THE WONDERFUL MARINE WORLD

Sukanya Datta

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SUKANYA DATTA

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I am particularly thankful to Shri R.S. Rawat for the cover design that has added much value to the book. The production staff at Publications Division deserves my special thanks for the care they have taken to ensure that the production standards remain flawless, as ever.

My mother has always been my rock. Despite keeping her doctors busy, she has always found time to be interested in the lives of her family members, scattered as they are across the globe. She reads a lot, but suffers from a peculiar block when it comes to matters scientific—then, a shutter descends. I am sure many others share this syndrome. Perhaps this is the reason why I chose popular science writing as my career, to share the wonders of science without intimidating the readers. And for the first time, my mother has evinced keen interest in a scientific topic...the call of the sea is hard to resist.

My sister Dr. Sutapa Ray was ever the spirit of support, despite being thousands of miles away. In a way Alexander Graham Bell who developed the telephone and Vinton Cerf, Father of the Internet deserve my thanks too, for the communication revolution that made this possible.

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—Sukanya Datta

This book is dedicated to

Mrs. Prabhati Datta.

My Mother.

Always, the wind beneath my wings.

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1. OUR OCEANS

How inappropriate to call this planet Earth when it is quite clearly Ocean.

Arthur C. Clarke

Ours is a watery planet. Salt water covers about 70 per cent of the Earth's surface. About 97 per cent of all the water found on Earth is salt water; the remaining three per cent is freshwater. These large expanses of salt water are called oceans, which the Concise Oxford Dictionary defines as, "*a great body of water surrounding the land or the globe.*"

Earth also has many seas which can be thought of as smaller branches of the oceans; some of which are wholly landlocked. The word sea is also used to describe a large saline lake that lacks a natural outlet, such as the Caspian Sea and the Aral Sea. Many seas are large enclosed bodies connected by narrow passages to the oceans. Examples include the Baltic Sea and the Black Sea. The largest seas on Earth are: South China Sea, Caribbean Sea, and the Mediterranean Sea.

Strangely enough, the Sea of Galilee is the largest *freshwater lake* in Israel and also, the lowest freshwater lake on Earth. To add to the confusion in nomenclature, the words “ocean” and “sea” are often used interchangeably.

In India, the word most often used for oceans/seas is *samudra*. The Sanskrit word *Samudra* is usually translated as ocean/sea. The word literally means “*gathering of waters*.” It is derived from two other Sanskrit words; “*sam*” meaning together and “*udra*” meaning water. The Sanskrit word *Salila* has also been used in the Rig Veda to mean unbounded ocean.

In all, oceans cover 361×10^6 sq. km, almost two-thirds of the third planet from the Sun. It was speculated that Mars may have had some water in the recent past. Traces of frozen water have recently been discovered on the Moon; also though the amount of water on lunar surface is pretty paltry. Harvesting roughly one tonne of the top layer of the Moon’s surface is estimated to yield a meagre 907 gm of water. So, it appears safe to conclude that vast expanses of liquid water currently exist nowhere else in the Solar System, except on Earth. The oceans on Earth are unique to the Solar System.

Origin of Oceans

There are several theories about the origin of the seas, but no single theory explains every aspect of this intriguing puzzle.

Most scientists agree with the hypothesis that both the atmosphere and the oceans have accumulated gradually, over

a mind-boggling time scale. According to one theory, the ocean was created when water vapour and other gases from the molten interior of Earth escaped. These later condensed to form giant clouds. After Earth's surface had cooled to a temperature below the boiling point of water, rain began to fall. This primeval rainfall continued for centuries. As the water accumulated on Earth's surface, the first-ever ocean came into existence.

There is also a rather controversial idea that collisions with comets had provided primitive Earth with most of its water. Not all scientists agree with this idea. However, at least one recent celestial event seems to have lent weight to the arguments of the proponents of this theory.

Comets are great celestial travellers and they go around the Sun in huge elliptical orbits. One such Comet-the comet C/1999 S4, also known as Comet LINEAR, broke apart as it came near the Sun. Research into the remains of the comet *has* revealed that it had contained water similar to that found on Earth.

Now, water, as every one knows, is made up of Hydrogen and Oxygen. The chemical formula of water is H_2O because each molecule of water consists of two hydrogen *atoms* bonded to an oxygen molecule. This is where Mother Nature has scripted a twist in the tale. Hydrogen has an isotope called Deuterium, which is basically Hydrogen with an extra sub-atomic particle called neutron. When Deuterium replaces Hydrogen in a water molecule we call the resultant, "heavy" water.

Waters in comets, and also in our oceans, contain small, and differing, amounts of this heavy water. Comets born in the outer solar system i.e., close to Neptune's orbit, contain ice that is relatively rich in heavy water. Thus the isotopic signature of their water does not match that of water found on Earth.

However, the isotopic signature of Comet LINEAR's water was similar to that of the water in Earth's oceans. Michael Mumma (NASA's Goddard Space Flight Center, USA) who

subsequently authored a research paper on this, exulted, “*The idea that comets seeded life on Earth with water and essential molecular building blocks is hotly debated, and for the first time, we have seen a comet with the right composition to do the job.*” He had reason enough to be excited. It has been found that the comet contained about 3.3 billion kilograms of water; enough to fill a small lake. And this was just one comet!

Recognising the Earth’s Oceans and Seas

An Indian legend holds that the Earth originally comprised of seven landmasses (*Sapta dweep*) and the seven seas (*Sapta samudra*) placed in concentric circles...the land and water forming alternating rings, which were broken up into the present configurations because of earthquakes. Almost all myths and legends talk about the “seven seas.” Bangla folklore goes a step further. It is replete with stories about royal adventures that take place beyond the seven seas and thirteen rivers...*saat samudra teroh nodi!*

It is now believed that these are merely figures of speech and not references to actual bodies of water. The argument is that the number seven occurs frequently in nature: for example the seven colours of the rainbow, and that there is no need to take the number seven at face value, so to say. Still many researchers think that if a list of the seven seas had to be drawn up, ancient seafarers would definitely include:

- The Mediterranean Sea, long celebrated as “the cradle of civilization,”
- The Adriatic Sea
- The Black Sea
- The Red Sea
- The Arabian Sea
- The Persian Gulf
- The Caspian Sea

Till 2000, only four Oceans were formally recognized. These were: Pacific Ocean, Atlantic Ocean, Indian Ocean, and Arctic Ocean. In 2000, the International Hydrographic Organization delimited the ocean around Antarctica and extending to 60 degrees latitude as a new ocean and named it the Southern Ocean.

However, despite the fact that different oceans have been named and delineated; it is important to realize that Earth’s oceans are all connected to one another. Technically speaking therefore, there is only one oceanic body on Earth. This is often referred to as the World Ocean or Global Ocean.

The ancients got it partially right when they thought that there was one huge body of water...only they thought it was a salt river that encircled the known world. They veered off course when they supposed that beyond the great salt river there was the “rim” of Earth and beyond the rim was a great void.

Ocean	Area (square kilometres)	Maximum depth (m)
Pacific Ocean	Largest ocean; larger than the total land area of the world. 155.6 million sq. km	Challenger Deep in the Marianas Trench, 11,022m deep
Atlantic Ocean	Second-largest ocean. 76.8 million sq. km	Milwaukee Deep in the Puerto Rico Trench, 8,605m deep
Indian Ocean	Third-largest ocean. 68.6 million sq. km	Java Trench, 7,258m deep
Southern Ocean	Fourth-largest ocean. 20.3 million sq. km	Southern end of the South Sandwich Trench, 7,235 m deep
Arctic Ocean	Smallest ocean. 14.1 million sq. km	Fram Basin - 4,665m deep

Comparing Earth’s Oceans

Deep Blue Sea

Ask anyone about the colour of the sea and the answer will almost always be the same. The sea is “blue.” Sailing off into the blue means disappearing into the horizon...and is supposedly a romantic thing to do. However, is the ocean really blue? And if so, why?

Initially it was thought that the oceans were blue because they reflected the blue of the sky above. Lord Rayleigh who had given the first correct explanation for the sky being blue said, “...*the much admired blueness of the sea ... is simply the blue of the sky seen by reflection.*” However, it soon became clear that this was just part of the answer and it was an Indian who first discovered the reason behind the ‘blueness’ of the oceans.

In 1921 Professor C. V. Raman went to England by sea and was fascinated by the deep blue colour of the waters. *While still on the ship he carried out a simple experiment* and discovered that the blueness of the sea was not because of the reflection of the blue sky. Rather, the blue of the sea was due to the scattering of light by the waters of the ocean. His co-passengers appeared to have been quite bemused by his actions as there are reports about the “... *extra-ordinary sight on the ship to see this turbaned Indian scientist conducting his experiments on the ship’s deck with a simple polarizing nicol prism on samples of sea water!*”

Anyway, Professor Raman’s efforts proved that the colour of seawater is due to the absorption and *refraction* of light of various wavelengths by the water and by matter suspended in it.

Particles suspended in the water increase the scattering of light. Water preferentially absorbs red light, and to a lesser extent, yellow and green light, so the colour that is least absorbed by water is blue light. Because red light is absorbed strongly, it has the shallowest penetration depth, and blue light

has the deepest penetration depth. So clear ocean water appears blue... because blue is the only colour that is not strongly absorbed by water.

Professor Raman's work on the scattering of light by liquids earned him the Nobel Prize in Physics and Raman Effect entered the Physics textbooks all over the world.

Bad News Blues

Today we know, that the surface of water can reflect up to 80 per cent of light striking it. The penetration of light has a huge role to play in determining the colour of the waters because light is important for tiny plants called phytoplankton to grow. These also serve as food to a large variety of marine fauna including fishes.

Generally, coastal waters are greenish because of the presence of phytoplankton. It is the green colouring matter or chlorophyll in these organisms that imparts a distinctly green tinge to the waters. Chlorophyll-containing phytoplankton preferentially absorbs the red and blue portions of the light spectrum (for photosynthesis) and reflects green light. So, the waters that have high concentrations of phytoplankton appear to be different shades of green; depending upon the type and density of the phytoplankton population.

Interestingly, blue water indicates a lack of phytoplankton. Such waters are called "ocean-deserts." The tropical and equatorial seas are deep blue, or indigo in colour because of poor productivity. NASA's Sea-viewing Wide Field-of-view Sensor has consistently indicated a region of the ocean where chlorophyll concentrations are lower than anywhere else. This area is in the Pacific Ocean, near Easter Island.

That the colour of living organisms in the water affects the colour of the waters too is evident in the pictures taken from space by NASA which have clearly captured the turquoise

swirls of the Malvinas Current. It is thought that the colour is because of marine plants called coccolithophorids.

Coccolithophorids secrete microscopic spheres made up of calcium carbonate plates called coccoliths. The bright white calcium carbonate spheres reflect light, producing the milky turquoise-blue colour of a coccolithophorid bloom. As the coccolithophorids are in deeper, clearer ocean water, NASA scientists have found that the colour of the water deepens to azure.

Colourful Seas

Now that it is known why the sea is blue, scientists have pointed out that the colour of the sea is not the same everywhere; although there are only four seas that are named by colour. Interestingly, no ocean is characterized by colour. Neither is any sea nor any ocean named after the colour blue. The four 'colourfully' named seas are: Black Sea, Red Sea, Yellow Sea and the White Sea.

Apparently, one reason why the Black Sea got its name is because of its hydrogen sulphide-rich black sediment layer. The Red Sea got its name because of a type of algae called *Trichodesmium erythraeum* which is found in its waters. Population explosions or 'blooms' of this species appear to turn the waters a reddish-brown. The Yellow Sea gets its name from the sand particles that turn the surface of the water golden yellow during sunset. The White Sea appears to be a bit of a misnomer because its colour is usually green; not white. Perhaps it ought to be renamed the Green Sea?

Salty Seas

"Water, water everywhere...nor any drop to drink..." The Ancient Mariner in S.T. Coleridge's poem learnt it the hard way that marine waters are un-drinkable. Sea water has been described as a *"weak solution of almost everything."* It is actually a complex

solution of mineral salts and of decayed biologic matter originating from dead marine life. No wonder it does not taste 'fresh.'

It is believed that the primeval seas were only slightly salty. Over time, the oceans have become saltier. Today, seawater is 220 times saltier than freshwater. If the salt in the sea could be spread evenly over Earth's land surface, it would form a layer more than 152.4 meters: about the height of a 40-storey building.

The average salinity of ocean waters is about 35 parts of salt per 1000 parts of water, i.e., 3.5 per cent.; varying between 3.2-3.7 per cent depending on where it is sampled. The salt content of the open oceans is usually never less than 3.3 per cent and usually never more than 3.8 per cent. Average salinity of seawater was analyzed by William Dittmar of Glasgow University in 1884. He studied 77 sea water samples collected from many parts of the world during the scientific expedition of the British ship *H.M.S. Challenger* in 1872. Today, scientists measure Salinity in practical salinity units (psu). Using this unit, we say that ocean water has an average salinity of 35 psu.

About 80 per cent of the dissolved salts is Sodium chloride. The rest mostly consists of salts of Magnesium, Calcium and Potassium...for example, Magnesium bromide, Magnesium sulphate, Magnesium chloride. Calcium carbonate, Calcium sulphate, and Potassium sulphate.

Phosphorous, Iron, Aluminium, Barium, Bromine, Fluorine, Iodine, Arsenic, Manganese, Copper...even Gold, have been identified in sea water, most in extremely small amounts. Probably all the Earth's naturally-occurring elements exist in the sea. It has been estimated that the oceans contain almost 50 million billion tonnes of dissolved solids.

The Importance of Salt

Salt tastes salty...even children know this. We know this because the taste buds on our tongues tell us so. Each taste bud is a

receptor, which responds to one of at least five basic taste qualities: salty, sweet, sour, bitter, and umami or savoury – spicy?

Great importance has been attached to salt by different races and cultures. The salt from *Sebkha* or open cast mine in Tichit-a village in the North African country of Mauritania is, even today, celebrated as “*white gold*.” The first of the great Roman roads, the 242 km *Via Salaria*, or Salt Road, was built for transporting salt. Egyptians placed salt in tombs as funeral offerings. They used Natron, a naturally occurring salt, to embalm mummies and recorded salt making as an art as early as 1450 BC.

In India the phrase “...*aapka namak khaya hai*,” literally meaning ‘I have eaten your salt’ is a declaration of one’s loyalty. A complimentary description of a dependable person is, “*Salt of the Earth*.”

As common as salt has become these days, there was a time when special allowance, payable in salt, (“*salarium argentums*”) was paid to Roman soldiers. The term was derived from the Latin word “*sal*” meaning salt and literally means “salt money.” The term *Salarium* has been transformed to the word salary and is also the basis of the idiom, “*Not worth his salt*,” for a person whose performance is under par.

Salt the important component of the sea

By salt, most people usually mean Sodium chloride (NaCl), which is the basic table salt we use. Table salt is mostly mined from underground salt deposits. It is heavily processed to eliminate trace minerals and may contain added anti-caking compounds to prevent clumping. Most table salt also has added iodine. Sea salt is produced through evaporation of seawater, usually with little processing. This retains the trace minerals that add flavour.

Apart from being an indispensable item of food, salt is an important raw material for the manufacture of several heavy chemicals e.g. soda ash, caustic soda and chlorine. It is used by the pulp and paper Industry; for setting dyes in textiles and fabric; for producing soaps and detergents and for de-icing roads. Besides, salt is also used in food processing industries, such as fish curing, meat packing, dairy products and fruit & vegetable canning.

However, although to the common man, salt continues to mean Sodium chloride; it is by no means, the only salt recovered from the seas. Even the ancients knew about the different types of salts that could be derived from the salty waters of the oceans. The manufacture of salt is one of the oldest chemical industries. (The *Peng-Tzao-Kan-Mu*, published in about 2,700 years B.C. in China details descriptions of 40 kinds of salt.)

Salt has also been taxed in ancient, and not so ancient, times. Many believe that the Salt tax originated in ancient China. *Guanzi*, a Chinese book written in around 300 BC recommends taxation of salt. Historians say that at one point of time, salt taxes constituted over half of China's revenues and contributed to the construction of the Great Wall of China.

Salt tax was also collected in India during the time of Chandragupta Maurya (340 BC– 298 BC). The *Arthashastra* says that a special officer called *Lavanan-adhyaksa* (*Lavan* means salt) was appointed to collect the tax. In India, the Dandi

March marks a crucial turning point in our history where Mahatma Gandhi defied British salt laws.

(Although salt has been produced all along the Rann of Kutch in India for the past 5,000 years, post Independence) India faced an acute shortage of edible salt. In April 1948, a Salt Expert Committee was constituted under the chairmanship of P.A. Narielwala to advise the Government on the measures necessary to place the Indian salt industry on a sound footing. The Central Salt Research Institute (now known as Central Salt & Marine Chemicals Research Institute), under the Council of Scientific and Industrial Research, Bhavnagar, was inaugurated by Pandit Jawaharlal Nehru, in 1954.

At the inauguration, Narielwala said, *“As the bulk of our salt is obtained from sea water, there are large potentialities of recovering the other salts present in the sea, like potash of which there is shortage in the country, bromine, because of its use in the manufacture of dyes, insecticides, etc, magnesium salts from which we may produce magnesium metal, the alloys of which are coming increasingly into use in the manufacture of aircraft and finally the recovery of elemental sulphur of which we have no known source in the country.”* His words reveal just how important the salts from the seas are!

The question, however, is why the seas are salty? Or rather, how did so much salt get into the water?

Why are the Seas Salty?

The question why the sea is salty has been asked and answered by all ancient civilizations in their own way. There is much-loved fairy tale in which the Devil is tricked into parting with a magic stone mill, which after many amusing incidents ultimately sinks into the sea while producing salt. With no one around to utter the magic words that will stop it, the mill, according to the tale, is still hard at work!

Although wide-eyed kids have no trouble conjuring up pictures of this incredibly hardworking salt mill, scientists take this explanation with an extra large pinch of salt. They say that the roots of the ocean's saltiness lie in the very-distant past. They believe that when the Earth was still young, its atmosphere was rich with a noxious mix of Hydrogen chloride, Hydrogen bromide, and other such gases that the volcanoes belched out. Some of these gases dissolved in the primitive ocean, making it salty.

To add to this, dissolved chemicals eroded from the Earth's crust are all ultimately washed into the waters. The world's many rivers carry an estimated 4 billion tonnes of dissolved salts to the ocean annually. This is because their waters dissolve the soluble material from the soil over which they flow and ultimately it all ends up in the oceans. No wonder a French proverb says, *"Follow the river and you will find the sea!"*

Most of the ocean's salts were derived from gradual processes of erosion of the rocks on the Earth's crust; by the weathering of the rocks in the mountains, and by the dissolving action of rains and rivers which transport the minerals to the sea. Volcanic ejections and suspended particles were also swept to the ocean by winds. All these, plus the materials dissolved from sediments on the ocean floor, contribute to the salinity of the waters.

Surface salinity depends on the ratio between evaporation and rainfall. This of course, is dependent on the climate. Salinity usually increases with depth but becomes relatively constant at depths of 4000 m and beyond.

Landlocked or enclosed smaller seas have a higher degree of salinity because of a higher rate of evaporation. Salinity levels are lower near the mouths of rivers as they empty into the oceans because the fresh water dilutes the salinity. Melting icebergs also lower salinity.

The Saltiest Sea

The Dead Sea, located on the border between Jordan and Israel, has the distinction of being the lowest point on Earth at 418 m below sea level. It is also the saltiest of all the seas on Earth. The Dead Sea has salinity about nine times greater than average ocean salinity. Down to about 40 m, it has about 300 grams of salt per kilogram of seawater. Below 91 m, though, it has 332 grams of salt per kilogram of seawater and the waters cannot dissolve any more; so salt simply precipitates out and piles up on the bottom of the Dead Sea.

The mineral content of the Dead Sea is significantly different from that of ocean water. It consists of approximately 53 per cent Magnesium chloride, 37 per cent Potassium chloride and 8 per cent sodium chloride.

The waters of the Dead Sea are so salty that almost nothing can live in it. This has earned it the Hebrew name "*Yam ha Maved*", meaning 'Killer Sea.' However, scientists have found a bacterial species called *Halobacterium* in the Dead Sea. This discovery means that the Dead Sea is not really dead. At least one organism is holding aloft the flag of life even in these impossibly haline and hostile waters. Scientists have sequenced the genetic makeup or the genome of a species of *Halobacterium* in an attempt to understand just how it can survive in such harsh environments.

Interestingly, the Dead Sea is beaten in the saltiness contest by Lake Assal, in the Danakil Desert, Djibouti. Lake Assal is the most salty waterbody on Earth. Though it is only a lake, it has waters ten times saltier than the ocean. The evaporation rate of Lake Assal is very high because summer temperatures sometimes reach 52 degrees Celsius. The strong dry winds aid evaporation, which increases concentrations of salt in the water.

The Marine Environment

While lounging on the beach, the inviting blue waters seem to extend all the way to the horizon. What very few of us stop to think, as we frolic in the waters, is that they go down very, very deep indeed. So deep, that not even the Sun's rays can penetrate beyond a certain point. The amount of light that penetrates water depends upon many factors including the time of day, season, geographic location and the clarity of the water.

As Prof. Raman showed, when light passes through water, it is absorbed and scattered by water molecules and particles in the water. In the clearest water at midday, sunlight dims by one-tenth about every 75 m. As water depth increases, the longer (red) wavelengths are the first to be absorbed and scattered. By about 10 m below the surface, most of the red and orange wavelengths of visible light are no longer present. By about 150 m, we can only see blue light. At depths of 800 m and more, the human eye can detect no visible light from the surface. We are effectively blind at these depths!

The deep sea environment is characterized by near-total darkness, immense pressure and incredible cold. The temperature of almost the entire deep ocean, except some areas that are infernally hot, is 4 degree Celsius.

How Deep is Deep?

It has been said that the oceans are as deep as the mountains on land are high. This platitude had to suffice till science came out with instruments that could accurately determine just how deep the oceans were.

In 1920, the sonic depth sounder was used to get an idea of just how deep the waters went. The scientists could use this system because the speed of sound is known. The time taken by a sound produced on the ship, to bounce back from the

bottom of the ocean to a hydrophone installed on the ship, was used to calculate the distance it had to traverse. The process was also called echo-sounding because it studied echoes.

Another technique called Seismic reflection profiling was also used, especially for studying sea floors. This technique is sensitive enough to study the basement rocks buried under ocean sediments and to reveal the depths and contours of both, the rocks and the sediments.

Based on such measurements, it was estimated that the average depth of oceans is about 3790m. It was found that 74 per cent of the oceans have a depth range between 3000-6000 m; 25 per cent of the oceanic area has a depth of 0-3000m. Only one percent of the oceans is deeper than 6000m. Actually, the maximum depth was recorded at the Pacific Ocean... a whopping 11,022m as compared to the height of Mount Everest (8848m).

However, scientists were not convinced that they had got the figures right and generations of scientist used the newer tools at their command to get more accurate and more precise values. Matthew Charette and Walter H.F Smith pioneered the use of satellites to calculate ocean volume. In 2010, they estimated that the ocean's mean depth is 3,682.2 m—that is 21-to-51 m less than all other previous estimates.

How Big is Big?

The oceans stretch out far and deep. But exactly how far do they extend? What is the volume of the Earth's oceans? People have been asking these questions for millennia.

