pit" or Sima de los Huesos, has yielded the world's largest assembly of ancient human fossils from the Middle Pleistocene era. Matthias Meyer and colleagues of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, developed new methods for decoding highly degraded ancient DNA. They then teamed up with Spanish paleontologist Juan-Luis Arsuaga and used the techniques on a cave bear from the site. Later the group sampled some bone powder from a thigh bone of a hominin, or extinct human relative, found there. They compared its mitochondrial DNA with that of Neanderthal people, Denisovans, present-day humans, and apes.

Based on "missing mutations," the researchers calculated that the Sima hominin lived about 400,000 years ago and shared a common ancestor not with Neanderthals but with Denisovans— an extinct group from Asia related to the Neanderthals—about 700,000 years ago. The result is also "unexpected" since the skeleton shows Neanderthal-like features, said Meyer. The bones, attributed to a species known as *Homo heidelbergensis*, may be related to the population ancestral to both Neanderthals and Denisovans, he said. This "points to a complex pattern of evolution in the origin of Neanderthals and modem humans," added Svante Pääbo, director at the Max Planck Institute.

The findings are published in the Dec. 4, 2013 issue of the research journal *Nature*. "Our results show that we can now study DNA from human ancestors that are hundreds of thousands of years old," Pääbo said. "This opens prospects to study the genes of the ancestors of Neanderthals and Deni-sovans. It is tremendously exciting."

GALAXY GROWTH EXAMINED LIKE TREE RINGS

Watching a tree grow might be more frustrating than waiting for a pot to boil, but luckily there are tree rings. Beginning at a tree trunk's compact core and moving out to the soft bark, concentric rings mark the passage of time, revealing chapters of the tree's history.

Galaxies outlive trees by billions of years. But like biologists, astronomers can read the rings in the disk of a galaxy to unravel its past, a study suggests. Using data from two NASA telescopes, scientists have gained more evidence for an "inside-out" theory of galaxy growth, showing, they say, that bursts of star formation in central regions were followed one to two billion years later by star birth in the outer fringes. "Initially, a rapid star-forming period formed the mass [material] at the center of

these galaxies, followed later by a star-forming phase in the outer regions. Eventually, the galaxies stop making stars," said Sara Petty of Virginia Tech in Blacksburg, Va. She is the lead author of a paper on the work in the October 20B issue of *The Astronomical Journal.* "This later star-forming phase could have been caused by minor mergers with gas-rich neighbors, which provide the fuel for new stars."

The discovery may also solve a mystery of elderly galaxies, she said. The galaxies in the study, known as "red and dead" for their red color and lack of new star births, have a surprising amount of ultraviolet light emanating from the outer regions. Often, that light comes from hot, young stars, but these galaxies were considered too old to host many of those, Petty explained. The solution to the puzzle is likely hot, old stars, according to the researchers. They used a new approach analyzing light at multiple wavelengths, or "colors," to show that the unexplained ultraviolet light seems to be coming from a late phase in the lives of older stars, when they blow off their outer layers and heat up.

The astronomers used two NASA telescopes, the Wide-field Infrared Survey Explorer and Galaxy Evolution Explorer. The first sees the infrared light coming from older stars, whereas the other is sensitive to ultraviolet. Both are forms of light in energy ranges, or "colors," invisible to the unaided eye. Both telescopes have large fields of view, allowing them to easily capture images of entire galaxies. "The synergy between GALEX and WISE produces a very sensitive measurement of where the hot, older stars reside in these red-and-dead galaxies," said Don Neill, co-author of the paper from the California Institute of Technology, Pasadena. "This allows us to map the progress of star formation within each galaxy."