Now, scientists who audited the world's waters know the exact figure: 1.332 billion cubic km. This is about 0.3 per cent lower than the estimates of 30 years ago. It is vindication of the findings of earlier generations of scientists who did not have sophisticated satellite technology to aid their studies. Despite using much cruder instruments to measure ocean

depths, their findings were surprisingly accurate. In 1888, for example, John Murray dangled lead weights from a rope off a ship to calculate ocean volume. He arrived at a figure just 1.2 per cent greater than what Charette and Smith who used satellite measurements, have reported in May 2010.

Marine Zones

When we say “Sea” our mind’s eye sees a stretch of beach and the clear sparkling waters beyond. But to a scientist the word includes many different “zones.” The lifeforms too belong to different categories depending on which zone is ‘home’ to them.

The Littoral zone is the area that straddles two totally different worlds...the terrestrial and the aquatic. It is exposed to the tidal effects, pounding waves, as well as exposure to the elements in all their fury when the tidal waters recede, leaving exposed land.

The lifeforms that exist between the sea-surface to the sea floor are divided into two main types. Pelagic and Benthic. Very simply, pelagic pertains to those lifeforms that live or grow at or near the surface of the ocean. Benthic refers to bottom-dwelling lifeforms. Depending on how deep the sea is, there can be up to five vertical layers. From the top down, they are:

- ***Epipelagic:*** This extends from the surface down to around 200 m. This also called the Photic zone because sunlight penetrates here. There are plenty of plants and animals in this zone.
- ***Mesopelagic:*** This is the Twilight zone. It extends from 200 m- 1,000 m. As the name suggests, only some sunlight penetrates till this depth. With plants unable to receive enough sunlight to carry out the process of photosynthesis that releases Oxygen as a bye product, at about 500 m the water becomes oxygen-depleted. This is known as the oxygen minimum layer.

Despite the paucity of oxygen, an abundance of life thrives here. The species that live here have evolved to cope with the oxygen shortage. Beyond about 800 m, the human eye can detect no visible light from the surface. At these depths the only visible light is given out by living organisms. This is called Bioluminescence. It is almost as if Mother Nature has equipped these lifeforms with their own torches...and batteries too.

- ***Bathypelagic:*** This marks the beginning of the totally dark zone which extends from 1,000 m - 4,000 m. Food is even scarcer here than in the mesopelagic zone above. With less energy available, most of the fish are 'sit and wait' predators. Bathypelagic organisms are usually black, red or transparent. These colours, or the lack of it, render them practically invisible. Compared to their mesopelagic relatives, bathypelagic fish tend to have lower metabolic rates, less developed gills and muscles, and small eyes – if they have them at all.
- ***Abyssopelagic:*** This zone extends from 4,000 m down to above the ocean floor.
- ***Hadopelagic:*** This includes the deep water in ocean trenches. This zone is not easy to explore, so we know little about it. Very few species can survive the crushing pressure and the terrible cold of the waters here; the lack of enough food and light. Some insist that the hadopelagic zone is, "*waters below 6,000 m, whether in a trench or not.*"

Handling Pressure

The pressure at the surface of the seas is the same as that which we experience on land. It is one atmosphere or about i.e., 1 kg/sq.cm... slightly less if we live high up in the mountains. This pressure is something that we are not even 'aware' of because we are used to it. However, the pressure increases by about one atmosphere for every 10 m of depth.

At a depth of 1500 m the pressure is more than 150 atmospheres. The Marianas Trench in the Pacific Ocean is the deepest location on the Earth's crust. Roughly speaking, the pressure here is about 1100 times what we are accustomed to on land. It is difficult to comprehend exactly how crushing the pressure is at the bottom of the seas. The description from the *National Geographic* is pretty graphic, though. *"At the ocean's deepest point, the water pressure is the equivalent of having about 50 jumbo jets piled on top of you."*

Coral Reefs and Atolls

Coral reefs are nothing but carbonate limestone built up from the seafloor by the accumulation of the skeletons of the tiny animals called 'corals.' Many other organisms and animals call this structure, home. These also contribute to the formation of the porous limestone structure. The reefs branch upwards as they grow.

Coral reefs are the oldest and most diverse communities on Earth and these ecosystems rival the tropical rain forests in the diversity of life that they support. So much so, that some marine scientists believe that the number of species found on a coral reef equals all the currently described lifeforms on Earth. It has been estimated that these "*tropical rainforests of the sea*," support a quarter of the ocean's lifeforms. At present, there are 93,000 known species of coral plants and animals. Almost 66,000 of these are invertebrates that can be seen with the unaided eye. However, the mention of coral reefs elicits the mental image of colourful fishes for most people; not small invertebrates. This is because coral reefs shelter bizarre-looking residents, particularly fishes that have evolved into strangely non-piscine shapes. Some coral-dwelling fishes resemble rocks, snakes and even, plants.

However, corals by themselves are also pretty curious specimens. Scientists who first studied coral reefs were intrigued

that these were “*luxurious ecosystems*” that supported huge species diversity and numbers grew in some of the least fertile waters of Earth.

Studies revealed that corals are actually a beautiful partnership between tiny algal plants called Zooxanthellae and soft-bodied animals belong to a group called Cnidaria. Most reef-building corals harbour the photosynthetic zooxanthellae in their tissues. Research papers have been published on how this association helps both organisms. According to US National Oceanic and Atmospheric Administration (NOAA), the coral provides the algae with a protected environment and compounds they need for photosynthesis. In return, they produce oxygen and help their hosts to remove wastes. Zooxanthellae supply the coral with glucose, glycerol, and amino acids, which are the products of photosynthesis. The coral uses these products to make proteins, fats, and carbohydrates, and to produce calcium carbonate that makes up the coral skeleton. This mutually helpful or symbiotic relationship between the algae and coral polyps enables a tight recycling of nutrients in nutrient-poor tropical waters.

Corals grow in waters that are less than 90m deep and not colder than 16 degrees Celsius. Under optimal conditions, corals can grow 30 cm in a decade; although the entire reef grows rather more slowly.

Because of the narrow range of conditions under which corals thrive, reefs are restricted to the tropics; generally between 25 degrees North and South latitude. Coral reefs thrive in the Caribbean and the Indo-pacific areas. However, although tropical coastal zones cover almost 2 per cent of the Earth’s surface coral reefs cover slightly less than 0.1 per cent of Earth—which indicates just how precious these are.

Coral reefs are intimately associated with the common man’s idea of ocean islands. The waters off the coasts of

Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste are thought to form, what is called, the Coral Triangle. About 600 different reef-building coral species – an amazing 75 percent of all known coral species – are found in these waters. The region is also home to 3,000 species of fish.

Depending on their proximity to land, coral reefs are subdivided into:

- *Fringing reefs*: These reefs parallel the coastline at a distance less than 1 km from the shore.
- *Barrier reefs*: Those reefs grow paralleling the coastline at distances more than 5km from the shore. The Great Barrier Reef off Australia stretches for 2000km.
- *Atoll reefs*: These are mid-oceanic reefs without any connection to continental land masses or islands.

Atolls with their island shape encircle a shallow central lagoon

Atolls are roughly oval arrays of coral reef islands that are perched around an oceanic volcanic mountain and encircle a shallow central lagoon. The small islands are separated from each other by channels that lead from the sea into the central lagoon. Atolls are most commonly found in the Pacific Ocean and Indian Ocean and vary greatly in size. The Enewatak Atoll is an example.

Hidden Depths

The oceans hide their secrets well. From surveying the flat surface waters, that appear so inviting, we could never guess that the bottom of the ocean is as irregular, if not more, than the land surface on which we walk so confidently. Actually, the ocean bottom is a continuation of the land and the conspicuous shoreline is just the boundary between the terrestrial and watery realms.

Continental Shelf

As we move seawards from the shore, the continental shelf... a broad and relatively shallow surface gives way to a steep and narrow slope. This is the ocean's terrestrial border. The richest fishing grounds of the world are here. This is also mineral-rich because the continental shelf has the same rocks as the continental mass.

Most continental shelves have irregular surfaces. The average width of the continental shelf varies between 20-100 km and its average width is about 65 km. The Atlantic Ocean has a larger shelf region as compared to that of other oceans. The continental edge marks the end of the continental shelf.

We, landlubbers can never hope to see all this, for barring a catastrophe; such regions are never exposed to human eyes. However, Francis P. Shepard has painted a beautiful word-picture of this region for our benefit. He says, *"If a great tidal wave should suck away the water and expose a typical continental*

shelf to our view, it would look like a mass of sand dunes dotted with myriads of small depressions. In the shallow portions, there would be a great many rocks, more or less covered with growing plants and animals. Some of these 'rock gardens' would be extremely colourful..."

Continental Slope

Beyond the edge, the sea bottom descends steeply. This is the second main region of the ocean floor. The average depth at the outer edge of the shelves where the slide begins is 120m-160m. It descends to the floor of the ocean basin...sometimes to a depth of 3000-6000m or deeper (up to 11 km!). The continental slopes may include precipices but usually these are gentle slopes. Some slopes are smooth while others have canyons on them.

Irregular surfaces are more characteristic of the upper portions than the lower kilometre or so. Earlier, oceanographers used to think that these canyons were carved out by pre-historic rivers before the land sank, but this theory does not have many takers now. Current scientific opinion holds that these were formed underwater and that such canyons are still being carved out by the currents flowing down the continental slope at great speeds. Such currents are called turbidity currents as they are mud-laden in nature.

The lower part of the continental slope is called continental rise as it is less steep.

Abyssal Plains

From the base of the continental slope, the ocean floor begins to flatten out into sediment-filled, abyssal plains. These plains usually occur at depths of over 3000m and account for nearly 30 per cent of the Earth's surface. Abyssal plains extend over hundreds of kilometres. Both the Atlantic Ocean and the Indian Oceans have many abyssal plains and in comparison, the Pacific Ocean has fewer abyssal plains.

Ocean Deep

Beyond the abyssal plains are the great ocean deeps. These are large, oval-shaped basins with gently sloping sides. Such basins are more common on the floor of the Pacific Ocean and less so, on the floors of the Atlantic Ocean and the Indian Ocean.

Ocean Bottom Deposits

Deposits near the coasts are rich in quartz and other mineral matter carried from land by the rivers or because of the relentless pounding of the waves on coastal rocks.

The deep ocean deposits are quite different.

Pelagic sediments or marine sediments are those that accumulate in the abyssal plain of the deep ocean. Pelagic clay covers over 30 percent of the seafloor. Less than 30 per cent of its constituents are organic in nature. The rest is a varied mixture of very fine quartz, and clay minerals etc. It is called "red" because it sometimes oxidized iron minerals tinge it so. However, it is usually brownish in colour. Red clay has industrial use and it is speculated that it might be a source of metals such as Nickel, in the future.

Marine Ooze

Under the waters, the ocean bottom is often covered with the shells of shrimps, snails and their relatives. Oozes are basically deposits of soft mud on the ocean floor. The pelagic or deep sea deposits include two major types of Oozes: siliceous oozes (containing skeletons made of Silica) and calcareous oozes (containing skeletons made of Calcium carbonate). Calcareous oozes are formed due to calcium deposits from the shells of animals such as the single-celled foraminifera, snails, and sea urchins. These oozes are never found deeper than about 4,000m - 5,000m because the Calcium dissolves at deeper depths.

Oozes are further subdivided depending on their organic origin into: Diatoms, Radiolarian, Globigerina, and Pteropod Oozes. These derive their rather peculiar names from the organic material that they are rich in.

Ooze aids the study of the Earth's past, and provides clues to the ancient climatic conditions. This is because many of the organisms whose skeletons make up the ooze grow only in narrow ranges of temperature. Oceanographers can decipher, from the fossils found in the ooze layers, the climatic variations over geologic time.

Siliceous Oozes

Diatom Ooze

Diatoms are tiny plants that have shells rich in Silica. They are often described as being, "silica coated." Although some diatoms are colourless, many contain pigments and appear golden-brown or yellow in colour. Diatoms are an important food source for fish. However, even when they are ingested, the siliceous shells cannot be digested by the hosts and are egested unchanged. Even otherwise, diatom shells do not degrade easily; not even after death. The shells accumulate over millennia and give rise to what is called Diatomaceous earth or diatomite or *kieselgur*. Diatomaceous earth has industrial use.

Radiolarian Ooze

Radiolaria are one-celled organisms called Protozoa. Silica-rich radiolarian skeletons have spiky, arm-like extensions. The remains of radiolarians form radiolarian ooze over geologic time scales. Such ooze is found widely distributed in the Pacific Ocean and the Indian Ocean.

Calcareous Oozes

Scientists onboard the *H.M.S. Challenger* expedition discovered calcareous oozes in the deep-sea. Today, this ooze has stimulated

climate research. Researchers studying the climatic conditions of ancient Earth are uncovering long-buried clues in the population densities of the organisms that formed the ooze.

Globigerina ooze

Globigerina ooze is rich in the shells of a one-celled organism called *Globigerina bulloides*. Globigerinas live in vast numbers on or near the surface of the sea. When they die, the shells settle slowly to the bottom of the sea, forming the deep beds of Globigerina ooze. This ooze gradually solidifies into chalk, a soft, form of limestone. About two-thirds of the Atlantic Ocean bed is covered with Globigerina ooze. The chalk cliffs of England and France, and many limestone ridges of USA are made of Globigerina ooze.

Pteropod Ooze

Pteropod Ooze comprises of the shells of pteropods, which are tiny snails. Depending on the species, there can be many different types of shells in this sort of ooze. Pteropod ooze is found in shallow parts of the oceans; particularly in tropical areas.

Hills and Mountains under the Waves

It is a little difficult for us, land creatures, to imagine it but the deep-sea floor exhibits the same features that we see on land. So, there are features undersea that compare with our highest mountains and the deepest valleys...only called trenches, undersea.

Mid-oceanic ridges

The seafloor can boast of at least one geographical feature we do not have on land. These structures are known as mid-oceanic ridges. These massive chains of mountains are more than 25 times longer than the Himalayan range. The mid-

ocean ridge system extends for 75,000 km; towering about 1000m-4000 m above the ocean floor although their peaks remain submerged about 2500 m below the ocean surface. The ridges vary from 2000-4000 km in width.

Iceland is part of the mid-Atlantic ridge that runs down the middle of the entire Atlantic Ocean. This ridge is crossed by many parallel cracks or fractures...each extending many hundreds of kilometres. Enormous scientific interest centres on the systems of undersea cracks and fractures.

Sea Mounts

Mountains other than those in the mid-oceanic ridge also exist under the ocean's waters and most are of volcanic origin. Underwater mountains are called seamounts. Most seamounts remain about 1000m-1500m under the surface; however, the tops of some seamounts may protrude above the surface of the water as islands. Guyots are seamounts with flat tops. The tops of most guyots remain within a kilometre or two of the surface. Smaller seamounts are called abyssal hills. The Pacific Ocean is rich in both seamounts and abyssal hills.

Underwater Trenches

Trenches long, narrow, V-shaped depressions with steep sides usually found at the boundaries of the continents and the ocean basins. Most lie in a zone of earthquakes and volcanic activity. The areas within the trenches are the places of the ocean's greatest depths. In the Marianas Trench we would have to dive about 10, 912 m to hit the bottom. It is deep enough for Mount Everest to hide here with 2,438 m. to spare above its peak!

Other trenches include the Tonga Trench, Mindanao Trench, Puerto Rico Trench, South Sandwich Trench and Diamantina Trench.

Hydrothermal Vents

Hydrothermal vents are cracks on the ocean bed from which heated water gushes forth. These are places where molten magma from the Earth's interior is welling up to form the mid-ocean ridges. Sea water enters via the fissures and approaches the molten magma chamber deep inside the bowels of the Earth. The water gets heated up. It also reacts with the minerals contained in the surrounding rocks. When the mineral-rich hot water is forced back out it meets the cold ocean water. Then the dissolved minerals rapidly precipitate out. The precipitated minerals accumulate to form towering structures called chimneys. This is why Vents are sometimes also called "black smokers." At the vent, the waters can reach temperatures of about 400 degree Celsius. Hydrothermal vents are found only in areas where there is volcanic activity and magma is close enough to the surface to heat the fluids.

Hydrothermal vents are often called 'Black Smokers'

Normally we would expect water at such high temperature to be vapour; not liquid. However, down in the deep ocean around hydrothermal vents, where the water is at temperatures around 400 degree Celsius, it doesn't boil! What prevents the seawater from turning into vapour is the extreme pressure of the overlying water. It has been calculated that, a single vent emitting hot fluid at 350 degree Celsius through a 20 cm diameter opening produces nearly 108 Watts of energy per

second. If converted efficiently enough this could mean 10^9 Watts of useful energy per vent! However, tapping such non-conventional sources does seem to be buried many fathoms deep...literally, as well as figuratively.

The largest vent field is named Trans-Atlantic Geotraverse, or TAG for short. It is as big as a football stadium. Other vent fields have more whimsical names. Examples include Clam Acres, Mussel Bed, Rose Garden, Garden of Eden, Broken Spur, and Lucky Strike. Snow Blower is named for the white, flaky bacteria discharged from its vents. Genesis vent got its name because it seemed to have fizzled out but “*flickered back to life*” a few years later.

Underwater Volcanoes

Underwater volcanoes have been known for a long time. The many islands in the Pacific Ocean and the islands such as Tristan da Cunha and the Azores in the Atlantic are volcanic mountain peaks.

Underwater volcanoes help earth to acquire new land

We know that there are more than 5,000 active underwater volcanoes, which account for more than 75 per cent of the total lava erupted every year. An underwater volcano erupts quite differently from a volcano on land. This is because the sea waters, almost immediately, cool down the lava. A hard shell forms around it. This is called pillow lava. Layers of pillow lava build up and cool down to solidify into a new crust. Underwater volcanoes build up over time, and can eventually reach the surface of the ocean. This is a way in which Earth acquires new land.

Undersea Rivers

In August 2010, Dr. Dan Parsons and his colleagues at the University of Leeds, UK, using a robotic submarine made the astounding discovery that there was a river flowing along the sea bed of the Black Sea.

This is a current of water 350 times greater than the River Thames. The undersea river, which is up to 35 m deep in places, even has rapids and waterfalls! It originates thanks to salty water spilling through the Bosphorus Strait from the Mediterranean Sea into the Black Sea. Had this river been a terrestrial one, it would have qualified as the world's sixth largest river in terms of the amount of water flowing through it. Scientists still have not given this river a name yet. It remains, till date, the only active undersea river to have been found so far.

Of course, there is no reason to rule out existence of other rivers such as this one. We just have to keep looking and we do not know what our reward will be. It may be a pirate's treasure trove. It may be the relics of a sunken ship. It can even be a secret that Mother Nature decides to share.

Even with all the technology at our command and with all the advances that we have made in science, the deep waters still retain many mysteries. The more we know; the more there is to know. Fascination with the marine environment is like embarking on an everlasting journey. No wonder Jacques Yves Cousteau once said, *“The sea once it casts its spell, holds one in its net of wonder forever.”*

2. GLOBAL ROLES AND UNIVERSAL GIFTS

Endless water cycle replenishes water bodies on earth

The sea is the source of water and the source of wind; for neither would blasts of wind arise in the clouds and blow out from within them, except for the great sea, nor would the streams of rivers nor the rain-water in the sky exist but for the sea; but the great sea is the begetter of clouds and winds and rivers.

– Xenophanes

Life began in the seas about 3.1 billion - 3.4 billion years ago. Land dwellers appeared 400 million years ago—pretty recently as geologic ages go. However, apart from having served as

a cradle of life; oceans even today help sustain life in many ways. Oceans influence the life of every living being on Earth, whether or not the life form exists near or even in the ocean; is or is not aware of the existence of the marine waters. It is a statement of simple fact to say that without the seas there would be no life on Earth—at least not life as we know it. Be it a landlocked nation or an island continent, our debt to the oceans is enormous.

Water Cycle

The oceans are huge reservoirs of water but what not everyone realizes is that all water on Earth is also recycled by the seas and oceans in an endless water cycle.

Water, irrespective of where it is (oceans, lakes, swamps, rivers) turns into water vapour because of the Sun's heat. Rising air currents carry it upward, often high into the atmosphere. Here the air cools and water vapour condenses to form clouds. Clouds lose their water as rain or snow. Scientists call this precipitation.

Precipitation is either absorbed into the ground or it runs off into rivers. River waters eventually flow into the oceans from where it evaporates back into the atmosphere. Water that was absorbed into the ground is taken up by plants, which later give up this vapour, by the process of transpiration to the atmosphere. The water cycle is a continuous exchange of moisture between the oceans, the atmosphere, and the land. It is a journey that the water molecules make from Earth's surface to the atmosphere, and back again. Over and over again.

Interestingly, over the continents, precipitation routinely exceeds evaporation. On the other hand, over the oceans, evaporation exceeds precipitation. In the case of the oceans,

this would eventually have emptied the oceans had it not been for continuous replenishment, largely through runoff from the land. In addition, sea levels around the globe are rising because of the calving of glaciers or melting of ice sheets and glaciers, partly due to global warming.

The oceans, seas, lakes, rivers, streams provide nearly 90 per cent of the moisture in our atmosphere. All the water that is present on Earth today is all the water it ever had. Water molecules can take an immense variety of routes and branching trails that lead them again and again through the three phases of ice, liquid water, and water vapour. However, whichever the route it takes...we drink the same water that the dinosaurs did...it has been recycled many million times, that's all...and the oceans played a huge role in this recycling.

Breezy Relief

On a daily basis too, the relationship between the marine waters and the land mass help provide relief from extreme heat and cold...as residents of coastal areas will testify.

Land breezes and sea breezes are regular features in areas adjoining the seas and oceans of the world. Refreshing sea breezes spring up to provide relief on hot, summer days because of the unequal heating rates of land and water. During the day, the land surface heats up faster than the water surface and so, the air above the land becomes warmer than the air above the ocean. Now, since, warm air is lighter than cooler air, the air above the land rises. Cooler air from above the ocean is drawn in to take its place; leading to a delightful cool breeze. This is called sea breeze. The cycle is reversed at night when the surface of the land cools quicker than the water's surface. At night, therefore, the warm air rises above the ocean-surface and the cooler air from the land flows oceanwards. This is called land breeze.

Land and sea breezes are regular features in areas adjoining sea

Thermo-regulating the Earth

Extending their effect to more remote parts of the Earth, the oceans serve to moderate global weather and temperature as well. The most immediate influence arises because oceans absorb the heat coming from Sun and store much of it in the warm surface waters. The temperatures of the oceans across Earth vary greatly. It may be around 28 degree Celsius in equatorial regions and below zero in the Polar Regions. Smaller, more or less enclosed, seas such as the Red Sea can reach temperatures exceeding 32 degree Celsius.

There are three distinct thermal zones in ocean waters:

Surface zone: This is about 50-100 m from the top and is influenced by heating, cooling, evaporation and local rainfall. In the Polar Regions this zone freezes to form sea-ice.

Pycnocline zone: This extends up to 2000 m down. Marine waters in the Polar Regions do not have this zone. The cold water zone between 200m-1000m is called the thermocline. The thermocline is actually the transition layer between the mixed layer at the surface and the deep water layer. The deep waters below the thermocline layer decrease in temperature much more gradually toward the seafloor.

Deep zone: This zone extends right up to the ocean basin.

Ocean Currents

For centuries, sailors around the world have known that the salt waters girdle the globe. They have relied on the oceans to take them to exotic harbours. Ancient adventurers and explorers used the oceans as routes to foreign lands. Merchants entrusted the waves to speed the transport of goods to the market. Kids dropped messages in bottles in the hope that these would be carried to strange places. The ocean currents helped them in all their enterprises. It was much later that scientists realized that the currents play another huge role.

Ocean currents influence weather patterns all over the globe

They realized that the oceans act as a huge global thermostat not just because they are huge heat-sinks but also because they distribute the heat energy absorbed by the waters. Currents help influence weather patterns not only along the coast but inland as well. Surface currents also transport nutrients and thus influence biodiversity of the ocean. In recent times, ocean surface currents have been instrumental in redistributing pollution and hazardous materials dumped in the ocean.

Currents exist at all depths in the ocean; in some regions, two or more currents flow in different directions at different depths. Although the current system is complex, all ocean currents are basically driven by two forces: Sun and the rotation of Earth.

The Antarctic Circumpolar Current (21,000 km in length) is the world's largest ocean current, transporting 130 million cubic meters of water per second - 100 times the flow of all the world's rivers.

The Sun heats the atmosphere. This gives rise to winds that strongly affect the surface layer, although its influence does not extend much below depths of about 100 m. The Sun also alters the density of the ocean surface water directly by changing its temperature and/or its salinity. These density changes give rise to specific water masses, which have well-defined temperature and salinity characteristics, and which can be traced for long distances in the ocean. For example, water from Mediterranean Sea can be traced across North Atlantic Ocean because of its high salinity.

Such currents are also known as the thermo-haline circulation because these involve the interaction of heat and salinity. For example, warm ocean water from the Pacific moves through Indian Ocean and into Atlantic Ocean. The tropical heat causes warm water to evaporate leaving its salt behind. So, the water in these currents is extremely saline as it moves

north. On reaching the north Atlantic Ocean and flowing into the Greenland and Norwegian Seas, the warm, salty current meets cold water coming from the Arctic Ocean. This leads to rapid cooling and sinking of the waters. Eventually the water reaches the sea floor and flows back southwards as a counter current towards the south Atlantic Ocean. From there it flows into Indian Ocean and Pacific Ocean, to replace the warm surface waters flowing into Atlantic Ocean.

Ocean currents move in circular circuits called gyres and the average speed is 10 km per day. However, some currents are over ten times swifter. The Gulf Stream in Atlantic Ocean and the Kuroshio Current in the Pacific Ocean zip along at speeds reaching 100km-160 km per day. The currents do not flow continuously. There are many small gyres where water may get “stuck.” It is then forced to re-circulate before it can continue on its journey around the globe. So, there is considerable variation in the paths taken by the currents; although, by and large, they do stick to a general route from one year to another.

Interestingly, scientists on board the *H.M.S. Challenger* had recorded that ocean waters circulate. They came to the conclusion when they found that deep-sea temperatures are not as constant as had been supposed, but vary considerably. These results were described in *The Depths of the Sea*, published in 1873.

Global Thermostat

Ocean currents have been likened to a global conveyor belt because these by transport heat and water around the Earth. The term actually used is Great Ocean Conveyor and this ‘conveyor belt’ plays a major role in controlling global climate.

Ocean currents heat the land and air during winter and cool it during summer, thus regulating the climates of countries. For example, the warm Gulf Stream keeps the coast of Norway

ice-free. The Humbolt or Peru Current exerts a cooling influence on the climate of Peru, which would have been much hotter had it not been for this current.

Serendipitous Accident

On 27 May 1990 the *Hansa Carrier*, enroute from Korea to the USA, faced a severe storm that washed shipping containers overboard releasing at least 60,000 pairs of shoes. Interestingly, each shoe had a unique, listed serial number, and the exact position of the accident was known from the ship's log. So, scientists realized that they could plot the time and the place the shoes eventually landed up to get an idea about the ocean currents.

It was fortuitous that in the late 1970s computer modelling scientists at the Alaska Fisheries Science Center's Resource Ecology and Fisheries Management Division had began developing a numerical model to investigate how ocean currents might have influenced various fish populations in the North Pacific Ocean and Bering Sea. This later led to the development of the Ocean Surface Currents Simulator (OSCURS) model. OSCURS allowed retrospective analyses of daily ocean surface currents anywhere in a 90-km ocean-wide grid. Oceanographer Curtis Charles Ebbesmeyer and his colleague Jim Ingraham validated OSCURS to measure the movement of surface currents over time, as well as the movement of what was in/on the water. OSCURS predicted that most of the shoes would make landfall on the northern tip of Vancouver Island and the coast of central British Columbia about 249 days after the accident. The first reports of shoes on Vancouver Island came in after 220 days. In 1992 shoes started to arrive in Hawaii.

Despite the success in predicting when the shoes would begin arriving, scientists realized that it not always easy to pick a starting point that drifts to a particular end point. So,

ROSCURS; a numerical model, (the reverse of OSCURS) is being developed in order to go backwards in time from a given spot in order to aid the study of ocean currents.

El Niño and La Nina

El Niño and *La Nina* alter the climate across more than half the planet. An *El Niño* event sees a rise in temperatures and a *La Niña* event witnesses a drop in normal temperatures.

El Niño:

El Niño is a semi-periodic, abnormal warming of surface ocean waters in the eastern tropical Pacific Ocean that not only disrupts weather around the world but also causes the fishery trade to crash. The precise causes behind *El Niño* are not clearly known. Although the intensity and longevity of the *El Niño* phase cannot be accurately forecast; it typically lasts for 8–10 months or so. Because this usually happens around Christmas, South American fishermen call this phenomenon, *El Niño*: Spanish for “the Boy Child,”... a reference to baby Jesus.

A permanent thermocline exists beneath the relatively warm, well-mixed surface layer, from depths of about 200 m-1,000 m at which temperatures diminish steadily. The deep waters below the thermocline layer decrease in temperature much more gradually toward the seafloor. This holds the key to these two phenomena.

The surface waters of the tropical Pacific Ocean are warm. Normally, trade winds blow towards the west, across Pacific Ocean, pushing warm surface water away from the South American coast towards Australia and the Philippines. Meanwhile, the deeper, colder waters in the eastern Pacific Ocean rise to the surface. Along the Peruvian coast the water is cold and nutrient-rich, supporting marine ecosystems and fisheries. With the onset of spring in the northern hemisphere,

the trade winds become weaker and push less water westward. So, waters in the central and eastern Pacific Ocean begin to heat up and the thermocline tilt diminishes. Then, the summer monsoon winds come to the rescue and the balance of the thermocline tilt is regained. This is usually the pattern in normal years.

However, sometimes, this choreography of natural events does not follow usual rules. The trade winds relax in the central and western Pacific Ocean. This allows warm water to accumulate in the surface. Little of the nutrients normally produced by the upwelling of cold water are now available. This is called the *El Niño* effect.

El Niño causes a change in traditional rainfall patterns, which releases of large amounts of latent heat into the atmosphere. This heat affects the weather in various ways and at different places. Also, since the plankton die, the fish that fed on them, die too. Sea birds that preyed on the fish die next. Fisheries suffer enormous losses.

The impact of the 1997- 1998 *El Niño* was particularly bad. Floods devastated the Americas, storms hit China, drought parched Austria, and forest fires blazed in Asia and Brazil. Indonesia experienced the worst drought in the last 50 years and Guadalajara (Mexico) saw snow for the first time since 1881. In the Indian Ocean, it affected the movement of the monsoon winds. In 2009 a new *El Niño* developed in the Pacific Ocean and most likely adversely impacted monsoon in India.

La Nina

La Nina (*El Viejo*, The Little Girl, anti- *El Niño*) is a similar phenomenon; only the waters of Pacific Ocean are cooled, not warmed. This event generally follows an *El Niño*. Because the waters cool, it is referred to as 'a cold event' or 'a cold episode.' *La Nina* is characterized by unusually cold ocean temperatures

in the equatorial Pacific Ocean. Typically, *La Nina* occurs roughly half as often as *El Niño*. The impacts of *La Nina* on the global climate and ocean temperature tend to be opposite those of *El Niño*.

Life-giving Monsoon Showers

Without the oceans and seas there would have been no life-sustaining monsoon showers, which are seasonally shifting winds in the Indian Ocean and surrounding regions, including the Arabian Sea. The Indian Ocean is unique in that it has a circulation pattern influenced by the monsoon. No where else in the world is there a seasonal reversal of direction of the prevailing winds.

The monsoon winds blow from the southwest during one half of the year and from the northeast during the other. The southwest monsoon carries moisture from the Indian Ocean and brings heavy rains from June to September.

The Arab traders of yore knew about these rain-carrying winds and gave it the name "*Mausim*" meaning 'Season of the winds.' Even today, the Indian subcontinent receives more than 80% of the annual rainfall during these four months. During October to December, monsoon winds blow from the northeast and bring copious showers to the coastal areas along the Bay of Bengal.

Upwelling of the Waters

An additional advantage of the monsoons is that during the period, strong upwelling of the waters is triggered in the Arabian Sea, along the west coast of India. Upwelling, as the name implies, is a sort of churning of the oceans when deeper, colder water from the bottom rise up because of the action of winds.

Along some coastlines strong seasonal winds blow parallel to the coast, which push the water downwind, while the force

of Earth's rotation deflects water to the right of the winds (left in the southern hemisphere). As a result, the waters in the upper 10m - 30m of the ocean are blown offshore, drawing colder, nutrient-laden waters from the depths to replace them. These waters are rich in nutrients. As much as 40- 50% of the world's commercial fish catch comes from upwelling areas that comprise just One percent of the global ocean.

Since upwelling is a wind-driven phenomenon, it should occur equally everywhere. However, most inexplicably, it appears to favour the western coasts of continents.

Coastal upwelling occurs against the western sides of continents in the Atlantic Ocean, Indian Ocean, and Pacific Ocean. Coastal Peru and Chile, coastal California, the Iberian-Canary islands off Spain and Portugal, and the Benguela system off southwestern Africa—are home to some of the world's most important fisheries. Thanks to this goes to the upwelling produced by currents.

Each of the five oceans has an eastern boundary current, which is narrow and shallow. The only ocean without an equator-ward eastern boundary current is the Indian Ocean. Eastern boundary currents are often associated with upwelling; the Peru Current and the California Current are examples.

The Peru Current originates in Antarctic waters and flows north along the west coast of South America. Just south of the Equator it joins the South Equatorial Current. The southeast trade winds cause upwelling from moderate depths. In winter the California Current is weak or absent. As upwelling-favourable winds begin to blow, the current forms near the coast but quickly moves offshore. It is most strongly developed in July-August; at the height of the upwelling season.

The Benguela current flows northward in the South Atlantic Ocean along the west coast of southern Africa nearly to the Equator before merging with the westward-flowing Atlantic South Equatorial Current. The prevailing southerly and south-

westerly winds produce upwelling of water with a cool temperature, a relatively low salinity, and a high concentration of plankton, creating excellent fishing grounds.

The Somali current, off Africa's eastern coast, reverses direction twice a year. From May to September it runs north; from November to March it runs south. As it flows northward, upwelling supports productive marine life, but productivity falls when the current begins to move southward.

Generous Provider

The marine waters and coastal areas are generous providers. Seas provide fish and other seafood that are relished the world over. Pearls and precious corals have adorned beauties down the ages and today, we are looking to the marine lifeforms to provide us with effective new drugs and enzymes for industrial applications.

Bio-prospecting in the Oceans

In recent times there has been a surge in the search for bioactive compounds in marine organisms including invertebrates, algae, plankton, and bacteria although the sea's potential as a resource remains largely untapped. This search for bioactive compounds is called Bio-prospecting. Pharmaceutical companies use compounds derived from deep-sea bacteria, fish and plants for drugs to cure some of the world's most deadly diseases.

Historically, one of the most widely-used nutritional supplements is cod liver oil. As the name indicates, cod liver oil is derived from the liver of the Atlantic Cod (*Gaddus morhua*) and its cousins. The oil has high levels of the omega-3 fatty acids, EPA and DHA, and very high levels of vitamin A and vitamin D. It is believed to be useful to ease the symptoms of arthritis and was once commonly given to children, because the high levels of vitamin D in cod liver oil have been shown to prevent rickets.

In the 1950's Ross Nigrelli of the Osborn Laboratories of New York, USA extracted a chemical from the Sea cucumber *Actynopyga agassizi*, which had anti-tumour activity in mice. It was named Holothurin but never commercialized.

Post 1959, sponges came into the limelight when it was discovered that some species produced substances that could kill microbes. Soon thereafter scientists found that many other marine invertebrates, such as Corals, Sea squirts, Snails, Star fish and their cousins, did too.

At the turn of the century the number of potential compounds isolated from marine lifeforms exceeded 10,000 and hundreds more are being discovered every year. For example, Tor Haug, Norwegian College of Fishery Science, Tromso, Norway, has isolated novel antimicrobial peptides from the blood of the Spider crab *Hyas araneus* and the Green sea urchin *Strongylocentrotus droebachiensis*. Antimicrobial peptides are a new class of drugs. These act against fungi, bacteria, and viruses and only rarely induce resistance.

No wonder, marine organisms have remained firmly on centre stage and with good reason...the more scientists look the more they find. And now that the science of Genomics is coming into its own; scientists are also turning their attention to the decoding of the genomes of marine organisms that have yielded promising pharmaceutical compounds.

The genome of *Salinispora tropica* for example, has been decoded. This bacterial species produces compounds that are being tested as anti-cancer drugs. Salinosporamide A is undergoing human clinical trials for treating multiple myeloma and also solid tumours.

Bradley Moore, Scripps' Center for Marine Biotechnology and Biomedicine and the UC San Diego Skaggs School of Pharmacy and Pharmaceutical Sciences, USA, says "*By sequencing Salinispora tropica we are now able to look in greater detail at this organism and potentially pull out some of the other*

compounds from the gene clusters that may make highly potent anticancer agents,...it is exciting to be able to use this genomic information to maximize the discoveries from this prolific organism."

The best thing is that there are many more such prolific producers under the waves that are just awaiting discovery.

Marine Fungi

An antibiotic has been derived from the marine fungus *Cephalosporium acremonium*. It acts on a wide range of microbes.

A new antifungal antibiotic named YM-202204 (1) has been isolated from the marine fungus *Phoma sp.* It is effective against other fungi such as *Candida albicans*, *Cryptococcus neoformans*, *Aspergillus fumigates* and yeasts.

Marine Alga

Kainik acid has been isolated from a red alga named *Digenia simplex*. It is also being used as a diagnostic agent in Huntington's chorea, a fatal nervous disorder. It can also kill worms.

Many brown algae are the source for the drug Fucoidan that can be used to treat a form of leukaemia. It is also an anticoagulant that stops blood from forming clots... a property that can be exploited for medicinal use.

Carrageenans, long used to make milk pudding, are undergoing clinical tests for use as anti-retroviral agents and for treatment of genital herpes.

The Scripps Institution of Oceanography, USA has isolated Pestalone, a new antibiotic from the brown algae *Rosenvingea sp.* It also acts on human tumour cells.

Sponges

Sponges cannot move about and so cannot run away from their enemies. They have no teeth or claws, not even venom. So what is their defence strategy? They produce chemical

deterrent and also, outsource defence by entering into partnerships with bacteria and fungi that take over the military operations in return for the food and shelter provided. Fungi and bacteria have long been rich sources of compounds that are active against microbes. Such compounds are called antimicrobials. Studying sponges therefore also means studying the aggressive lifeforms they harbour. However, a new technology called natural product MALDI-TOF (Matrix Assisted Laser Desorption Ionization-Time of Flight) is an imaging technique that can probe the cellular working of marine organisms to determine if the therapeutic compounds they are producing are being made by them or their symbiotic friends. This is an emerging techniques being used to localize the molecular machinery responsible for potential new drug candidate.

Azidothymidine or AZT obtained from the sponge *Cryptotethya crypta* was the first antiretroviral medicine approved for treating HIV/AIDS, and continues to be used even today, especially for prevention of mother to child transmission of disease.

The sponge *Luffariella variabilis* is the source of Manoalide, a compound with analgesic and anti-inflammatory activity.

Aeroplysinin was isolated from the Mediterranean sponge *Verongia aerophoba*. It is antibacterial and anti-tumour in nature.

Discodermolide isolated from the Caribbean sponge *Discodermia dissoluta* is being tested as an anti-cancer drug as is Hemiasterlin isolated from the sponges *Hemiasterella minor* and *Cymbastela* sp. Laulimalide isolated from *Cacospongia mycofijensis* is used for treating breast and ovarian cancers that are taxol resistant. Ircinamine B isolated from the marine sponge *Dactylia* sp., has shown activity against the leukaemia in laboratory cultures, raising hopes of a drug in the future.

Anti-viral compound Ara-A, and anti-tumour compound Ara-C have also been developed from sponges. The former

is being used for the treatment of herpes, and the latter for the treatment of myelocytic leukaemia- a form of cancer.

Halichlorine was isolated from the marine sponge *Halichondria okadai*. Its action have encouraged researchers to consider it a potential drug candidate to target coronary artery diseases, angina, and non-cardiovascular inflammatory diseases.

Contignasterol (1) was isolated from extracts of specimens of the marine sponge *Petrosia contignata*. It has potential as an anti-allergy drug.

As recently as in 2010, Agelastatins—a compound released by deep sea sponges (or the bacteria they harbour) are making news as inhibitors of cancer-cell proliferation. Agelastatins are known to interfere with cell division and they also repress an enzyme known as glycogen synthase kinase-3, a potential target for treating Alzheimer's disease and bipolar disorder which is characterized by massive mood swings.

Corals

Human bone structure and coral skeleton are strikingly similar and use has been made of this similarity. A chemical process has been invented to use coral as a medium to encourage new bone tissues to grow. Norzoanthamine hydrochloride isolated from *Zoanthus* sp. is expected to be a good candidate for a drug to stop age-related loss of bone mass.

Bryozoa or Moss animals

Bryostatins were first isolated in the 1960s by George Pettit from the bryozoan, *Bugula neritina*. These had antiviral activity. Today, these chemicals are promising weapons against HIV and various types of cancer. Additionally, these can also improve cognition and memory in animals, giving them potential to combat Alzheimer's disease.

Molluscs

Kahalalide F is a novel anti-tumour drug sourced from the marine slug *Elysia rufescens*. It has shown a potent activity against a panel of human prostate and breast cancer cell lines in laboratories. It is under clinical trials for cancer and psoriasis treatment. Similar molecules created synthetically are promising agents to fight leishmaniasis.

Dolastatin 10 and Dolastatin 15 were isolated from the Indian Ocean Sea hare *Dollabella auricularia*. These molecules are promising anti-cancer drugs showing potency against breast and liver cancers, solid tumours and some types of leukaemia.

Marine cone snails *Conus* are predatory molluscs that use venom apparatus to capture prey. The venom is biologically very active particularly affecting the transmission of nerve signals in animals. Conotoxins have great potential as pain killers. Ziconotide is a powerful painkiller derived from *Conus magus*.

The Prickly pen shell *Pinna muricata* and *Pteria sp* have yielded alkaloids with potent biological activities. These have been named Pinnatoxins and Pinnamine, Unfortunately the toxic nature of the compounds may limit its usage in drugs.

Sea Squirt

That a medicine of marine origin can also be a new drug in decades may sound too good to be true. But Yondelis®, a drug for treating soft tissue sarcoma- a sort of cancer is one such drug. It was derived from the sea squirt *Ecteinascidia turbinata* and is the first to be released in 30 years.

However, the path to finding a molecule from a marine organism that may be used as a medicine is a long and arduous one. Sometimes a promising molecule turns out to have

unintended side effects. But the trick is to keep looking. For example, Didemnin, the first marine compound that entered phase II human clinical trials for the treatment of certain cancers, was too toxic to be used as a medicine. It had been isolated from the Sea squirt *Trididemnum solidum*. Researchers have now homed in on Aplidin, isolated from another Sea squirt- *Aplidium albicans* which is far less toxic.

Dogfish shark

Squalamine is a broad-spectrum antibiotic isolated from the dogfish shark *Squalus acanthias*. This water-soluble antibiotic exhibits potent anti-bacterial activity against both Gram-negative and Gram-positive bacteria.

However, since bio-prospecting is a recent trend; drugs from marine sources are not too many in number. In 2006 there were only four marine-based drugs on the market and about 40 in clinical/preclinical development. However, growing research interest in the field is reflected in the fact that there is even a journal named *Marine Drugs*. It is devoted to the research, development and production of drugs from the sea and which includes marine natural product chemistry. This is only to be expected as marine organisms have evolved many biologically unique molecules which may have pharmaceutical applications. Added to that is the fact that the sea—primeval home to all life are repositories of the most diverse forms of life; each of which could be a potential candidate to yield a new drug molecule.

“The marine environment has received much less attention than its terrestrial counterpart in the search for natural compounds,” said Helga Pedersen (Fourth International Conference on Marine Bio Prospecting, BIOPROSP 2009). It is safe to say that once the world wakes up to the benefits and profits of bio-prospecting the marine waters, the dictionaries should get ready to welcome a new word; Aquapreneur.

Other Gifts

Over one-fifth of the world's oil and gas supplies are extracted from under the seabed. The oceans also provide useful minerals and metals, such as Bromine, Magnesium and salts.

The oceans are also one of the most important sources of renewable energy. The tides, waves, currents and temperature differences are powerful enough to meet our energy demands if only we can design adequate technology to harness these great reserves of energy.

Microbial enzymes have been used in various industries for many centuries. Recently, with the advent of biotechnology, there has been a growing interest in and demand for enzymes with novel properties and many such enzymes are being sourced from bacteria recovered from the depths of the oceans. The cosmetics industry, the detergent industry and chemists are greatly interested in the unique properties of such enzymes.

Marine ecosystems provide natural goods and services such as carbon storage; atmospheric gas regulation, particularly by the phytoplankton; nutrient cycling; and waste treatment. Marine algae contribute to nearly 40% of global photosynthesis.

Our gifts from the oceans also include opportunities for ecotourism, recreation, and research. The economic return from activities such as whale watching, swimming with dolphins, undersea diving, and visits to marine aquariums far exceeds that which could be earned from otherwise exploiting the animals/environment.

Natural Safeguards

Barrier beaches, coral reefs, mangroves and wetlands offer protection from storms and other natural disasters to over half of the world's population. A research paper published in 2005 in *Science* showed that areas buffered by coastal forests, like mangroves, were strikingly less damaged by the 2004 tsunami

than areas without such vegetation. Interestingly, it has been known that mangroves are able to absorb between 70–90% of the energy from a normal wave although just how much of a buffer it could provide in case of a tsunami had always been debated. Seagrass beds and shellfish reefs filter pollutants from water. Mangroves, coral reefs and underwater seagrass meadows and kelp forests also serve as nurseries for fish and other lifeforms, providing a safe haven for the next generation.

Anne Morrow Lindbergh said, *“The sea does not reward those who are too anxious, too greedy, or too impatient.”* The aviation pioneer was right. We have to be patient, understanding and caring; only then will all the marine gifts flow to us in a sustainable manner ensuring that there is enough for all, including the generations to come.

3. DIVING UNDERWATER

Can ye fathom the ocean, dark and deep, where the mighty waves and the grandeur sweep?

Fanny Crosby

Salt water is not the preferred habitat of human beings because we have lungs, not gills. We cannot breathe the oxygen dissolved in the waters and therefore cannot survive long periods underwater. However, this has not deterred us from experiencing the fluid embrace of the sea. Perhaps the early pearl divers represent mankind's most daring attempts to face the challenges of the marine environment. This is because they did not hesitate to dive into the waters, armed with little more than what Nature had gifted our species.

The early pearl divers closed their nostrils with bone or wood clips; held on to a line leading to the surface, and plunged right in. The other end of the line was tied around a heavy stone to aid a fast descent into the water. A sharp jerk on the line signaled to their partners to pull them to the surface. Each dive lasted about two minutes, and a diver would make 60 to 100 dives every day. Oblivious to the corrosive action of saltwater on the skin, they also bravely faced dangers from marine animals such as the Moray eel and sharks. Basically it was a death defying descent, the success of which depended on how long the divers could hold their breaths.

Interestingly, this tradition of diving for pearls is still practiced by a small group of Japanese women who are referred to as "*Ama*." The word "*ama*" literally means "sea person" in Japanese. The history of the *Ama* has been chronicled since

300BC. The *Manyoshu*, a seventh-century collection of Japanese poetry also includes verses about the *Ama*.

What began as dives to collect seafood such as abalone, sea urchin, lobster, sea cucumber and octopii evolved into pearl fishing over the ages. These women have developed a unique physiology wonderfully adapted to their job. They are unusually tolerant of cold and this, allows them to remain underwater for longer. The *Ama* divers of today wade into the water armed with a float attached to a net for collecting the oysters. As a concession to modernity, they use wetsuits and flippers, not the traditional white cotton robes although they do use scarves decorated with lucky symbols. It is reported that the *Ama* practice a distinctive breathing technique called “sea-whistling,” which apparently prevents lung damage.

However, the ingenuity of the human brain worked out other ways and means to stay under water for more prolonged periods.

There is at least one recorded account of Chinese divers who stayed underwater for longer periods of time, thanks to a crude technology...a breathing tube. They breathed through a long curving pipe that led up above the surface of the water. This long breathing tube was strengthened by rings of tin and fastened to a watertight leather face mask. Interestingly, there are records of modern-day commandos hiding undetected under water by using the hollow stems of water plants as a breathing tube!

Diving Bell

The ancient pearl divers relied on their lung capacity to see them through their dives. However, those divers seeking to stay under water on more than just a lungful of air soon worked out other techniques. They dived with cauldrons on their heads. These inverted devices trapped air over the diver's head, allowing them to remain underwater for longer periods.

The Diving Bell is one of the earliest types of equipment for more prolonged excursions underwater. Available descriptions say it was a cable-suspended airtight chamber, open at the bottom and that it was lowered underwater. Aristotle (4th century BC.) wrote, “...*they enable the divers to respire equally well by letting down a cauldron, for this does not fill with water, but retains the air, for it is forced straight down into the water.*”

It was Guglielmo de Lorena who in 1535 designed the first modern Diving Bell. He designed it to rest on the diver's shoulders. Much of its weight was supported by slings. The bell provided enough air for about an one-hour dive. This contraption was, most probably used for commercial sponge fishing.

In 1689, the French physicist Denis Papin proposed, what was perhaps the first plan to provide air to the Diving Bell. His design incorporated a system to supply air under pressure from the surface. Unfortunately, it remained confined to paper and apparently, a working model was never built.

Two years later, Edmund Halley designed a Diving Bell capable of allowing the diver to remain submerged for longer periods of time. He was far-sighted enough to include a window in it to facilitate undersea exploration. Other designs came and went till in 1772, French scientist Sieur Freminet came up with a design for the first practical Diving Helmet. Unfortunately, even this design was not a success.

Subsequently American John Smeaton incorporated several improvements to the Diving Bell. In 1788, he managed to adapt a hand-operated pump to provide fresh compressed air. His design was successfully used by divers who worked salvage operations.

Diving Suits

Soon however, simple Diving Helmets/Bells no longer pleased anyone. The effort was on to create a suit that would envelop

the entire body and facilitate diving. The Diving Helmet/Bell was evolving; it was being upgraded to a Diving Suit.

The credit for designing the first waterproof diving suit goes to Chevalier de Beauve (1715). His suit was basically an iron corset that protected the chest against water pressure. A leather jacket over the corset provided the waterproofing. The outfit was complete with trousers and weighted shoes. It even had a helmet with clear glass over the eyes. Two pipes were attached to the helmet for air to be supplied, thanks to some vigorous bellows action on the surface.

Without a doubt Chevalier de Beauve's outfit was cumbersome and perhaps divers were relieved when the same year, John Lethbridge developed a completely enclosed, one-person diving machine. Lethbridge's contraption was basically an airtight oak barrel that allowed the diver to remain underwater long enough to carry out salvage operations. This is how he described it, *"It is made of wainscot perfectly round, about 6 feet in length, about 2 feet and a half diameter at the head, and about 18 inches diameter at the foot, and contains about 30 gallons; it is hooped with iron hoops without and within to guard against pressure."*

There are two holes for the arms, and a glass about 4 inches diameter, and an inch and a quarter thick to look through, which is fixed in the bottom part, so as to be in a direct line with the eye, two airholes upon the upper part, into one of which air is conveyed by a pair of bellows, both which are stopt with plugs immediately before going down to the bottom. At the foot part there's a hole to let out water.

Sometimes there's a large rope fixed to the back or upper part, by which it's let down, and there's a little line called the signal line, by which the people above are directed what to do, and under is fix'd a piece of timber as a guard for the glass.

I go in with my feet foremost, and when my arms are got through the holes, then the head is put on, which is fastened with screws. It

requires 500 pound weight to sink it, and take out 15 pound weight from it and it will buoy upon the surface of the water.... I can move it about 12 foot square at the bottom, where I have stayed many times 34 minutes. I have been 10 fathoms deep many a hundred times, and have been 12 fathom, but with great difficulty...”

His design appears ludicrous by today's sophisticated standards but it did work.

However, the first of what came to be called a proper “Diving Suit” was made in 1797 by German mechanic Karl Heinrich Klingert who wanted to create a diving machine which would allow a person to “*walk, talk, breathe and move freely*” under water. His design consisted of a jacket and trousers made of leather, a helmet with a porthole, and a metal front. It was linked with an air reservoir. However, he tested it successfully under the waters of the River Oder...not the ocean.

Augustus Siebe, a German instrument maker, refined and improved on the existing designs. He introduced the Siebe Improved Diving Dress in 1837, which was the true predecessor of the deep-sea suits used now. From the 1840s onwards, he began to manufacture the first ‘closed diving suit’ known widely as the ‘Standard Dress Suit’. The closed diving suit was completely watertight; the helmet was attached to the suit by bolts around the base.

Free-Diving

In retrospect, however, it would not perhaps be wrong to say that the true mantle of the ancient pearl and sponge divers has fallen on the shoulders of the thrill-seekers who enjoy the sport of free-diving.

The British Free-diving Association defines the sport as, “*one...of breath- hold diving in which the diver descends under water on a single breath of air.*” It describes No-limits free diving as the most spectacular form of free-diving due to the extreme depths and risks involved.

According to descriptions available about this extreme sport, the diver descends feet first, on a weighted sled, which runs along a rope. The sled has a scuba air cylinder and a large air bag. On reaching the target depth the diver inflates the air bag with air from the cylinder, which then rushes to the surface, taking the diver with it. Ascent speeds can be as high as 3-4m/sec. Swift speeds such as these has the potential of bringing on decompression illness that happens when a diver ascends too swiftly.

Needless to say, this is an extreme form of sports. It calls for tremendous fitness and expertise.

SCUBA

The nearest most people come to enjoying the unrestricted pleasures of underwater existence is when they Scuba-dive. SCUBA is an acronym for “self-contained underwater breathing apparatus”. The existence of the term, and the technology, attests to the fact that the human species has conceded the underwater world to those naturally better adapted.

Scuba divers enjoy the unrestricted pleasure of underwater existence

Scuba divers carry their own breathing gas; usually compressed air so that they have greater freedom during the dives. In the words of Cousteau, "To halt, and hang attached to nothing, no lines or air pipe to the surface was a dream..." It was a dream that many had dreamt and, in time, it spawned a design that freed humans to explore the underwater habitat with tanks strapped to the back and flippers on the feet!

William H. James was the first to design a self-contained underwater breathing apparatus in 1825. His equipment allowed the diver to remain underwater for up to an hour.

The television channels that showcase natural history often show glorious shots of scuba divers swimming amongst the colourful coral reef fishes or large aquatic mammals. It is a real joy to see the fluid grace of these aquatic animals as they go about their daily business of life and equally difficult to restrain a tiny frisson of envy as the scuba diver gets a glimpse, close-up.

The first commercially successful scuba sets were the Aqualung open-circuit units developed by Emile Gagnan and Jacques-Yves Cousteau in 1943. The Aqualung gave the diver complete freedom underwater. Three cylinders provided its air supply. It had a regulator that allowed the divers to control the amount of air they breathed. This system was called "open-circuit" because the gas flowed from the cylinder, to the diver, and then into the water.

In "closed circuit" or "re-breather" apparatus, the gas flowed from the cylinder, to the diver, through a scrubber (to remove carbon dioxide), back to a secondary bag, and then, again to the diver. The Aqua-lung was first sold in France in 1946 and soon took the world by storm.

Cousteau and his colleagues used the Aqualung on hundreds of dives. Recalling the experience, about ten years later, he wrote: *"From this day forward we would swim across miles of country no man had known, free and level, with our flesh feeling what the fish scales know."*

Bathysphere

The SCUBA equipment is necessarily designed for a single individual. However, there are other equipments designed for underwater use by more than one individual. The Bathyscaphe is one such vessel designed to operate at great depths.

American explorer Charles William Beebe and Otis Barton designed a spherical steel vessel called a Bathysphere that could be lowered from a ship and suspended from a cable. The word 'Bathysphere' was inspired by the Greek words meaning "deep ball." The 'ball' weighed 2250 kg and had a diameter of 4.5ft. The Bathysphere was tethered to a mother ship at the surface, via a steel cable. The mother ship provided backup support, communication facility, oxygen and electricity. In 1934 the Charles William Beebe became the first human being to observe marine species at hitherto unexplored depths, when he used it to descend to 923m beneath the ocean's surface – about six times the record depth survived by previous divers.

However, despite the grand success there was always a niggling fear about the inherent danger of the cable breaking and the occupants being unable to return to the surface.

Clearly a better craft had to be designed.

Bathyscaphe

Swiss physicist Auguste Piccard designed the first Bathyscaphe in 1947. The name was derived from the Greek words "*bathos*" meaning "deep" and "*scaphos*" meaning "ship or vessel." This term is appropriate only for deep submergence vehicles that use a gasoline-filled-float to carry the "sphere" housing the divers.

Piccard named his first Bathyscaphe, F.N.R.S.2 - an abbreviation for the *Fonds National de la Recherche Scientific* - apparently, the name of his funding agency. In 1954, he used

it to study life at depths of 4000 m. Subsequently, the Bathyscaphe *Trieste* set a world record on 23 January 1960, when it descended 10,915 m to the bottom of the Marianas Trench with Jacques Piccard (son of Auguste Picard) and Lieutenant Donald Walsh of the U.S. Navy on board. Resting on the seabed, the *Trieste* seemed unaffected by the eleven kilometers of water that weighed down on it.

Jacques Piccard, later described this almost surreal experience in these words, “... *indifferent to the almost 200,000 tons of water pressing on the cabin from all sides, ...slowly, surely, in the name of science and humanity, the Trieste took possession of the abyss, the last extreme on our earth that remained to be conquered.*”

It still remains the deepest dive ever carried out...ever.

Submersible

A submersible is a small vehicle that operates under water. It is not, strictly speaking, a submarine. A submersible, unlike a submarine, must be tethered to something ...be it a submarine or a ship or a platform.

Submersibles help to study ridges and canyons from close range

Submersibles travel at speeds of about 1.6 km-5.6 km per hour. This is not only pretty slow, but it also, rather restricts their range because they take unacceptably long time to cover decent depths. Another drawback is that a submersible must be transported to the dive site aboard a surface ship. Besides, work has to be done beforehand to recon the proposed site with towed cameras etc., to make sure it is worth deploying the submersible. So that too adds to the cost of operation as well as the time consumed.

Interestingly, it was Jacques-Yves Cousteau again, who developed the first submersible. His *Soucoupe Plongante* (Diving Saucer) was launched in 1959. It could seat two people and take them on dives as deep as 300 m. Later models could dive to 410 m. The advantage was that, since it was small, it could be easily maneuvered. Thus underwater nooks and crannies, ridges and canyons could be studied from close-up.

Bigger and better submersibles have since been designed.

Unmanned Robot Submersibles

Unmanned, robot submersibles are used for underwater exploration. For example, the *Argo*, which is capable of descending to depths of 6000 m was used in 1985 to locate the wreck of the *Titanic*. The smaller robotic *Jason* was used to explore the wreck.

Manned Submersibles

The *Alvin* is one of the world's first deep-ocean submersibles and arguably, almost legendary. It was named *Alvin* in honour of Allyn Vine, an engineer, geophysicist and pioneer of deep sea research and technology.

According to Woods Hole Oceanographic Institution (WHOI), USA, that owns *Alvin*, it can accommodate two observers and a pilot. It can safely transport them to depths of 4,500 m; thus bringing almost 63 percent of the global

ocean floor within reach. It uses water and expendable steel weights as ballast; sinking and resurfacing in accordance with the forces of gravity and principles of buoyancy. It is equipped with onboard cameras for both still and video photography. Its outboard lights provide adequate illumination for photography and observation. It also has two robotic arms that can manipulate instruments and a basket that can carry 680 kg of samples.

Unfortunately, the *Alvin* suffers from the one disadvantage that all submersibles have. It takes about two hours for the *Alvin* to dive to its maximum depth and another two to return to the surface. Each of its dives usually takes 6–10 hours...so the actual time spent in observation is only 2–6 hours.

The *Alvin* was built in 1964 and it has made more than 4,300 dives over the last four decades. However, despite its vintage it is a state-of-the-art submersible because it is completely disassembled every three to five years and parts are replaced as necessary.

Submersibles also have the potential for use to make strategic claims. On 28 August 2010, the *Hindustan Times* reported that China had used a 22-ton and 8 m long, manned submersible to dive to depths of 3759m and to plant its flag in “...*energy-rich and strategic South China seabed.*” According to the report, the Chinese submersible is, “... *designed to scour the seabed 7000 m deep—outpacing the technology of the US, France, Russia and Japan.*”

This submersible is named *Jiaolong* for a mythical sea dragon. It is capable of accommodating three individuals, albeit in a rather cramped manner. According to reports in Chinese electronic media, the *Jiaolong* is designed to reach a depth of 7,000 m. This makes it the world's only deep-sea vessel that can theoretically reach those depths since Japan's *Shinkai 6500* has a depth capability of 6,500 m. The *Jiaolong* also has the

technical capability of “*stable hovering*.” It is built for operating for 12 hours underwater although under emergency conditions, life support systems can sustain the demands of the three-member crew for 84 hours.

Speaking about the *Jiaolong*, Xu Qinan, the Chief Designer was justifiably proud to go on record that it “...*represents the most advanced technology in deep-sea exploration*.”

The *Jiaolong* makes China the fifth nation in the world to have such advanced technology and it has already announced its plans of taking it on deeper dives.

Remote-Operated Underwater Vessels

Remote-Operated Vehicles or ROVs have been designed to overcome the drawbacks of submersibles. An ROV is powered and controlled from a ship. It can carry every type of instrument that a manned submersible can; but not passengers.

ROVs are smaller than manned submersibles; so they can enter underwater caves/crevices. Also, since scientists do not have to sit in cramped conditions, as they have to do in submersibles, ROVs can be used for longer hours. These do not need pressure-resistant hulls to keep passengers safe; just pressure-resistant cases are needed to protect the on-board instruments. This cuts down on manufacturing costs.

The deepest-diving ROV was Japan's *Kaiko-10000*, built by the Japan Marine Science and Technology Center, which was designed to operate only as deep as 10,000 m. However, the plucky *Kaiko* went all the way down to the Challenger Deep. It almost equaled the *Trieste*'s record but failed by a paltry 0.6 m. However, it did sample 180 different kinds of microbes from the Marianas Trench and helped push forward the frontiers of science even if it did not break any records for depths descended.

The *Kaiko* was lost at sea on 29 May 2003. It had been surveying an underwater gorge 4.7 km under the Pacific Ocean, southwest of Tokyo.

SCINI

Some submersibles operate under ice. An example is the Submersible Capable of under Ice Navigation and Imaging, or SCINI. This is a remotely-operated vehicle that remains tethered to the surface but functions underwater. It responds to remote control orders from the surface and is deployed to provide real time images from beneath the frozen surface of the sea. Needless to say, it is an invaluable aid to studying snow/ice-bound areas that are almost inaccessible or too dangerous to explore.

Sampling Sled

Sampling sleds are lowered to the seafloor for collecting samples and either towed by a ship or manipulated using its thrusters. Sampling sleds are usually the size of a large car. These are equipped with lights, a navigation system, chemical sensors, and a video camera. In addition, these may also have a 'claw' for catching hold of rocks and a system to collect fluids or trap soft-bodied lifeforms.

Autonomous Underwater Vehicles (AUVs)

AUV's are unmanned submersibles that, like ROVs are transported to the dive site by a surface ship. It is powered by batteries but controlled by a pre-programmed computer onboard the ship. Once it is in the water, the AUV operates independently.

Once the mission is over, the AUV surfaces; deploys a buoy and a radio beacon for the mother-ship to locate it.

The disadvantage is that a pre-programmed machine cannot take on the spot action when unforeseen contingencies arise.

Other Unmanned Vessels

The WHOI uses many unmanned vehicles to study the ocean at varying depths. Some of their autonomous underwater vehicles are:

- The *Jaguar*: This is an autonomous vehicle designed for use under Arctic ice.
- The *Puma*: This is an under-ice autonomous underwater vehicle, equipped with sonar and sensors to search wide areas. It can detect temperature, chemical, or turbidity signals from hydrothermal vent plumes.
- *REMUS* or **Remote Environmental Monitoring Units**: These vehicles are designed for coastal monitoring, as well as survey operations at various depths in the ocean.
- The *SeaBed*: This is an autonomous underwater vehicle that can ‘fly’ slowly to depths of 2,000 m or hover over the seafloor to collect highly-detailed sonar and optical images of the seafloor.
- Spray gliders: These vehicles carry a variety of sensors and can be programmed to go to desired locations.
- The *Slocum Glider*: This is an autonomous vehicle which moves up and down in the ocean by changing buoyancy.

Multi-purpose Hybrid Vehicles

Multi-purpose ‘hybrid’ vehicles can operate even under crushing pressures. A totally new, one-of-a-kind vehicle designed and operated by WHOI has been used to explore the Challenger Deep.

The vehicle, named *Nereus* after a Greek God, uses lightweight ceramic materials, not the traditionally used heavier metals and glass to shield electronics from intense pressure.

The *Nereus* operates in two complementary modes. In its first avatar it is an autonomous underwater vehicle that can be used

to survey large areas, for example, to map the seafloor. It can easily be transformed into a remotely operated vehicle. In this new avatar, it remains tethered to the ship via a micro-thin, fibre-optic cable. This cable allows it to transmit excellent, real-time video images. Plus, its robotic arm can collect samples too.

Submarines

A submarine is a large manned vessel that can operate independently underwater. The first serious discussion of a “submarine”—a craft designed to be navigated underwater—appeared in 1578 from the pen of William Bourne, a British mathematician and writer on naval subjects. He drew up the first known plans for an underwater boat. His vision was that of a leather-covered wooden frame craft that could be rowed from the inside. This craft was never built although it is considered the intellectual forefather of all submarines.

Submarines though manned can operate independently under water

By all accounts Dutchman Cornelis Drebbel built the world's first submarine in 1620. It was made of wood reinforced with iron and covered with leather. It seated a dozen people who rowed with oars that stuck out the sides through tight fitting leather sleeves to keep the water out. Under the rowers' seats were large pigskin bladders, connected by pipes to the outside. For diving, it was necessary to fill the bladders, which had to be emptied out again when the vessel needed to surface. This primitive submarine carried out excursions in the Thames River at a depth of about 4–5m but never ventured out to the seas.

Robert Fulton built an early submarine called *The Nautilus* in 1800. This cigar-shaped craft was powered by a hand-cranked propeller when submerged and it used a sail for surface power. It was the first submersible to have separate propulsion systems for submerged progression and for surface sailing. It also carried flasks of compressed air to allow its two-man crew to remain underwater for up to five hours.

Modern submarines are usually used by the military.

Winged Submersibles

Engineer Graham Hawkes, of USA's Hawkes Ocean Technologies, has created the *DeepFlight* series of positively buoyant, 'winged' submersibles. The submersibles built by Hawkes Ocean Technologies weigh between an eighth and a tenth less than the weight of most other crafts and can therefore be launched from many different kinds of ships. The first *DeepFlight* submersible was unveiled by Hawkes Ocean Technologies in the 1990s. In 1995, Hawkes Ocean Technologies launched its first vessel, *Deep Flight 1*. In 2003 it launched *DeepFlight Aviator*.

According to the company's website, Hawkes Ocean Technologies had also designed and built the *DeepFlight Challenger* to be the first craft in history capable of taking a solo passenger to the bottom of the Marianas Trench. It had

been commissioned by Adventurer Steve Fossett, who died in a plane crash in 2007. Fossett had reportedly planned to take it on a solo dive of 11277 m.

Hawkes Ocean Technologies has also designed the fourth generation DeepFlight *Super Falcon*, which is much faster than conventional submarines. This is a \$1.5 million ‘flying’ submersible capable of diving 305 m below the surface with two passengers onboard. Unlike other submersibles, the *Super Falcon* does not rely on ballast to sink or rise. Rather, it follows the model of air flight, using ‘downward lift’ on the wings to descend. Lithium polymer batteries power it and LED lights allow passengers to appreciate the beauty in the inky darkness of the deep sea with minimal “...*impact on aquatic life unaccustomed to unnatural light.*” It carries enough air for up to 24 hours. It is also “*positive buoyant,*” meaning that when it comes to a complete stop, it naturally rises to the surface. The plan is to “... *use it for, among other things, promoting a new exploration of the vast areas of the deep sea that until now have been out of reach for nearly all of humankind.*”

Currently the company is on its fifth generation winged submersible intended for science, industry, and the military.

Aero-submarine

Hawkes Ocean Technologies has also designed and built the *Necker Nymph*, a three-person “aero-submarine” that can dive to depths of 10973 m. *Necker Nymph* has been acquired by Virgin Limited Edition, a UK company. According to reports, the *Necker Nymph* is, “...*a new class of high-performance, positively buoyant vehicles which safely extend the overall capabilities of scuba, while offering the unique experience of underwater flight.*” Each dive of the *Necker Nymph* can last up to two hours, during which time it can perform “*dolphin-like flips underwater.*”

However, a trip can be just a tad expensive. The craft is only available if you rent *Necker Belle*, the luxury catamaran

at a weekly charter rate of U.S. \$88,000. The *Necker Nymph* will cost an additional U.S. \$25,000 per week.

Graham Hawkes, the designer of the *Necker Nymph* has compared it to an “*underwater aircraft*.” No doubt the novel vehicle will attract affluent tourists to experience the pure visual pleasure that the cockpit with its near 360-degree viewing promises.

Perhaps only after having felt the fluid embrace of the waters and having dived to the mind-numbing depths will we truly understand what Graham Hawkes meant when he said, “*If people could see (the deep sea) we wouldn’t call this planet Earth. Earth is a stupid name for a beautiful ocean planet. The fact that we call it Earth means we don’t understand it.*”

4. LIFE UNDER THE OCEANS

“The sea is ... where man is never lonely, for he feels life stirring on all sides.”

Jules Verne

Indeed it is impossible to be lonely in or under the marine waters. There is three hundred times more living space available in the ocean than in the land and the air, combined. Every bit is colonized! There are no zones where traces of life are not found. So, there truly is abundant life “*stirring*” in the oceans—much more near the surface and less so, on the bottom.

Life and the seas have a relationship that goes back to almost 3.4 billion years when the primitive seas served as the cradle of life. Even today the marine waters support a bewildering variety of life...many so bizarre that even marine scientists are taken aback when first confronted with them.

Classifying Life

To aid the ease of study some Scientists have classified all life on Earth into five Kingdoms. Kingdom Plantae that contains all the plants, Kingdom Animalia that contains all the animals, along with Kingdom Protista, Kingdom Fungi and Kingdom Archaea. There are other systems of classification but this is one of the simplest.

Kingdom Protista includes the microbes; Kingdom Fungi includes all the fungal species; and Kingdom Archaea some of the most resilient forms of life. Most of us know what the members of Kingdom Plantae and Kingdom Animalia are: plants and animals respectively. Incredibly, representatives of all these Kingdoms are found in marine waters.

Plants are easy to characterize; they have the green colouring matter, chlorophyll and can 'fix' sunlight to manufacture their own food. Animals depend on plants for food. Plant-life is comparatively less diverse (basically just microbes, seaweeds and seagrass) as compared to the stunning diversity of animal-life, in the marine waters. So it is worthwhile to take a quick look at how scientists study animals.

Depending on whether the animal has a backbone, or not, they are subdivided into two large groups: Invertebrates and Vertebrates.

Invertebrates are those that have no backbone or vertebrae. The animals under each group are further subdivided into different sets called Phylum depending on shared characteristics. New phyla are added as scientists learn more about the lifeforms that share Earth with us. For example, in 1983, marine biologists discovered the thirty- third animal phylum, Loricifera. Even today not much is known about them although it is speculated that they live in mud between grains of sand, and feed on other microscopic animals. The first known loriciferan was *Pliciloricus enigmatus*, which was about one-quarter of an mm in size.

Some selected phyla that are commonly encountered in the marine waters are:

Phylum Placozoa (The only species known till now was discovered in 1883 from a marine aquarium in Austria. It is *Trichoplax adhaerens*)

Phylum Porifera (Sponges)

Phylum Cnidaria (Sea Anemones, Jellyfishes)

Phylum Ctenophora (Sea Combs)

Phylum Rotifera (Rotifers)

Phylum Nematoda (Nematodes)

Phylum Loricifera (Brush Heads)

Phylum Entoprocta (Marine Mats)

Phylum Ectoprocta (Bryozoans)
Phylum Phoronida (Phoronans)
Phylum Brachiopoda (Lamp Shells)
Phylum Mollusca (Sea Slugs, Octopii)
Phylum Annelida (Earthworms)
Phylum Tardigrada (Water Bears)
Phylum Onychophora (Peripatus)
Phylum Arthropoda (Sea Spiders, Crabs, Isopods)
Phylum Pogonophora (Beard Worms)
Phylum Echinodermata (Sea Stars)

Animals more evolved than invertebrates are grouped under:

- Phylum Hemichordata
- Phylum Chordata

Phylum Chordata contains the Sub phylum Vertebrata that includes animals with proper backbones. These are grouped into the following Classes:

- Class Agnatha (Jawless fish)
- Class Chondrichthyes (Cartilaginous fishes such as Sharks)
- Class Osteichthyes (Bony fishes such as Haddock and Cod)
- Class Amphibia (There are no marine Amphibians.)
- Class Reptilia (Reptiles such as Sea Turtles and Sea Snakes)
- Class Aves (Birds such as Penguins)
- Class Mammalia (Mammals such as Whales and Dolphins)

Pioneer Observers

It was the Greek philosopher Aristotle who made the most systematic observations of marine life. Of course, he had no microscope to aid him in his studies but that did not deter him from leaving behind a meticulously detailed account of that he had seen with his own eyes. Those writings have survived

the ravages of time, and remain, as Charles Singer, English historian of science puts it, “...an imperishable account...”

Much later, Edward Forbes classified ocean life according to the depths in which it was found. This is how he described his observations. “*As we descend deeper and deeper in this region its inhabitants become more and more modified, and fewer and fewer, indicating our approach towards an abyss where life is either extinguished, or exhibits but a few sparks to mark its lingering presence.*”

In his day, deep dredging the ocean was unheard of. So, he was of the opinion that oceans depths of 550 m, and below, were bereft of life. What he actually said was, “*Zero of Animal Life probably about 300 fathoms.*” This came to be known as Forbes’ azoic hypothesis.

Paradoxically, instead of killing all interest in the ocean’s supposedly barren lower levels, this statement somehow sparked renewed interest. Scientists became enthused about the possibility of discovering life at the depths. Within twenty years of Forbes’ disdainful dismissal of the ocean depths as nothing but deserted space, scientists around the world began to joyfully dismiss his claims. Ocean-going research vessels such as the Danish ship *Galathea* and the Russian ship *Vitiaz* aided them in their missions.

Lord Buddha had once said, “*Do not believe in anything simply because you have heard it. Do not believe in anything simply because it is spoken and rumored by many. Do not believe in anything merely on the authority of your teachers and elders. Do not believe in traditions because they have been handed down for many generations. But after observation and analysis, when you find that anything agrees with reason and is conducive to the good and benefit of one and all, then accept it and live up to it.*”

Forbes’ students honoured this saying of Lord Buddha, when they arranged the *Challenger* expedition. The *H.M.S. Challenger* was one of the first ships to be specifically equipped

for the study of the seas. The net result of this expedition exists as fifty huge volumes on knowledge about the ocean and the lifeforms it supports.

Sir Charles Wyville Thomson a Scottish zoologist and chief scientist on the *Challenger* expedition played a major role in documenting lifeforms found deep down. The dredging expeditions showed that animal life existed down to depths of 1200 m. It also documented that all marine invertebrate groups are present at this depth. These results were described in *The Depths of the Sea*, which he published in 1873.

Everyday, marine scientists are adding more information to what has already been collected. There seems to be no end in sight to the wonders that are being revealed with new and better technologies that are now available.

Census of Marine Life

Just how many totally marine creatures are there in the ocean waters? An idea may be gleaned from the Press Release of the world's first comprehensive Census of Marine Life, which was the result of a ten-year scientific initiative to assess and explain the diversity, distribution, and abundance of life in the oceans.

The Census of Marine Life announced in 2010, that it has documented 120,000 species of which around 6,000 are new discoveries. This includes two new species of sponges from the deep sea around the Andaman Islands. One of these sponge species was found on a volcanic sea mount at a depth of 705m. Many other new invertebrate species including deep sea sponges, crustaceans, echinoderms, spiders, corals, and nematode worms have been found in the Indian Ocean.

The Census of Marine Life, a foundation partner of the UN Atlas of the Oceans is a global network of researchers in more than 80 nations. It is one of the largest global scientific collaborations ever undertaken. It is the result of the tireless

efforts of 2,700 researchers who spent over 9,000 days at sea and many more days hunched over microscopes in the laboratories. It is the cumulative result of more than 540 expeditions that were instrumental in discovering about 1,650 new species every year- mostly invertebrates and crustaceans but also lots of fish species new to science.

The total cost came to about \$650 million...but no one doubts that its value is priceless. Priceless, because this is the first ever attempt to document, to the best of our ability, all underwater life.

The documentation process has been equally impressive. Over the first decade of the 21st century more than 2,600 academic papers were published – one, on average, every 1.5 days. The goal was to provide a sort of base level of total understanding of oceanic life which could serve as a sort of comparison standard for the future. There is no doubt that a lot has been achieved.

Ocean Biogeographic Information System

The Ocean Biogeographic Information System (OBIS) is a directory of names and addresses of all known species that live in the oceans. It not only establishes a reference against which decline/abundance of species can be measured but also delineates the vast areas of ocean that have not yet been explored.

Despite the colossal volume of information gathered and the many unknown species discovered, those associated with the study aver that they have merely scratched the surface of oceanic biodiversity. “*There are three to four unknown species for every known,*” points out Paul Snelgrove of Memorial University of Newfoundland, Canada. Sylvia Earle, explorer-in-residence at the National Geographic Society in Washington, DC adds, “*A conservative estimate of ocean species is 10 million, and it may be 50 million or more. Less than 5 percent of the ocean has been seen, let alone explored.*”

As Dr. Ian Poiner, Chairperson, Census Steering Committee puts it: *“All surface life depends on life inside and beneath the oceans. Sea life provides half of our oxygen and a lot of our food and regulates climate. We are all citizens of the sea. And while much remains unknown, including at least 750,000 undiscovered species and their roles, we are better acquainted now with our fellow travelers and their vast habitat on this globe.”*

Classifying Life in the Oceans

The living organisms of the Sea are divided into three main groups; Plankton, Nekton and Benthos.

Plankton

The word plankton comes from the Greek word for “wandering” and refers to the fact that these organisms float or drift passively; at the mercy of the waves and currents. Plant plankton is called phyto-plankton. Animal plankton is called zooplankton. Zooplankton includes the larvae of molluscs, worms and fish. Most plankton, such as diatoms and copepods are so small to be almost-microscopic but jellyfish can be quite large.

Planktons float or drift passively

Nekton

The word nekton comes from the Greek word for “swimming” and refers to the fact that these are strong swimmers. The many species of fishes, marine mammals and invertebrates, such as octopii, squids and even shrimps are examples. Perhaps the most important nektonic life form is the shrimp-like Krill.

Nektons include octopus, squids and shrimps

Benthos

*Benthos swim in the early phase of their lives
but later are fixed to one spot*

The word benthos comes from the Greek word for “depth of the sea.” It refers to all those lifeforms that swim about during the early phase of their lives but which, later become fixed to one spot. Barnacles that encrust the bottoms of boats and ships and Seaweeds called Kelps are examples. The term is also applied to the lifeforms that inhabit the sea-bed. So, clams, worms and crabs all qualify as benthos.

Marine Microbes

To most people, “life” refers only to that which can be seen with the unaided eye. However, the marine waters are teeming with microscopic microbial life and many of these marine microbes are intimately associated with the bio-geo-chemical cycles that drive the Earth’s engine.

Cultures of nutritionally- poor waters give a count of less than 10 bacteria per ml as compared to the 1000 bacteria per ml in the richer waters such as that of the Sargasso Sea. The count from waters taken from coastal regions and from sea-beds varies between 100,000 to several million microbes per ml. Direct viewing of the sea water through optical aids, yields values up to 3^{10} higher because the culture medium used to grow marine microbes is not perfect and many marine microbes do not grow in it.

International Census of Marine Microbes

According to the 2010 Census of Marine Life there may be up to 1 billion kinds of marine microbes – more than 100 times more diverse than plants and animals – and as many as 38,000 kinds of microbes in a typical litre of sea water.

The International Census of Marine Microbes (ICoMM), a research project under the Census of Marine Life, focused on the biodiversity of microscopic life forms in the world’s oceans. It has a databank of more than 25 million genetic sequences from microbes that inhabit 1,200 sites around the Earth – from polar bays to tropical seas; from estuaries to

offshore; from surface waters to deep-sea smokers; from corals, sponges, and whale carcasses.

When studying marine microbes, ICoMM scientists collected not just genetic data on the microbes but also information about the geographical coordinates, ocean depth, the acidity/alkalinity of the water and its salinity etc. This data revealed that all microbes are not found everywhere. A few microbial species dominate the oceans, but most are very low in abundance. Interestingly, although the microbes have the ability to disperse widely in the oceans; they do not appear to do so. Characteristic microbial communities can therefore be used to define different water masses in the ocean. These microbes can even be used as indicator species to ascertain the health of different ecosystems. Scientists are still scrutinizing the data that they have accumulated. No wonder, Mitchell Sogin ICoMM project leader, labels this unexplored realm of microbial life as the “*rare biosphere*.” Further studies will no doubt reveal many more of Mother Nature’s secrets.

Classifying Marine Microbes

Certain groups of marine organisms such as bacteria, yeasts and other fungi have narrow and specific requirements for growth. This aids the process of their classification into three groups.

- ***Surface flora*** which, as its name indicates is found in surface waters or rather shallow depths. The surface of the sea is rich in microscopic plants. Diatoms constitute the major part of floating micro-organisms. When the surface microbes die, they fall to the bottom of the seas. On the way, they are decomposed by bacterial action.
- ***Benthic flora*** is characteristic of the sea-bed.
- ***Pelagic flora*** is spread out between the surface and the benthic flora. The presence of pelagic flora is governed by ocean currents and the sedimentation process.

Interestingly, marine scientists also study what they call, “accidental flora” which exists in addition to the “specific and permanent” marine flora. Accidental flora is found in coastal waters, estuaries and shallow waters of the seas. Such flora survives in the salt waters only for very brief periods. As if these were not enough, scientists have labeled another group as “ubiquitous flora.” These microbes adapt equally well to marine as well as terrestrial conditions.

The undersea environment can be extremely hostile yet certain microbes have no trouble flourishing under these conditions. These are called Extremophilic microbes because they can thrive under extreme heat/cold/salinity/pressure etc. Microbes that can grow under crushing pressure are called Piezophiles. Microbes that can tolerate extreme cold are called Psychrophiles. Halophile microbes are those that can survive extremely high salt-concentrations.

Thermophiles

In 1993, John Baross and Jody Deming published a paper entitled “*Deep-sea smokers: Windows to a subsurface biosphere?*” This paper explored the idea that “super-thermophilic” microbes might live at extreme temperatures...near deep-sea hydrothermal vents. And soon enough, thermophilic bacteria were discovered. These were named thermophiles meaning heat-lovers.

Thermophiles are organisms with an optimum growth temperature of about 60 degree Celsius or more-temperatures fatally hot for most other organisms. Thermophiles include fungi, algae, and protozoa. Prof. Karl Otto Stetter, University of Regensburg, Germany, pioneered the study of organisms that thrive at extremely high temperatures and live around volcanic vents on the sea bed. In 2002, he discovered *Nanoarchaeum equitans*, the microbe with the smallest known genome, from a hydrothermal vent off the coast of Iceland; as well as *Pyrococcus furiosus*, *Aquifex aeolicus* and *Aquifex pyrophilus*.

After Baross and Deming published their paper, John Parkes, University of Bristol, UK, discovered marine bacteria that live at a temperature of 169 degree Celsius. These hyper-thermophiles require temperatures ranging from 80 degree Celsius -105 degree Celsius for growth. Hyper-thermophiles are almost exclusively restricted to the Archaea and some bacteria.

Hyper-thermophilic organisms have set a new limit for temperatures at which life can exist. *Pyrolobus fumarii* currently holds the record for the most thermophilic of all known organisms. It is unable to grow below 90 degree Celsius because it is too cold! Cultures of *P. fumarii* can survive for an hour inside an autoclaving machine i.e., temperatures up to 121 degree Celsius.

Scientists know that proteins are sensitive to heat. Too high a temperature and the protein structures break down or denature. So they were not surprised to find a specialized form of a molecule called a thermosome in extremophiles, which assisted proteins to refold correctly after denaturation due to heat exposure. Thermosomes are also called Heat Shock Proteins. At 108 degree Celsius, approximately 80% of the proteins of *Pyrodictium occultum* consists of a heat-induced thermosome. This allows it to survive one full hour inside an autoclave machine at the grueling heat of 121 degree Celsius.

The fact that the enzymes of these organisms work fine at such seriously elevated temperatures means that their enzymes are tolerant of high temperatures. Scientists are interested in such enzymes because of their potential for practical commercial use. They are also interested in learning about the stability factors that gave these enzymes their unusual properties.

The good news is that at least one of the mysteries about hyper-thermophiles has been cleared up. Scientists have discovered that all hyper-extremophiles possess an enzyme called Reverse gyrase that helps stabilize the structure of their

DNA. This is the only protein that is both specific for, and common to, all hyper-thermophiles. These organisms also contain other special proteins which significantly increase the temperature at which their DNA breaks up or denatures. Interestingly, when the thermophiles and the hyper-thermophiles find themselves in waters too hot for their liking, they enter a state of suspended animation or dormancy only to return to normalcy when the conditions are optimum again.

Tolerance to High Pressure

Pressure under the sea can be crushing, to put it mildly. However, marine microbes seem to have conquered even that! Pressure-loving organisms, called Piezophilic species, were discovered from the Marianas Trench in 1979. These grow quite well even when the pressure equals about 800 times what we experience at sea level. In fact they hardly grow at all if the pressure falls below 500 times the sea-level pressure. Scientists knew that the key to being able withstand such excruciating pressure lay in the genes. Sure enough, they located the *cydD* gene that was found to be essential for the bacterial growth under conditions of high-pressure. The product of this gene plays an important role in respiration and it is the respiratory system in piezophilic bacteria that holds the key to their survival in a high-pressure environment.

Salt- loving Organisms

Hypersaline habitats include salt flats, evaporation ponds and deep sea hyper-saline basins. These salty aquatic environs appear to be immediately lethal to most organisms because of the terribly high salt content. However, one has only to look to find a salt-loving organism or two flourishing here. The Archaea include many halophiles. Halophiles are often thermophiles as well.

No Need of Sunlight

At depths where sunlight cannot reach, the waters are cold and dark. One could be excused for presuming that life has been defeated by the harsh conditions...but such is not the case.

Once considered a barren plain, the seafloor appears to be teeming with life. Before these incredible extremophilic microbes were discovered, scientists didn't believe it was possible for anything to survive in the extreme environment around deep ocean vents. Then, it was thought that the dissolved sulphides that gush out from the vents hold the clue to this rich species diversity. This idea gained ground when scientists discovered that certain bacteria derive energy from the oxidation of sulphides and thrive as mats on rocky surfaces and on the surface of sediments.

However, despite the new discoveries, we are nowhere near to having listed out all the microbes that are present in the marine environment. This is a strange situation because marine microbes constitute 50–90% of the biomass found in the oceans. Yet until technological advances such as high-throughput DNA sequencing of genomes became possible, most microbial secrets remained largely hidden from humankind. An advantage that is now emerging is that many medicinally valuable marine microbes are being identified. We still do not know how many more microbes are awaiting discovery and what 'gift' they may bring for us. However, Dr. John Baross has pointed out, *"The total number of species of marine microbes, including both Bacteria and Archaea, based on molecular characterization, is likely closer to a billion."*

Mitchell Sogin agrees, *"In no other realm of ocean life has the magnitude of Census discovery been as extensive as in the world of microbes."*

But Sylvia Earle seems to have summed it up best when she said, *"...we have a lot more to learn about the ocean."*

5. MARINE LIFE UP CLOSE

“The bottom of the sea is cruel.”

Hart Crane

The bottom of the sea may be cruel; but this cruelty has not led to a divorce from life. So diverse is the life that thrives in the oceans that scientists are spoilt for choice when they decide to study, “Marine life.” This is because they have a wide variety of habitats from which to choose. They may study the beaches or the inter-tidal zones, the coastal areas, the frozen Polar Sea, or the black, freezing depths of the deepest waters. The options are many and wherever they look; life is thriving despite the obvious challenges. There are few more challenging habitats than the ocean bottoms...and the flag of life is held aloft here by bizarre creatures that science is only meeting for the first time as technology to explore the sea bed slowly emerges.

As scientists study these creatures they realize that they sometimes share common features. For example, ocean creatures tend to be significantly larger than their terrestrial counterparts. Sea spiders, which are not “true” spiders but only distantly related to them, can grow to gigantic sizes. Scientists studying the seas around Antarctica in 2008 discovered sea spiders the “*size of dinner plates*.” The giant tubeworm *Riftia pachyptila*, found around hydrothermal vents, can grow 1.5 m long, yet has no mouth or anus and only a vestigial gut. Their shallow water cousins never grow so long. While terrestrial isopods (example Woodlice) range in size from 1–5 cm, the giant isopod (*Bathynomus giganteus*), a scavenger species in the pitch darkness of the bathypelagic

zone grows to 37 cm in length and maximally reaches a weight of 1.7 kg.

It is clear many surprises await us under the waves.

Holding Aloft the Banner of Life

Usually when people talk about life in the seas they mean animal life because plants are perceived as being basically terrestrial in nature, with the few aquatic ones being restricted to freshwater. They may not be far wrong but there are some interesting representatives of plant life in the salty waters. However, sea plants are at a relative disadvantage when compared to terrestrial plants because sunlight is not so abundant where they grow.

Phytoplankton

Phytoplankton plays a key role in ocean ecosystems because these are photosynthetic organisms and thus qualify as plants. The word photo synthesis is derived from the Greek words "*Photo*", meaning "light" and "*Synthesis*" meaning, "put together". It is the creation of complex organic materials, especially carbohydrates, from carbon dioxide, water and inorganic salts, using sunlight as the source of energy and with the aid of the green colouring matter called chlorophyll. Photosynthesis releases oxygen as a byproduct. No animal tissue contains chlorophyll. Thus at a fundamental level all animal life is dependent on plant life...for food and oxygen, both.

Plants are called producers because they produce their own food. Phytoplankton is one of the fundamental or primary producers in sea waters. Additionally, phytoplankton also serves as food for other organisms.

Meadows under the Sea

Meadows on land are where the grasses grow. Under the waves one, or sometimes two, species of Seagrass give rise to huge underwater 'meadows.' Although these 'grasses' do not belong

to the family to which terrestrial grasses belong, these are called grasses because of the grass-like shape of their leaves.

The first seagrasses appeared about 100 million years ago today these are found in almost all marine waters. For example, the seagrass *Zostera marina*, can be found in sub-tropical to sub-arctic waters. seagrasses grow in diverse habitats ranging from the inter-tidal regions to depths more than 50 m, where the waters are clear. The Polar seas are the only places where seagrass does not grow. Australia has the highest number of seagrass species of any continent. Of the sixty or so seagrass species found worldwide, 30 are found in Australia.

Seagrasses have separate roots, leaves and root-like structures called rhizomes, which are often heavily colonized by fungi.

Seagrass meadows provide safe habitats for many animal species. Fish communities tend to be more abundant in seagrass meadows than in adjacent un-vegetated sea bottoms, perhaps because of the shelter that the seagrass provides. However, despite preferring seagrass meadows as places of residence, not many fish species seem to relish seagrass. Only about 20 species of fishes, worldwide, feast on seagrass although more than double that many species of fish call seagrass meadows, home. The green turtle (*Chelonia mydas*) loves seagrass. Many birds such as gulls and pelicans feed on seagrass meadows, particularly those growing in inter-tidal zones. Marine mammals, such as the dugongs (*Dugong dugong*) and manatees (*Trichechus sp.*), 'graze' in Seagrass meadows. Molluscs such as the large Queen conch (*Strombus gigas*) and the shell-less Sea Hare (*Aplysia sp.*) like to munch on seagrass. Sea urchins like to eat Seagrass so much that they sometimes cause denudation of the meadows. These are called seagrass barrens!

Algal communities develop on the leaves of the seagrasses. Benthic diatoms settle on newly developing seagrass leaves. As the leaves grow, the diatom population gives way to larger algae and sessile invertebrates. The leaves of the Mediterranean seagrass *Posidonia oceania* last for about a year. So, the gradual

establishment of colonies and their replacement as the young leaf grows old can be easily studied. As different communities come and go on the leaves, their predators too come and go. Piscine species such as the cow bream (*Boops salpa*), the 90 different species of parrot fish and 28 different species of rabbit fish (*Synganus sp.*) often visit the meadows to nibble on the tenants on the grass blade.

Seagrass ecosystems are important reservoirs of biological diversity—more than 350 large algal species that take up residence on the blades of seagrass have been listed. There are over 170 species of invertebrate animals that live in association with seagrasses. This list includes diverse groups such as nematodes, rotifers, tardigrades, copepods, hydrozans, ascideans, bryozoans, even sponges, and annelid worms. seagrass meadows are important prawn nurseries; especially for tiger prawns (*Penaeus semisulcatus* and *Penaeus esculentus*).

Green-sea-turtle

Sometimes the associations are mutually beneficial or symbiotic as in the case of blue mussels (*Mytilus edulis*) and seagrass. The activities of the mussels provide inorganic nutrients to the waters and sediments where these grasses

grow. The mussels feed on the particles trapped by the seagrasses and are also relatively safe here from predation as the fronds of the Seagrass afford protection.

Sometimes the association can become almost-exclusive as is the case of the mollusc *Pinna nobilis* with *Posidonia oceania*. The trouble is that widespread decline in *Posidonia oceania* across the western Mediterranean Sea is leading to a decline in the population of *Pinna nobilis* too. To add to the sorry tale, *Pinna nobilis* is host to a species called *Pontonia pinnaphylas*, which, as part of another symbiotic relationship, lives safely within its shell. So, if the Seagrass dies, so does its mollusc friend, which in turn means doom for its tiny tenant too. This has been termed the Biodiversity Russian doll after the Matryoshka dolls- in- a- doll. It is a small example how a threat to the seagrass meadows may snowball into a crisis for many other species.

It is unfortunate that seagrass populations have suffered decline although just how much remains unquantified as there is little data on which to base studies. Restoration efforts are underway although there is no guarantee of success and even less idea about just how long it may take to reverse the damage.

Marine Alga

Algae are among the world's first lifeforms and are quite primitive plants. Many different kinds of algae grow in the seas. Most algae are tiny but some marine algae can be huge.

Giant kelp

For example, the multi-branched giant kelp, (*Macrocystis pyrifera*) can reach lengths of 46m.

Large marine algae are called seaweeds. Seaweeds can form huge floating masses. The best example is found in the Sargasso Sea where two species, namely *Sargassum natans* and *Sargassum fluitans* gave the Sea its name. These *Sargassum* species stay afloat thanks to gas-filled bladders, which act like buoys. Many creatures, such as worms, sea spiders, crabs and snails rely on them to provide shelter. Some fish and crabs even look like *Sargassum*- a great camouflage indeed. The pipefish *Syngnathus pelagicus*, for example is not only brownish-green in colour but is also covered by flaps of skin which resemble the leaf-blades of the Giant Kelp.

Seaweeds come in many colours: Green certainly, because these contain chlorophyll but also, blue-green, and shades of red, pink and brown. These colours are derived from pigments other than chlorophyll and mask the green colour so that it is not apparent to the eye. Scientists recognize three groups of Seaweeds according to the colour of their pigments. These are green, brown or red.

Seaweeds can absorb the nutrients directly from the surrounding water and have no need for roots or complex conducting tissues.

Seaweeds form a large part of the diet of many species and are also relished in many countries. For example, Dulse (*Palmaria palmata*) a red algae with leathery fronds is much appreciated for its taste and flavour. Dried dulse is often served as a salty cocktail snack that is often offered free-not because hospitality demands it but because it induces thirst! Although dulse used to be harvested from the wild it is cultivated these days. Dulse is a good source of minerals. It has a high Iron content and also, many trace elements. Dulse with small frilly outgrowths is sold as a sea vegetable with the trade name "Sea Parsley."

Seaweeds *Nori* (*Porphyra* sp.), *Wakami* (*Undaria pinnatifida*) and *Kombu* (mixture of dried *Laminaria longissima*, *L. japonica*, *L. angustata*, *L. coriacea* and *L. ochotensis*) are regarded as delicacies. *Nori* figures high on the list of nutritious seaweeds because fresh *Nori* has high protein content and also, significant amounts of Vitamins A, C, niacin and folic acid. *Kombu* contains about ten percent protein and is quite rich in minerals, vitamins and Iron. *Wakami* contains Iodine and essential trace elements such as manganese, copper, cobalt, iron, nickel and zinc. Irish moss or carrageenan moss (*Chondrus crispus*) is used for making carrageenan- a thickening agent used to make blancmange, a traditional vanilla-flavoured pudding.; hence the name. It is sold in Japan as *Hana-Nori*. *Ao-Nori*. The algae *Monostroma* spp. and *Enteromorpha* spp. are cultivated in Japan. The alga *Callophyllis variegata* is eaten in Chile. Hiziki (*Hizikia fusiforme*) is a species of brown seaweed. Its protein, fat, carbohydrate and vitamin contents are similar to those found in *Kombu*. *Mozuku* (*Cladosiphon okamuranus*) is a brown seaweed. Winged kelp (*Alaria esculenta*) is a large brown alga eaten in Ireland, Scotland and Iceland.

Seaweed

Sea farina is an innovative product made out of seaweeds. It is a ground, dried seaweed of varying particle size. The fine particles are used for baking while the coarser particles are used as condiment.

Apart from using seaweeds as food, people living in coastal areas also use these as fertilizers. Maerl is a fertilizer derived from the red algae, *Phymatolithon calcareum* and *Lithothamnion corallioides*. Maerl is used to neutralize acid soils, and as a substitute for agricultural lime. It is more expensive than lime but since it contains trace elements that are beneficial to plants, many farmers consider it a good bargain.

Seaweeds are also used to stabilize soil. Like all brown seaweeds, *Ascophyllum* contains alginate, a chain-like carbohydrate compound. When calcium is added to alginate, it forms strong gels. This property is used to stabilize soil, particularly steep slopes that are likely to suffer soil loss by runoff. *Ascophyllum* is composted under controlled conditions for 11–12 days and its alginate chains are broken into smaller chains. The granular, dark brown composted product contains 20–25 per cent water. The slopes are sprayed with composted *Ascophyllum*, clay, fertilizer, seed, mulch and water. The spray is fluid when spread but it sets to a weak gel over time and sticks to the sloping surface. It holds any available soil in place and retains enough moisture to allow seeds to germinate. Plants quickly grow on it and topsoil forms after a few years. Composted *Ascophyllum* is used after the construction of roads in many countries.

Animal Life

Despite the many problems associated with life in water, many animals call it home. However, the bodies of these animals show many structural and physiological changes that allow them to exploit the habitat better. Scientists call these changes, “adaptations” because these help the animals to best suit its surroundings.

Mammals

Although the whale is the name that first comes to mind when talking about marine mammals, there are others too, such as dolphins, manatees, dugongs (*Dugong dugong*), otters, seals, walruses (*Odobenus rosmarus*). Like land mammals these are warm blooded, breathe air using lungs and give birth to live young which they suckle. Many years ago...about 100 million years for blue whale...their ancestors re-chose the waters as their habitats, and here the descendants have remained ever since.

Marine mammals have streamlined bodies that considerably reduce drag and allow them to knife through water. Since effort is minimal, energy demands are little and oxygen consumption is lowered.

Manatee

The sea otter (*Enhydra lutris*) is one of the smallest marine mammals, and it spends most of its life in water. Its body is very buoyant making it easy for it to float. It also has a huge lung capacity that is almost double that of a land animal of comparable size. It can drink sea water, with impunity because it's large and ultra efficient kidneys filter out the excess salt, effortlessly.

Dugong and baby

Elephant seals and weddell seals (*Leptonychotes weddellii*) can go without breathing for well over an hour. During their dives Weddell seals may reach depths of 860 m, while Southern elephant seals (*Mirounga leonina*) can dive to depths of 1,500 m and more. Seal muscles contain much higher concentrations of a protein called myoglobin, which like hemoglobin in the blood, can also bind to oxygen. This turns its muscles into oxygen stores. Marine mammals have higher blood volume, a higher proportion of oxygen-carrying red blood cells plus the ability to reduce their heart rates while diving when compared to their terrestrial cousins.

Presence of hair or fur is a mammalian characteristic that most marine mammals lack. But this is only to be expected. Fur is a great insulator of heat but this purpose is defeated when fur gets wet. This is why most marine mammals have smooth skin. The skin does not have skin glands because oil and sweat are washed away by the water. Smooth, almost furless bodies help them move through the water with little friction. For example, whales have no hair or fur on their bodies except perhaps for the few bristles around their

mouths. However, fetuses of many whale species are covered by hair. This is thought to indicate an ancestrally hairy condition.

Fur seals (*Arctophalus sp.*) and sea otters are exceptions. The sea otter has the thickest fur of any animal. The fur is actually two kinds of hair: long waterproof guard hairs and short under-fur. The guard hairs keep the dense under-fur layer dry. sea otters also secrete natural oils that help their fur repel water. The skin therefore remains dry and heat loss is limited.

Fur seal

Swimming seals

The ability of the guard hairs to repel water depends on utmost cleanliness, and the Sea otter regularly grooms its fur. Its unusually supple body allows it to reach, and meticulously groom, every part of its body. If the fur is not kept immaculate, its insulation will fail with fatal results. The Sea otter also has long, highly sensitive whiskers to help it locate prey when waters are dark or murky.

Development of Blubber

As a compensation for the loss of hair, the mammals have developed a layer of fat in the connective tissue beneath the skin. This fat layer helps retain body heat which would otherwise have been radiated into the water. Blubber is a thick layer of fat found under the skin of all marine mammals. Marine mammals, being warm-blooded animals, need a way to maintain a constant body temperature. Blubber acts as an insulator and helps to conserve body heat despite the cold waters in which the animals swim. It is also a storehouse of energy. Depending on the species, blubber can make up anything from 20 per cent to 45 per cent of a whale's body weight. The thickness of the blubber can vary from 50 mm in smaller whales and seals to over 30 cm in larger whales.

Southern elephant seals are the largest of all seals. Males reach 4-5 m in length and up to 3500 kg in weight. They are also the deepest diving seals in the world. Females can dive as deep as 1600m with dive durations of up to two hours. During its annual cycle, the southern elephant seal spends most of the time at sea. It returns to land merely for breeding. These animals feed during the aquatic phase but fast while on land. During this time their blubber serves as a food store or energy reserve. This is important from the viewpoint of a male seal because other males in the colony will opportunistically mate with the females if it leaves the latter unguarded to forage for food.

Tail Tales

Tails provide powerful impetus during swimming. In the manatees and the dugong, the tail has become modified into a paddle used for propulsion. Dolphins are great swimmers too—all thanks to the incredible thrust their tails generate. An US study has found that the thrust from a dolphin's tail is more than triple that of what Olympic record holder, Michael Phelps generates in the swimming pool.

Loss of Limbs

Aquatic animals such as the whales, manatees and dugongs show no discernable signs of hind limbs. In the manatees and the dugong, the hind limbs are merely two small bones lodged deep in the muscle. It is believed that hind limbs began to regress after the ancestors of whales re-entered the aquatic environment. Interestingly, the fetal development of whales reflects this loss as well. In foetuses of the southern minke whale, (*Balaenoptera acutorostrata*) the fore-limb first appears in the 11.4 mm fetus, and the hind-limb in the 15.3 mm fetus. The fore-limb develops progressively during gestation, while the hind-limb subsequently disappears.

Changes to Eyes, Ears and Noses

The demands of the aquatic environment have been met in various ways by the aquatic mammals. The sea otter and the killer whales (*Orcinus orca*) can completely close off their nostrils when under water.

Dolphins have a highly advanced sense of hearing due to an arrangement of their teeth, which seems to work as a receiving device for incoming sound.

Sea otter

Most whales have very tiny ears but their sense of hearing is very vital to them, especially deep in the sea where no sunlight reaches. Hearing probably takes place through the lower jaw. The ears of killer whales, for example, are small inconspicuous openings, with no external flaps. They are able to receive sound through the soft tissue and bone surrounding the ear. High frequency sounds in the range of 50 kHz and above appear to be received effectively by the lower jaw.

The lower jawbone of toothed whales broadens and is hollow at the base, where it hinges with the skull. Within this very thin, hollow bone is a fat deposit that extends back toward the auditory bulla (earbone complex). Sounds are received and conducted through the lower jaw to the middle ear, inner ear, and then to hearing centres in the brain via the auditory nerve.

Many whales can produce sounds for communicating and navigating. The rapid series of clicks passes through the melon (the rounded region of a killer whale's forehead), which contains fats. The melon acts as an acoustical lens to focus these sound waves into a beam, which is projected forward into water in front of the whale. Higher frequency clicks probably function in echolocation that allows them to determine size, shape, speed, distance, direction, and even some of the internal structure of objects in the water. These whales hunt in the dark depths of the oceans. Under these conditions, sight is of little use and perhaps their ability to echo-locate as been honed as a response to this. The function of lower frequency pulses created by killer whales is unknown. Killer whales have acute vision both in and out of the water.

Beluga whales (*Delphinapterus leucas*) too probably rely on sound production and reception to navigate, communicate, and to locate breathing holes. The frequency and large repertoire of their vocalizations has earned them the nickname "sea canaries."

Beluga whale

Most dolphins have extremely good eyesight, both above and below the water. Dolphin eyes have a well-developed tapetum lucidum, a light-reflecting layer that facilitates vision in dim light. But the Yangtze River dolphin (*Lipotes vexillifer*) is almost blind and depends on echolocation to navigate and to hunt.

Reptiles

Members of the Class Reptilia that have a marine connection are few in number. These include sea turtles, estuarine crocodiles, Indian gharial (*Gavialis gangeticus*), sea snakes, and marine iguana (*Amblyrhynchus cristatus*).

Gharial

Of these, the sea turtles have the most intimate association with the sea. The only reason they ever return to land is to lay eggs. In the open ocean, Sea turtles routinely encounter strong currents. Their eyesight is just about adequate at best and they can only raise their heads a few cm above the water, and there are usually no visible landmarks—only a great watery expanse. Even with these limitations, these turtles regularly navigate long distances to return to the same tiny stretch of nesting beach. This speaks volumes about their navigational capability—which we are yet to understand, let alone be able to duplicate.

The sea turtle swims so well because its forelimbs are long, paddle-like flippers. They can even sleep at the ocean surface while in deep water. Sea turtles can live in seawater with no need for a freshwater source. They are able to obtain sufficient water from their diet and by metabolizing seawater. They have a salt gland that empties into their eyes and which rids their bodies of excess salt. No wonder that the Sea turtles look as if they are always crying.

Even when it comes to diving, sea turtles are champions! Hawksbill turtles (*Eretmochelys imbricata*) can remain under water for as long as half an hour. Green sea turtles (*Chelonia mydas*) can stay under water for as long as five hours. During the period of submersion, their heart rate slows down to conserve oxygen. When sea turtles dive deep, their blood is shunted away from tissues tolerant of low oxygen levels toward the heart, brain, and the more-demanding central nervous system. Leatherbacks (*Dermochelys coriacea*) have high concentrations of red blood cells; therefore, their blood retains more oxygen. Their muscles are rich in myoglobin; an oxygen conducting compound akin to the hemoglobin found in blood. But although sea turtles can remain submerged for long periods, they must return to the surface for a breath of air from time to time...a reminder of their secondary aquatic animal status.

Sea snakes are mostly confined to the warm tropical waters of the Indian Ocean and the western Pacific Ocean. There are no Sea Snakes in the Atlantic Ocean because it is too cold for their liking. Despite their aquatic adaptations, most prefer shallow waters not far from land and are common around islands and mangrove swamps.

The US Navy describes sea snakes as, “*generally mild tempered;*” still there is variation among species. The more aggressive species include *Aipysurus laevis*, *Astrotia stokesii*, *Enhydrina schistosa* and *Hydrophis ornatus*.

All sea snakes have flattened bodies with very small scales on their bellies. This means that they are unable to get a good grip on soil and are quite helpless on land. The Sea kraits (*Laticauda sp.*) are the only ones that can manage to slither about on land as their belly-scales are comparatively larger.

Sea snakes are well-adapted for a completely aquatic lifestyle. Their tails form an oar-like paddle to help them swim. However, they do not have gills for breathing, as fish do. Therefore, they are constrained to breathe air and must periodically surface or risk death by drowning. The lungs are very large and extend almost the entire length of the body. Apart from helping in gas exchange, the lungs are thought to aid buoyancy and serve to store air allowing the snake to undertake deeper dives.

Most sea snakes are able to, partially at least, respire through their skin. Reptiles, such as the sea snakes have scaly skins. Being able to breathe through such skin is pretty unusual. However, experiments with the black-and-yellow sea snake (*Pelamis platurus*) have revealed that it is able to supplement roughly 20 per cent of its oxygen requirements via the skin. Scientists think that this could be an adaptation that allows it to stay under water for longer periods.

Most unusual too are the light-detecting cells or photo-receptors in the skin covering the tail of *Aipysurus laevis*. Scientists think that these cells allow it to detect light even when sheltering in crevices and caves under the waves.

Birds

While many birds are associated with the seaside or even over the sea, few birds are actually adapted to life in the sea. The penguin is one such rare species; being a champion swimmer and diver amongst all avian species. Some species of penguins spend up to 75 per cent of their time at sea. Penguins have been described as being able to literally 'fly' through the sea and their cruising speed in water is about 10km per hour. They are excellent divers and can descend to depths of over 250m. However, most of their dives are usually restricted to 10m. Their wings are stiff, short flippers—almost paddle-like in appearance — that propel them underwater. Overlapping feathers create a surface practically impenetrable to wind or water; providing waterproofing critical to survival in freezing Antarctic waters. Tufts of down feathers on shafts trap air which provides 80 to 84 per cent of their insulation.

Fish

“Like a fish takes to water,” we say, emphasizing that fishes are meant for a life in water. Yet, so little is known about deep-sea lifeforms, that 50 percent of the fish species collected from deeper than 3,000 m, turn out to be unidentified species.

Fish can 'breathe' the dissolved oxygen of the water because they have gills and deep sea fish have gills too. They have large mouths and teeth, large stomachs (in proportion to their body size) and dark colouration. Many have a special dark lining in their stomach to conceal light emitted by engulfed prey — protecting them from attracting other larger predators, while they digest their own prey in peace!

Body Contour and Swimming Habits

Absolute precision has been achieved in the piscine body contour. The streamlined body reduces friction when the fish moves through water. So well proportioned are swiftly swimming fish such as the spanish mackerel (*Scomberomorus maculatus*) that viewed from the front, its body is like a perfect ellipse. This body shape reduces drag and requires a minimum amount of energy to swim. Fish that remain constantly on the move, searching for prey which is captured after a chase usually have torpedo-shaped bodies.

On the extreme other side of the spectrum, quite literally, lie the flatfish. These are laterally flattened fish that spend their adult lives lying on one side. Flounders are flatfish that inhabit the bottom of most warm or moderate oceans but are also found in some Arctic areas. These fish have both eyes situated on one side of the head, but they are not born this way. Their life involves a dramatic change called metamorphosis. During metamorphosis, one eye migrates to the other side of the body so that both eyes are situated on the upward-facing side of its body. After metamorphosis, Flounders lie with one side of the head placed on the ocean floor. The Flounder's body allows it to be completely undetectable as it lies flat on the sandy or muddy bottom, an adaptation that protects it from enemies, as well as allows it to grasp unsuspecting prey.

Eels and Pipefish on the other hand have elongated, snake-like body shapes. This allows them to enter small crevices in the reef and to negotiate seemingly inaccessible areas to hunt for food or to escape enemies.

There are other fish species which have rather peculiar body shapes and habits. For example, the Shrimpfishes *Aeoliscus* sp. and *Centriscus* sp. are quite 'horse-like' in looks. They have the strange habit of swimming permanently upside down...as

if searching for some treasure lost at sea. Another fish that swims belly side up as it forages in undersea caves and ledges is the beautifully coloured royal gramma (*Gramma loreto*).

The butterflyfish get their name because their bodies are compressed sidewise and with their characteristic colourings resemble butterflies quite closely. The resemblance is intensified as they dart here and there among rocks and coral just like a butterfly flits from flower to flower. The butterflyfishes *Chelmon rostratus* and *Forcipiger longirostris* have enormously elongated jaws that resemble a pair of delicate tweezers. These enable them to catch molluscs and crustaceans hiding deep within the coral growths.

The boxfish, also called trunkfishes have a strange box-like shape characterized by a high domed back and almost flat belly. They are also sometimes called Hovercraft fish because their transparent and rapidly beating pectoral fins appear to propel them forward like a hovercraft. The cowfish (*Lactoria cornutus*) is a boxfish that has been described as being “*armour plated*” much like a battletank.

The tripod fish (*Bathypterois grallator*) gets its name because its ventral and tail fins act like a tripod helping the adult fish to ‘stand’ on the ocean bottom. These fish are virtually blind but have long feelers on their pectoral and tail fins. The sensitive pectoral fins are extended sideways and can detect any vibration caused by potential prey. When small crustaceans bump into the greatly elongated and extended pectoral fins, it gently fans the prey toward the mouth.

However, one of the most spectacular body shapes that ‘can be assumed’ is perhaps that of the Porcupine fishes. These fishes, of which *Diodon hystrix* is one, can swallow huge amounts of water and inflate itself to many times its normal size when threatened. When thus inflated, the spines on its body stand

out at angles giving it an uncanny resemblance to a porcupine...and deterring potential predators. When in this state, the fish has been described as, "...a *football with the face of a Pekinese dog and the tail of a fish.*" The Pufferfish also have this ability to inflate their bodies and thus the reason behind their name can be easily guessed. However, this is a stress response and normally these fish do not swim about in this state.

Porcupine fish

Champion Swimmers

Fish swim by using their fins, body movement, or both. In general, the main moving force is the tail (caudal) fin and the area immediately adjacent to it, known as the caudal peduncle. Fin movement is powered by muscles that are attached to the base of the fin spines. The dorsal fins on the back of the fish serve to protect it against rolling, and assist in sudden turns and stops. Dragonfish, also called lionfish and turkeyfish (*Pterois* sp.) bear toxin-containing spines on their dorsal fins. The toxin is strong enough to incapacitate adult humans.

The anal fin is located behind the anus. It stabilizes the fish while swimming. The paired pectoral fins are located on each side, usually just behind the gill covers or operculum. The paired pelvic or ventral fins are located below the pectoral fins. The pelvic fin assists the fish in going up or down, turning sharply, and stopping quickly. The pectoral fins enable flying fish to “fly” and the mudskippers to “walk.” The Wrasses usually swim by using only the pectoral fins and their movement has been called “*hops through the water.*” However, if pursued by a potential predator the wrasses use strong undulatory movements of the body to achieve short burst of high speed. Eels also rely on snake like undulations of the body to move forward. Sailfish (*Istiophorus* sp.) fold their “sails” while swimming actively and rely mainly on their large, rigid tails to move forward.

Staying Afloat

Most fish have a swim bladder, which is an air-filled organ used to maintain balance and to swim up and down. A fish can inflate or deflate the bladder and thereby control its buoyancy. The gas in the swim bladder usually comes from the blood. It is transported into the bladder chamber from a network of small blood vessels in the lining of the bladder. If the fish starts to float upwards, gas diffuses out of the swim bladder into the blood. Conversely if the fish begins to sink, air enters the swim bladder. A fish must change depth slowly and in stages so it can adjust its buoyancy. Swim bladders in certain herring-like fish are also involved in depth perception. The bowfin fish's (*Amia calva*) swim bladder functions much like a lung, allowing it to gulp air when dissolved oxygen levels become dangerously low.

Deep-sea fish often die from gas expansion in the swim bladder as they are hauled up to the surface without giving them time to deflate. However, not all fish have a swim bladder. Sharks for example, do not have a swim bladder.

Marine fish lacking a swim bladder must keep swimming all the time if they are to prevent themselves from sinking. Many species such as the grey nurse shark (*Carcharias taurus*) use a different strategy to regulate buoyancy. They have a large, oil-rich liver and specialized body shape. This is thought to be an adaptation to the shark lifestyle. Since sharks need to be able to rapidly change the depths at which they swim, while in pursuit of fast moving prey, a swim bladder would only be a hindrance, causing life threatening buoyancy and depth-related trauma problems.

Eyes: Aye or Nay?

The eyes of some deep sea fishes are 15 to 30 times more light-sensitive than human eyes; able to detect light at depths down to 1300 m. Many deep sea fish have enlarged eyes, presumably for gathering as much light as possible where there is little or no light at all. Many deep-sea fishes make daily vertical migrations to surface waters at night and thus eyesight stands them in good stead. Snake mackerels (*Nesiarchus nasutus* and *Gempylus sp.*) are examples of deep-sea fish that make daily migrations to the surface and which enjoy good eyesight.

The rat-tails are deep-sea fishes that resemble deformed tadpoles more than the land mammal after which they are named. The eyes of these fish are really remarkable as these actually grow bigger as time passes. In addition, some species of Rat-tails have light-producing bacteria that live inside special glands under their eyes. It has been suggested that the eyes are capable of 'seeing,' courtesy the light produced by the bacterial tenants.

However, it is likely that it is the giganturids that have the strangest eyes. Their eyes are tubular and directed forwards, not upwards. So, it looks as if the fish is wearing binoculars. This has earned the genus the common name of Telescopefish.

The placing of the eyes ensures excellent forward vision but little lateral vision. It has been suggested that the binocular-like eyes serve as 'telephoto' lens allowing the fish to spot prey from a long distance away. This makes sense because the fish are poor swimmers and presumably need to 'stalk' prey. Interestingly, the fish appears to compensate for the loss of all-around vision by having scale-less skin that is sensitive to vibrations. Scientists think that they have an accessory retina in addition to the main retina, especially adapted for picking up bioluminescence from potential prey.

Because deep-sea fish live under conditions of little or no natural illumination, they cannot solely rely on their eyesight for locating prey or finding mates. But that does not seem to hinder their daily activities in any way. The Round goby (*Neogobius melanostomus*) is a small, bottom-dwelling fish that is capable of foraging in total darkness!

Many deep sea fish have trailing, sensitive, 'feelers' to help them locate prey in the dark of the deep ocean. Some depend on special organs that can 'see' infrared light, so they can sense some sort of body heat. Some deep sea anglerfishes have antennae-like appendages present directly on the trunk or mounted on long stalks or fin rays. These fish can sense the 'noise' created by movements of other animals.

Living at extreme, lightless depths, whalefish have eyes that are either very small or vestigial. The whalefish *Gyronomimus* sp., for example, has tiny degenerate eyes covered by a small area of pigmented skin. It has no remains of a lens, no iris and no eye muscles. Mere vestiges of the retina and optic nerve persist. The whalefish *Ditropichthys storeri* has retained its optic nerves; but the branches of the nerves reach an area where the eyes would have been—had there been visible eyes! Close microscopic examination has, however, shown that there are remains of retina and lens in the tissues.

Neuromast Organs and Lateral Line

Surprising at it may sound; fish have sensitive skin because nerve endings throughout the skin react to the slightest pressure and change of temperature. They also have numerous receptors on their skin. These are called neuromast organs, which have been described as “*fluid-filled pits*.”

Fish also have a row of specialized sensory organs along the sides of their bodies, called lateral line. Lateral line sense organ is a specialized neuromast organ. It consists mainly of a series of tiny canals under the skin. A main canal runs along each side of the trunk. Branches of these two canals extend onto the head. The fish senses the flow of water around it as a series of vibrations. The vibrations activate certain sensitive areas in the line. Any change in the flow of water around the fish changes the pattern of vibrations sensed through the lateral line. This alerts the fish of approaching danger or indicates the location of objects outside its range of vision. It is used to hunt for prey, to spot predators, avoid collisions, to orient in relation to water currents and as an aid in synchronized swimming as the school moves through water.

Researchers studying shark behavior have suggested that the lateral line may provide advance warning for inclement weather. Apparently juvenile blacktip sharks (*Carcharhinus limbatus*) sensed that massive turbulence (Hurricane Gabrielle) was about to strike and moved to deeper and calmer waters as it approached. Rat-tails have an armoured head pitted with sense organs. Plus they also have a well-developed lateral line organ, a sensory barbel on the chin and long sensitive filaments on the fins. All in all they are extremely well-adapted to detecting even minute vibrations in the water. They can, for example, detect the current set up as water flows through sponges and target small crustaceans and worms that settle around and on sponges and other sessile animals.

The whalefish have a well developed lateral line system too. This sensitive system can detect the merest hint of movement in water. Scientists guess that the Whalefish catches its prey by reading the vibrations set up by the prey's motions, which means that the lateral line system can sense direction as well.

Otoliths

The inner ears help the fish keep its balance. They contain a fluid and several stone-like, free-moving objects called otoliths or ear stones. If a fish begins to swim in other than an upright, level position, the fluid and otoliths change position to move over sensitive nerve endings in the ears. These nerves signal the brain about the changes in the position of the body and corrective messages are flashed by the brain to the fins. Fish can also sense changes in the pressure, salt content, or temperature of the water. Flying fish have unusually large otoliths. It is speculated that this is because of their need for balance when launching for "flight."

Electroreception and Electro-magnetic reception

Specialized electro-receptors empower the animals to detect weak electric fields in water. This ability is called electroreception. Electroreception is an adaptation for detecting prey and for navigation in murky water. Sharks have thousands of tiny pores on their skin. These are connected to little fluid-filled sacs. Called the ampullae of Lorenzini, these sacs help them to sense the faint electromagnetic fields generated by all living things. This gives sharks the hunting edge! It can attack the prey without necessarily needing to see it. This is an advantage in murky water where visibility is limited. Bottom feeding sharks rely greatly on this ability. Reportedly, this ability is so well developed in some sharks that they can find fish hiding under sand by the weak electric signals sent by twitching muscles. It is speculated that the aptly named head of the hammerhead sharks (*Sphyrna* sp.) gives them better electroreception senses. Since they have a larger surface area,

their ampullae are spread out over a greater distance. This better equips them to locate hidden food sources.

Hammerhead shark

Sense of Smell

In general, the sense of smell is well developed in fish. The nasal areas and extent of the sense of smell vary among species. Fish have nasal pits, which are actually blind sac-like structures in most species. Each of the nares is divided into incurrent and excurrent apertures so situated that the forward motion of the fish propels a stream of water into one aperture and out the other. The cells of the nasal or olfactory pits monitor the water stream and are stimulated by the smells emanating from potential mates or food or even enemies.

Two-thirds of a shark's brain is devoted to smell, its olfactory sense alerts the shark about the presence of a meal even in dark and murky waters. Sharks can pick up and follow a scent as dilute as one part of blood to 50 million parts of water.

Studies suggest that smell guides at least some species of salmon to their home streams during the breeding season. Scientists favour this hypothesis because they know that thanks to local differences in soil and vegetation, each stream has a unique chemical composition and, thus, a distinctive odour. Secondly juvenile salmon "imprint" this odour before they migrate to the sea and so it is likely that the odour "guides" them back to the very place where they once hatched. Another school of thought believes that the juveniles release population-specific "pheromones" which the adults track to find their way home. Whatever is the correct theory just imagine the feat involved—tracking odoriferous molecules diluted by all the water in the deep, vast blue sea. No human has ever duplicated this ability.

Underwater Hearing Ability

Fish have no external openings to the ears. Sound waves travel through soft tissue to the ears. There is great variation in hearing sensitivity among bony fish species. The hearing range of the Cod is about 2 to 500 Hz, with peak sensitivity near 20 Hz - probably typical for most bony fish species.

Swim bladders can detect sound vibrations and relay them to the inner ear via a set of bones in the middle ear called the Weberian apparatus. Hair cells in the inner ear respond to the vibrations and transmit the sound information to the fish's brain. In some species, the swim bladder lies against the ear and acts as an amplifier to enhance sound detection. It has been reported that the american shad (*Alosa sapidissima*) and certain related species can detect sounds from 200 to 180,000 Hz. It is speculated that this ultrasonic hearing is an adaptation for avoiding predatory, echolocating Dolphins, which typically produce clicks at about 100,000 Hz.

Enormous Gapes and Elastic Tummies

Because only 5 per cent of the food produced up in the epipelagic zone reaches the deep sea, deep-sea denizens eat

anything that comes their way, exhibiting extraordinary adaptations to enable this. Fish that live deep down must adapt to a very low food supply, eating only “scraps” that sink down from above, or sometimes, if lucky, being able to capture prey. Many have large mouths, often armed with extremely long, inwardly pointed teeth. This ensures that any prey captured has little chance of escape.

The fish *Saccopharynx lavenbergi* often described as “*pythons of the deep*” because of their body length are also referred to as gulpers. These can swallow prey much fatter than themselves. They swallow the prey whole, easing it through their “sack-gullet” (hence the term sacco-pharynx) and into their stomachs, where digestive enzymes finish the job.

Eurypharynx pelecanoides, is commonly called the umbrellamouth gulper—a name that more than hints at the wide gape of its mouth. It can open wide the loosely-hinged jaws and balloon out its mouth to engulf prey. It also has a pouch-like lower jaw, which has led to second nickname—Pelican eel. It can stretch its stomach to consume prey as big as itself. This is an asset because the stomach serves as a large warehouse for food storage and food can be digested at ease.

The fangtooth (*Anoplogaster cornuta*) has a huge gape lined by large, sharp teeth. Animals caught by this fish have little chance of escaping.

The stoplight loosejaw (*Malacosteus niger*) is another fish that has an enormous lower jaw. It can shoot forward its jaw suddenly. The long, inward pointing teeth on the jaw act as hooks to grab a prey object. Then the jaw is retracted; drawing the prey into the huge, tooth-lined mouth. There is no skin connecting the lower jaw bones. This reduces drag in the water when the jaw is retracted.

Bristlemouths (*Cyclothone microdon*, and *Cyclothone pallida*), together with Lanternfish and Hatchetfish, constitute the “Liliputian” fauna of the seas. But Bristlemouths can open their mouths nearly 180 degrees—a prodigious gape. Their mouth is lined with bristle-like teeth which gives them their name.

Gigantura *sp.* has needle sharp teeth that can be lowered or raised at will. This means that the teeth can be lowered out of the way when a large prey is to be swallowed. It also has an elastic stomach that can accommodate large prey.

The Atlantic Footballfish has teeth that can be depressed much like the teeth of the *Gigantura*. Whalefish and the Black swallower (*Chiasmodon niger*) also have distensible stomachs allowing them to accommodate large prey. Distensible tummies are an important adaptation where food is scarce.

Parasitic Males

The female anglerfish is much larger than the males. Some females can grow close to a meter in size while the average male is less than 5 cm long. Once it hatches out the male anglerfish have no other work other than to find a mate. It probably never even feeds. Males have large eyes, presumably for spotting a female and a much larger olfactory organ to catch her scent. After locating a female anglerfish, the small male hangs on to the female by biting into her. From this moment onwards the male begins to degenerate. His teeth and the jaw recede. His skin fuses with that of the female's and the blood systems of both, merge. Effectively the male becomes parasitic on the female. What remain relatively unchanged are the sperm-producing testes that guarantee fertilization when the female spawns. It is thought that the female anglerfish controls the delivery of sperms with her hormones so it is coordinated with the moment she ejects her eggs from the body. Once fertilized, the eggs, which

contain large oil droplets that give them buoyancy, float to the surface of the ocean.

Interesting Marine Invertebrates

Krill is the name given to the tiny shrimp-like creatures found in marine waters, worldwide. The name krill is a bit of a misnomer because it comes from the Norwegian word “*krill*” meaning “young fry of fish.” Krill can swim; at least they are capable of individual motion against weak currents. Adult krill are therefore often classified as micro-nektonic life-forms although larval stages are considered zooplankton.

Different species of krill are found at different depths of the marine waters. For example, the Antarctic krill commonly lives at depths of 100m. Ice krill (*Euphausia crystallorophias*) may inhabit depths up to 4,000m. However, most often these are encountered at depths of 300m–600 m. Krill of the genus *Nyctiphanes* are abundant in the upwelling waters of the California, Humboldt, and Benguela current systems. Interestingly, the species *Nyctiphanes capensis* is restricted only to the Benguela current.

Krill have a hard outer covering made up of chitin. The body can be divided into head, thorax, and abdomen. The first two segments are fused into one segment, the cephalothorax. This outer shell of krill is transparent in most species. Krills have intricate compound eyes. Most krill are about 1cm–2 cm in size although some species are larger (6cm–15 cm). The largest krill species is the bathypelagic *Thysanopoda spinicauda*. Except for *Bentheuphausia amblyops*, all krill are bioluminescent. They give off light, thanks to organs called photophores.

Krill feed on phytoplankton and are themselves, a major part of the diet of many animals. Krill may be poor cousin

to the lobster but its sheer abundance makes it one of the largest protein sources on Earth. *Euphausia superba* often forms swarms containing 10,000 to 60,000 individuals per cubic metre of water triggering feeding frenzy among fish, birds and even, mammals. In the Southern Ocean, the Antarctic krill, *Euphausia superba*, makes up an estimated biomass of over 500,000,000 tonnes. Over half of this is eaten by baleen whales, seals, penguins, squid and fish each year. Most krill species undertake daily vertical migrations, thus providing food for predators near the surface at night and in deeper waters during the day.

Commercial fishing of krill is done in the Southern Ocean and off the coast of Japan. Harvested species include: Antarctic krill (*Euphausia superba*), Pacific krill (*Euphausia pacifica*) and Northern krill (*Meganyctiphanes norvegica*). In 2010, the total global harvest was about 150,000–200,000 tonnes annually, most of this from the Scotia Sea. Krill or *Okiami* is relished in Japan and Russia, although it is reported that, krill tastes “salty and somewhat stronger than shrimp.” Krill oil is also used as a dietary supplement and there are research papers on the effect of krill in treating the pain of arthritis and in lowering of lipid levels. Environmentalists have already called for better krill management and warned about the consequences of over-fishing.

Another interesting animal living under extremely high pressure and low light conditions is the pom-pom anemone (*Liponema brevicornis*). It can assume many shapes—from low and flat to round and puffy. It can even roll along the seafloor like tumbleweeds, “blown” by deep sea currents. Scientists aren’t sure why pom-pom anemones change shape and roll around. It is speculated they might be looking for more hospitable areas where there is more food to eat.

Pom pom anemone

The deepest dwelling crab in the Gulf of Alaska is the Large-clawed spider crab (*Macroregonia macrochiera*), often collected from a depth of 3300 m. They have very long legs as compared to the rest of the body. A Large-clawed spider crab is about 10 cm across, but the spindly legs are five times as long! Scientists think this may be an adaptation for traveling long distances on the sea bed. Deep sea crabs have evolved specific adaptations to cope with life in deep water. Because there isn't much food down there, they can tolerate long periods of fasting. Eggs of golden king crabs (*Lithodes aequispina*) contain large amounts of yolk. This is probably an adaptation allowing the larvae to survive at depths where there is much less plankton available as a food source. The scarlet king crabs (*Lithodes couesi*) live in waters with very low oxygen. They too have legs that are much thinner in respect to their length. Scientists think that this may be an adaptation to low oxygen levels, since thinner legs mean less tissue. Less tissue mean less oxygen demand and hence less energy expenditure.

The vampire squid (*Vampyroteuthis infernalis*) colonizes the lightless depths of the oceans—in particular, a habitat known as the oxygen minimum zone (OMZ). Within the OMZ oxygen saturation is too low to support the oxygen-dependent (aerobic) metabolism of higher organisms. However, the vampire squid is able to live and breathe normally in the OMZ at oxygen saturations as low as 3 per cent; a feat few other animals, can match.

In order to cope with life in the suffocating depths, these animals have developed several other adaptations. They have extremely low metabolic rate which translates to a low demand for oxygen (energy). Vampire squid hemocyanin (a blood pigment) binds and transports oxygen far more efficiently than the hemocyanin in their relatives that live in shallower waters. They have weak musculature but maintain agility and buoyancy easily because of balancing organ called statocysts and ammonium-rich gelatinous tissues closely matching the density of the surrounding seawater.

Illuminating the Dark Waters

The depths are dark because there is no light filtering down from the Sun, so many of the deep sea denizens carry around their own torches. They are said to be bio-luminescent. The organ which emits light is called a photophore. Photophores appear as luminous spots on the animals. Light can be produced from specialized cells in the organism called photocytes, or by tissues associated with symbiotic bacteria. Scientists think that those species that harbour luminescent bacteria in their bodies are able to control the process of lighting up by somehow influencing the bacteria to glow on demand.

Most deep-sea bioluminescence is blue/blue-green, as light of these wavelengths penetrates the furthest through water. A good example of a blue-bioluminescent invertebrate is the midwater shrimp (*Sergestes similis*). It gives out light from

photophores present on the undersides of its translucent, red-and-white bodies. The blue glow matches the colour and intensity of dim light from above; essentially making the shrimps 'disappear.'

Although most deep-sea animals show blue-green bioluminescence, some produce red and yellow lights too. For example, instead of flashing blue-green, the peculiarly named stoplight loosejaw flashes a red light. Each of its eyes has a comma-shaped photophore beneath it from which shines forth a deep red light. It also has another circular photophore that flashes a bright green light. All rather reminiscent of traffic lights!

The *Ereunna* jellyfish is the first marine invertebrate ever found that produces red light. Scientists studying the new find under the microscope have found that the tips of the tentacles end in glowing red blobs. They say that the red light is unusual since beyond 10 m, or so anything that is red actually appears black. This is because longer wavelengths, such as red and orange, do not penetrate into these waters and those animals that colonize these depths cannot see longer wavelengths. So there is no evolutionary reason for very deep sea creatures to detect this colour.

However, currently, scientists are veering around to the theory that the red lights at the end of writhing, twisting tentacles serve as fatally- attractive lures for fish. The reason is that these jellyfish were found to have eaten lots of fish which typically do not live at the depths these jellyfish call home obviously they had been able to lure their prey close enough to kill.

Interestingly, it is increasingly becoming evident that many marine fish 'glow' a brilliant fluorescent red. The discovery was aided by serendipity when Nico Michiels (University of Tübingen, Germany) and his colleagues, were scuba diving

using filters that blocked out the blue and green light waves. It was then that an entire new world was revealed to them.

We have heard of looking at life through rose tinted glasses—Michiels' experience went a step further. It revealed a world dominated by all sorts of shades of red: cherry, ruby, rust and crimson to name a few. Today at least 32 species of reef fish including pygmy gobies and some wrasses have been found to emit red light. This colour originates from guanine crystals. And since the light emanates from the fish themselves it is visible to those swimming close by—a fact that has led scientist to speculate that this is a means of signalling to a mate or signaling that there is danger lurking near by or perhaps even as a kind of camouflage.

Bioluminescence is used for attracting prey species or for confusing predators. Light is also part of a strategy called counter-illumination. The light diffuses the animal's outline, effectively 'cloaking' its presence from the watchful eyes of potential predators. For example, the sword-fish squid (*Chiroteuthis sp.*) and the cockatoo squid (*Galiteuthis sp.*), which are largely transparent have photophores located below their eyes that shine downward, regardless of the position of the rest of the body, and eliminate their silhouettes.

The shining tubeshoulder (*Sagamichthys abei*) gets its name from the tube it bears on each shoulder. When threatened, these tubes release a glowing slime, which distract predatory fishes giving it an opportunity to escape. In any case, the fish itself is dark and blends perfectly with its surroundings and the photophores on its belly provide good counter-illumination.

Some deep-sea invertebrates also use bioluminescence as a distraction to throw off predators. The sea cucumber *Enypniastes eximia*, lives at depths up to 5,000 meters. It 'lights' up on physical contact. The light, generated by granular bodies in its gelatinous outer layer, rapidly spreads across the animal's

entire body. When attacked it 'sheds' its glowing skin, which momentarily distracts the predator during which time the Sea cucumber makes good its escape. Even better, sometimes the discarded glowing skin tricks the predator into transferring its attention to it, which effectively means that the Sea cucumber has managed to survive another encounter. This is similar to what a shrimp-like *Gnathophausia ingens* does. It spits out glowing fluid when attacked. The sudden flash of light distracts the attacker and gives it time to swim away.

The vampire squid is dotted with photophores. The photophores are larger and more complex at the tips of the arms and at the base of the two fins, but are absent from the underside of the arms. It produces disorienting flashes of light for durations lasting fractions of a second to several minutes. It can modulate the intensity of the flash.

Lanternfish is a name that applies to about 246 species. The term is an eloquent description of what they appear to be...lighted lanterns! These fishes have photophores arranged in specific patterns all over their bodies.

Hatchetfish (*Sternoptyx sp.*) are very small, flat-shaped fish with photophores on the underside of the body. They can regulate the intensity and colour of the light that they flash. Each species of Hatchetfish has its own particular pattern of lights. The *Grammatostomias flagellibarba* has a double row of photophores organs running down its flanks producing blue-violet light. It is thought that the shape and position of the photophores serve to signal to potential mates.

Of the one-hundred and fifty species of anglerfish, most have a 'light' hanging out in front of them like a fishing pole with bait. The deep-sea anglerfish (example *Ceratias holboelli*) are pretty 'en-lightened' too. These fish have a movable, glowing lure that is fixed on the head. Blood vessels line the lures'

cavity in which luminescent bacteria are housed. Scientists think that when blood flow to the cavity is increase, the bacteria light up. The glow dies down when blood flow to the cavity is reduced...rather reminiscent of blushing, one thinks!

Another deep-sea anglerfish *Linophryne arborifera*, has a pearl-onion sized light lure atop the head and a multi-branched, tangle of bioluminescent filaments hanging from the lower jaw that glow as a lure. The Wolftrap anglers (*Lasiognathus* sp. and *Thaumatichthys* sp.) have a light hanging down *inside* their enormous mouths! This luminous bait is simply irresistible to other fish that swim towards it attracted by the light. When it is about to pounce on the 'light' it realizes (to its horror, it is presumed) that the Wolftrap anglerfish is on the verge of swallowing it. It helps that these fishes have large hinged jaws that allow them to swallow animals twice its own size. The 'light bait' comes in useful otherwise too. These are used to 'recognize' each other when it is time to mate. Another reason for the light may be related to the migratory habits of these fish. The anglerfish migrate upwards each night. At depths where sunlight filters down visibility may make it an easy target for predators that can spot its silhouette. The lights help camouflage the fish by making them resemble the flickering rays of sunlight.

The lures of other deep sea anglerfishes are extraordinary elaborate, with sensory filaments and papillae etc. It is possible that different species mimic different kinds of small prey to attract larger prey. The female of the triplewart sea devil (*Cryptopsaras couesi*) has three luminescent sacs, called caruncles in front of the dorsal fin. These three wart-like structures give it its name. The lures of this mesopelagic Anglerfish are elaborate and bioluminescent, thanks to luminous bacteria which produce a bluish, greenish light. It can rotate the lure tip and produce either a flash or a glow. The light and movement

of the lure attract the prey to within reach of the gaping jaws. The fish then slides the rod part of the apparatus back into a groove, drawing the lure and prey closer to the mouth.

Footballfish (*Himantolophus groenlandicus*) bear a 'fishing rod' above the rather small eyes. At the end of the 'fishing rod' is a bulbous structure called Esca. It is home to symbiotic luminescent bacteria that are responsible for 'lighting up' the lure.

Viperfish (*Chaulodus sp.*) are black in colour with light organs in strategic places on their bodies, including one on the dorsal fin. This is akin to the 'light-bait' of the anglerfish. They also have about 350 tiny light-organs in the roof of the mouth and on the lower surface of the eyeball. These fish have huge fang-like teeth so any prey foolish enough to be lured by the light is usually caught. The Viperfish engulfs small crustaceans and fish along with the water it draws in for respiration. It has powerful muscles attached to the first vertebra that pull the head up and with the mouth opening at the same time, the lower jaw is shot forward. The throat opens at the sides and the gullet is free to swallow. An observer may be forgiven for thinking that the head has become detached from the body. At the same time that all this is happening, the heart is carried forward and the gills extended sideways. So even large prey, pass down the gullet without hurting delicate internal organs. Once the prey has been swallowed, the head, jaws, heart and gills return to the normal positions. Needless to say, displacement of organs and their reinstatement all happens very swiftly.

Black dragonfish (*Idiacanthus atlanticus*) is a long slender eel-like fish with tiny eyes and fang-like teeth. These fish carry a rod with a luminescent tip on what can be considered their 'chin.' As if this were not bizarre enough, they also have lights all over their bodies.

Dragonfish

Dead animals that sink in the marine waters and come to rest on the bottom are called “food-fall.” Bacteria feeding on the dead animals often give off phosphorescence that attracts adult deep-sea crabs and other perpetually hungry scavengers to the site of the food fall bonanza.

Bioluminescent yet Invisible

Flabby Whalefish are one of the most deep-living fish species known. Although named after the largest mammals, these fish are rather small in size. The resemblance is perceived to lie in the shape of their heads and the relatively huge mouth. The body is plump and tapers to a rather small tail fin. The dorsal and anal fins bear luminous patches. They are red to orange-brown in colour and have brightly coloured fins and jaws. But to all practical purpose—the whalefish is as black as the dark waters in which it swims.

The giant red mysid (*Gnathophausia ingens*) is also brilliant red in colour. But in the dim blue-green light of the water, this bright red animal is actually camouflaged from enemy eyes.

Life Impossible?

The waters near the hydrothermal vents deep down under the seawaters have been described as a “...*witch’s cauldron of deadly toxicants*.” In addition, it has been pointed out that in the “*sunless and otherwise chilly depths of the ocean*,” the waters may be, “*as acidic as vinegar and rich in a bevy of heavy metals*.” The picture painted is certainly not a pretty one! Any one, and this includes scientists before 1977, could be excused for thinking that the ocean floor was a sterile zone devoid of life. Well, in 1977 when the bathyscaphe Alvin descended into the Marianna Trench the world realized otherwise.

Scientists realized that it takes more than heat and heavy metals to deter life from establishing a toe-hold. They found out that instead of being deterred, life seems to flourish at these sites. They realized that hydrothermal vents are “*underwater oases*”, providing habitat for many creatures that are not found anywhere else in the ocean. More than 300 new species have been identified, from such inhospitable habitats, since the first vent was discovered.

It wasn’t till the 1970s that remotely operated vehicles, manned submersibles, and other advanced underwater technologies, came of age. So the world had to wait till 1977 to get a first-hand glimpse of the ocean bed. Once this became possible, scientists began to explore the hitherto unexplored habitats and plunged into the study the extraordinary, the bizarre, the grotesque, the wonderful lifeforms that had been calmly going about their business for millennia oblivious of their own importance!

Life around Hydrothermal Vents

Since no sunlight, not a single ray penetrates so deep it is only to be expected that there are no plants at these depths. However, that does not mean that producers of energy are absent. It simply means that Mother Nature has explored an alternative route for energy production.

Photosynthetic production of energy that relies on solar power is replaced by a system that relies on chemicals found at or near hydrothermal vents. The main actors taking centre stage are not plants but a variety of microbes that utilize sulphur, hydrogen, methane, etc., to produce energy. Hydrothermal vents and fractures in the sea floor support the only complex ecosystem known to run on chemicals, rather than energy from the sun. Thus these chemicals present in the dark marine habitats may be thought of as taking the place of chlorophyll on sunlit land.

Heat-loving archaea thrive near hydrothermal vents. There is a profusion of life that thrives on the hydrogen sulphide gas released from the vents. Tube-worms (*Riftia pachyptila*) grow in large clusters around the vents and live inside hard, shell-like protective tubes that attach to the rocks. These worms lack mouths, stomachs, intestines and even anuses.

Scientists were initially puzzled about how these tube-worms were getting nutrients. Now we know that their insides are lined with friendly bacteria that oxidize hydrogen sulphide, turning it into usable nutrients for the worms. The bacteria, in turn, benefit from the relationship because the worms deliver blood-containing hemoglobin, which helps the bacteria to break down the sulphides. The giant hydrothermal-vent clam (*Calymene*) houses sulphur-oxidizing bacteria in its gills. This mutually beneficial relationship allows it to live in the geochemical environment that is considered “hostile” by most species.

Gigantic tubeworms and mussels also thrive around vents. *Rimicaris exoculata* is a recently discovered shrimp species that swarms around hydrothermal vents on the volcanically active mid-Atlantic ridge.

Vents also spew out lots of heavy metals. So, many animals that live near the vents have metal-binding proteins in their systems, while others, like some tubeworms, appear to excrete

the toxic substances via the mucus they secrete. These enzymes are of great interest to the biotechnology community as these have potential applications in industry.

Prof. Cindy Lee Van Dover, Duke University, USA and her colleagues have recently discovered that the hydrothermal vents are luminescent! The light given off by the vents was more than they could attribute to just radiation due to heat. At one location, they recorded 19 times the expected amount of visible red light and also, infrared radiation.

This was an interesting observation because enough light, of the wavelengths that an organism can use, affects behaviour. When Van Dover first discovered evidence of eyes on *Rimicaris exoculata*, which was initially thought to be blind, she concluded that the shrimps used vent-light to keep at a safe distance from the hot plumes. Scientists know that the shrimps need to get close enough to the vents to feed on chemosynthetic bacteria, which derive nourishment from the sulphurous water. However, the shrimps obviously run the risk of getting “cooked” if they approach too close. The current opinion is that the intensity of the light probably is a signal that they are approaching too close for comfort.

Hydrothermal vent ecosystems fascinate scientists much like a new toy fascinates a child. The only difference is that the more a scientist looks the more facets these habitats reveal. So there is little chance that a marine scientist will ever be bored or run out of things to study!

We must figure out the marine mysteries if we are to understand just how the machinery of the planet works and where we fit into the scheme of things. Perhaps, deep-sea biologist Tony Koslow hit the nail squarely on the head when he wrote: “*The communities of the deep-sea benthos pose the greatest challenge of any ecosystem on Earth to our understanding of the planet’s biodiversity.*”

6. DESERVING SPECIAL MENTION

*My soul is full of longing; for the secret of the sea,
And the heart of the great ocean; sends a thrilling pulse through me.*
- Henry Wadsworth Longfellow

There are indeed great secrets in the heart of the oceans. Secrets, which would have remained secret had it not been for the advances in science and technology and the great daring of adventurous souls who risked life and limb to assuage their curiosity. It is thanks to them that the living fossils have been discovered and strange inter-specific friendships of sea creatures have come to light.

Fossils, as almost everybody knows, are the preserved remains of animals, plants, and even microorganisms from ancient times. Common sense tells us fossilized animals are dead; by definition they have been dead for millennia. Therefore when one hears the term 'living fossils' it does sound like an oxymoron. However, contradictory as the name may sound, living fossils are very much alive...some swimming happily in the marine waters even as we surf the waves.

Living Fossil

A living fossil is an animal or plant that was once known only by its fossils and believed to have been extinct for millions of years. But then, one fine day, to the amazement of the world, and incredulous joy of the scientists, they were found to be still swimming (or walking or flying!) on Earth. Living fossils are citizens of an age that has long been lost in the swirling mists of time. It closely resembles its fossil

ancestors and allows us to observe first-hand a species that we had thought we had lost for ever. It is a wondrous fact that these species have survived the passage of time almost unchanged.

The lineage of living fossils shows that the species have changed very little over time. Fossils over 300 million years old exist which are almost identical to the species that exists as a living fossil today. Some scientists think that these species inhabited relatively isolated habitats, where no major competitors existed. So, if their habitats were stable there was no pressure for them to adapt and change...and they didn't. Quite a few of the Earth's living fossils are found swimming in the depths of oceans.

Ancient Animals

Coelacanths are fish that figuratively speaking, rubbed fins with the dinosaurs. For long, scientists, had come across *only* fossilized specimens; some more than 350 million years old. They believed that the Coelacanth had died out about 65 million years ago.

On 22 December 1938, the *Nerine*, trawling off the mouth of the Chalumna River, returned to harbour. As usual, Marjorie Courtenay-Latimer, Curator of the East London Museum, South Africa came on board to search through the daily catch. Quite serendipitously she spotted an oddly shaped, blue-gray fin protruding from beneath a mountain of fish. She was intrigued enough to pull out the specimen to scrutinize it. The fish was about 1.5 m long, weighed 57 kg, and was covered with deep-blue scales. It had unusual fins that made it look like it had legs. She later said, "*It was so peculiar that I felt it had to be preserved.*"

So she brought back the "*heavy, dirty and oily*" specimen to the museum where she compared it against images of known species but failed to identify it. She immediately wrote a letter to Prof.

J.L.B. Smith at Rhodes University, South Africa and enclosed a rough sketch. She also preserved the fish for further study.

Prof. Smith recognized the fish from the sketch. He admitted later that, "*My surprise would have been little greater if I had seen a dinosaur walking down the street.*" However, he hesitated to commit himself without examining it first hand. He knew the risk of ridicule that he ran if he announced the existence of live coelacanths. So he sent a telegram to Marjorie saying "*Save viscera...fish interesting.*" It was the understatement of the millennium.

Despite knowing it in his heart that he was about to see a contemporary coelacanth, Prof. Smith was not prepared for his own reaction at the sight of the creature. He was so excited that he began to shake. He later wrote, "*Yes, there was not a shadow of a doubt, scale by scale, bone by bone, fin by fin, it was a true Coelacanth. It could have been one of those creatures of 200 million years ago come alive again.*"

The announcement that a live coelacanth had been caught was made on 20 February, 1939. Smith later wrote a book, '*Old Fourlegs, the Story of the Coelacanth,*' about the discovery.

The Coelacanth was given the name *Latimeria chalumnae* in honour of Marjorie Courtenay-Latimer who first spotted it and after the Chalumna river from where the first specimen was caught.

Today we know that coelacanths are elusive, deep-sea fish that swim at depths up to 700 m below the surface. They can be huge, reaching 2 m or more and weigh up to 90 kg. It is thought that they have a life span of about 60 years. There are only two known species of coelacanths: the steel-blue coloured ones that live off the east coast of Africa, and the brown coloured ones found in the waters near Indonesia.

The Indonesian species was first reported in September 1997 by Dr. Mark Erdmann who spotted it while on his honeymoon. Dr. Erdmann returned to Indonesia in November,

1997 in search of another specimen and spent the next five months interacting with local fishermen who admitted that they occasionally caught such a fish. The local name for coelacanth was *Raja laut* (King of the sea.) After careful monitoring their catch for several months, Dr. Erdman finally spotted the second coelacanth on 30 July 1998. When the fish eventually died, it was frozen and later, donated to the Indonesian Institute of Sciences.

Indonesian species is called *Latimeria menadoensis*. Although *Latimeria menadoensis* resembles *Latimeria chalumnae*, analyses of DNA from tissue samples have revealed significant genetic differences. It is believed that the two populations have been separated for at least several millions of years.

Coelacanth

The Coelacanth has been declared an endangered species. Their current world population is believed to be fewer than 5000. This means that without protection, this fish that has survived for over 350 million years could be wiped out in our lifetime. Local fishermen of course, knew about coelacanths much before Smith's discovery, but since it was not edible they had not been interested in it...a fact that perhaps extended the coelacanth's lease of life.

Coelacanth's true evolutionary relationships are still to be resolved although it has graced the covers of science journals such as *Nature* and *Genome Research* and stamps have been issued in its honour. Experts agree that they probably occupy a side branch quite low in the vertebrate lineage, closely related to, but distinct from, the ancestor of four-legged vertebrates.

Horseshoe Crabs

Blue-blooded human aristocrats are proud of their lineage which can be traced back to many generations. By that token at least, they should be honoured to acknowledge the horseshoe crab as a literally blue-blooded peer with a lineage pre-dating the dinosaurs. These animals are really 'blue' blooded as their blood contains a copper-based respiratory pigment called hemocyanin, which gives the blood, a bluish hue.

Horseshoe-Crab

Horseshoe crabs can claim a history that reaches back almost half-a billion years. In 2008, a paper in the British

journal *Palaeontology*, reported that a team of Canadian scientists have found horseshoe crab fossils from 445 million year-old rocks in Canada. The new fossil species has been named *Lunataspis aurora*. It lived at a time when plant and animal life on land was just getting established. Scientists think that even older fossils may exist that will push back Horseshoe crab lineage to 490 million years.

Actually, specimens of the Horseshoe crab had been making their way to laboratories quite frequently. In 1557, one of the early explorers brought back a specimen of the Horseshoe crab from the Molucca Strait to Europe. It took a year for scientists to study this hitherto unknown species. In 1588, British naturalist Thomas Hariot named these “Horse-foot” crabs, which over time, was changed to “Horseshoe.” Fifty years later, Sir Walter Raleigh led an expedition to the New World, during which he came across an identical creature that local Indians called “*See-ekanauk*.” They used its sharp tail spine as a spear point to hunt fish.

Horseshoe crabs are arthropods—like the regular crabs. However, despite that and even though they are called “crabs;” they are not crabs but distant cousins to spiders and scorpions. Their close relatives were the trilobites that existed 544 million years ago. Horseshoe crabs are currently represented by four living species: The atlantic horseshoe crab is called *Limulus polyphemus*. The japanese horseshoe crab is called *Tachypleus tridentatus*. The two species that occur along the east coast of India are *Tachypleus gigas* and *Carcinoscorpius rotundicauda*. All the four species look essentially similar. The upper side of the body is entirely covered with a hard, horseshoe-shaped shell, and it has a long, spine-like tail.

It is awe-inspiring to realize how long horseshoe crabs have survived and what is more, that they have hardly changed at all. As David Rudkin, Royal Ontario Museum, Toronto succinctly sums it up, “*They made it through all of these events, not necessarily unscathed, but in a continuously recognizable form.*”

Despite their hoary lineage, it has been estimated that fishermen chop up 20,000 to 25,000 Horseshoe crabs per year as bait. They are also caught for use by the Pharmaceutical Industry. A protein in the blood of the Horseshoe crab provides a valuable medical product critical to maintaining the safety of many drugs and medical devices. This protein is used to test products for the presence of bacterial toxins that can cause fevers and which can even be fatal to humans.

Japan has built the world's first-ever Museum dedicated to the horseshoe crab. This is the Kasaoka City Horseshoe Crab Museum built in 1990 to promote appreciation and interest in the conservation of *Tachypleus tridentatus*. In addition to educational exhibits, the museum rears Horseshoe crab larvae for release into the wild. Museum scientists use radio telemetry to track migration patterns, identify over-wintering grounds, and locate potential spawning beaches. Since habitat destruction and over-exploitation are major threats for these animals, it is hoped that the Museum's efforts will help this ancient coastal creature retain its tenuous hold on life.

Neopilina galathea

Many eyebrows were raised when the scientific community hailed the discovery of a lowly mollusc (cousin to sundry snails, slugs and squids) as, "*One of the greatest sensations in the (twentieth) century.*"

Although molluscs are second only to arthropods in species diversity, new species are still discovered occasionally. This time the discovery pertained to a member of the Class Monoplacophora. Mono-placophora means, "bearing one plate" and refers to the cap-shaped shell that covers the soft-bodied mollusc. Till 1957, all monoplacophora were considered extinct as they were known only from fossilized specimens about 550–380 million years old.

The picture changed dramatically, when on 6 May 1952 some molluscs, existing quietly at a depth of 3590 m, were hauled on to the deck of the Danish research ship *Galathea*. The area was the off Costa Rica's Pacific coast. Danish biologist Henning M. Lemche made the sensational discovery. The molluscs on the deck of the *Galathea* were nothing much to look at: neither attractively coloured nor beautifully sculpted. They had a single dome-shaped shell rather similar to limpet shells. Still, they managed to catch the attention of the Danish zoologist Dr. Henning Lemche as he sorted through the day's catch. "*They seemed to be fragile limpets of a rather uninteresting appearance*", he later wrote. "*But there was something about them I could not understand.*"

It would take him five years to understand them!

In February 1957, he published a paper identifying the mollusc as a living Monoplacophora. He named it *Neopilina galathea*. The name *Neo-pilina* means new- *Pilina* (*Pilina* is an extinct Monoplacophore that lived about 400 million years ago.) *Neopilina* apparently closely resembles *Pilina*. The species name, *galathea* honoured the Danish research ship. At that time, *Neopilina* was the only living Monoplacophore known to science.

Since then, *Neopilina* has been found in the Pacific Ocean, Indian Ocean, Gulf of Aden, and the Antarctic Ocean. Clearly, living Monoplacophora are widespread and have evaded detection only because they inhabit deep waters. Scientists studying the modern *Neopilina* say it has remained virtually unchanged since the early Paleozoic (about 542–241 million years ago).

Once the taxonomic identity of these unassuming animals was established, it sent seismic waves through the community of malacologists with eulogies calling the discovery, "*The most dramatic one in the history of Malacology.*" In a paper written in *Nature*, (March 1957) C. M. Yonge wrote, "*To a malacologist, at any rate, these dredge- hauls off the west coast of Mexico which*

secured no less than ten specimens with three extra shells of Neopilina galathea in themselves alone, more than justify the voyage of the Galathea around the world."

Neopilina also evoked tremendous interest because its organs such as nephridia (kidneys), heart, gills etc., are repeated serially; as in annelids (earthworms and their ilk) and arthropods (insects, spiders and crabs). Molluscs are not a segmented group; and it appeared that *Neopilina* might be an exception and so, a potential "missing link" between the molluscs on one hand and the annelids and arthropods on the other. However, this idea has now been dropped as has the idea of using *Neopilina* as a model archaic-mollusc. Currently, *Neopilina's* status is somewhat fuzzy although its ancient lineage is in no doubt.

Goblin Shark

The bottom-dwelling Goblin Shark *Mitsukurina owstoni* was named in honour of Japanese zoologist Kakichi Mitsukuri, who got it properly identified. The name also honours wildlife collector Alan Owston, who acquired the first specimen from a Japanese fisherman. This shark, which counts as its look-alike ancestor shark fossils found in Italy dating from the middle Pleistocene, has been described as "*an oddball*." Some call it the "*ugliest fish in the sea*." However, despite its looks its lineage is impressive.

This inhabitant of the deep sea still successfully manages to keep a veil of mystery around itself. All scientists know is that that pinkish coloured fish with bluish fins can grow up to about 3m in length. It has a bizarre-looking upper "snout" that acts as an electrical receptor to locate prey. It has extendable jaws that can catch and pull prey into its mouth. The mouth is armed with sharp teeth. Despite all its oddities, it is a shark after all.

Fossilized *Scapanorhynchus* sp. dating back more than 100 million years look almost similar to the Goblin shark-one reason why these are called living fossils.

Frilled Shark

The frilled shark (*Chlamydoselachus anguineus*) swims in the Atlantic Ocean and the Pacific Ocean. The scientific name has been derived from the Greek words “*chlamy*” meaning frill and “*selachus*” meaning shark. The word “*anguineus*” is Latin for snake-like. It is easy to see why scientists gave it this name. This dark brown shark with an eel-like body has six pairs of gill slits that adorn its neck like frills of lace.

A rare species, the frilled shark has been caught from waters as deep as 1,570 m as well as from shallower depths of 50–200 m. It grows to a length of about 2m. It has a broad and flattened head with a short, rounded snout. The nostrils are vertical slits. Some say that this shark with snake-like looks, gave rise to the myths about Sea serpents.

Sharks are among Earth’s oldest life-forms, having emerged between 455–420 million years ago; although over 100 million years have gone by since the “Golden Age of Sharks.” Among most ancient of sharks is the frilled shark with a lineage going back about 150 million years ago, if not more. It shares similar dental patterns with fossilized sharks from about 95 million years ago. Its ancient ancestry and primitive features are reasons why it is called a living fossil. Other common names for this species include lizard shark, scaffold shark, and silk shark.

Sea Lilies

Sea lilies are relatives of sea urchins and starfish but they look more like plants with a shape akin to tiny, slender palm trees. Sea lilies belong to crinoidea- a branch of echinodermata.

Crinoid fossils are extremely common in shale and limestone dating back to the Ordovician period, about 475 million years ago. At that point of time, life had yet to colonize land. Today's sea lilies still look extraordinarily like their long-dead ancestors who exist now only in petrified form.

Nautilus

The Chambered Nautilus (*Nautilus pompilius*) is very distant cousins to the Octopus and the Squid. These invertebrates are the living representatives of the Nautiloids-a group of molluscs that flourished during the Cambrian period- approximately a half a billion years ago. Ammonites that lived in prehistoric times and reached the incredible dimensions of about 3 m were close relatives. The present day *Nautilus* appears to have survived relatively unchanged for millions of years-a feat that has earned it the title of Living fossil.

Vampire Squid

The vampire squid is scientifically known as *Vampyroteuthis infernalis*, literally meaning vampire squid from hell. It is a scary sounding name for a small invertebrate that ranges throughout the temperate and tropical oceans of the world. It is the only known surviving member of its sort. It was first described and originally classified as an Octopus in 1903 by German biologist Carl Chun. Later, its exact position in the world of animals was revised when it was found to be related to many extinct groups.

Slitsnails

Scientists knew about fossil slitsnails long before they laid their hands on a living specimen. The fossils dated back to the Paleozoic era...so there was little doubt in scientific circles that the slitsnails were well and truly extinct. All that changed in 1856, when a hermitcrab crawled out on the beach with a living slitsnail on its back. Studies revealed that the shells of

living slitsnails are virtually indistinguishable from some of the fossilized forms.

Marine Turtles

Sea turtles are also called Living fossil because they appear to have remained relatively untouched by time, since they first appeared during the Triassic period, about 245-209 million years ago. The earliest known marine turtle fossils have been dated to be about 208-144 million years old. Just for record, the 4m long extinct sea turtle *Archelon ischyros*, was one of the largest turtles that ever lived. It swam in the Earth's seas about 144 to 65 million years ago

Community Service

Sometimes celebrity status comes not from who you are; but from what you do. So, unlike living fossils that are famous thanks to their lineage; some other species have earned the right to etch their names in the marine hall of fame by virtue of their actions.

For example, inter-specific associations between vertebrates and invertebrates are interesting. In Commensalisms one species benefits from the association while it makes no difference to the other. Taken a step further, associations may benefit both partners—a situation called symbiosis.

The blenny, a fish that inhabits the Caribbean waters, lays eggs inside sponges. The young fish stays for a while inside the sponge. It is protected by the sponge and it feeds on the tiny plankton that the filter-feeding sponge manages to trap. Without the sponge's all enveloping sanctuary, the baby blenny would not have survived easily. The sponge neither gains nor loses anything from the association- but the hospitality of this insignificant invertebrate makes a world of difference to the Blenny.

Similarly, the invertebrate sea anemones of the genus *Stoichactis* are the chosen friends of the clown anemone fish. The fish takes shelter among the tentacles of the giant anemones whose lethal sting-bearing tentacles can reach 1.2 m across. It may leave the anemone fish to forage, but at the least hint of danger, it dashes back into the protective embrace of the anemone's tentacles. Some observers have claimed that they do this not so much as to save their skins, but to lure their pursuers into the anemone's reach. If so, then the fish has a win-win situation at its fins! The tentacles of the anemone provide protection to it from the pursuer. Also, if the pursuer has been foolhardy enough to make a mad dash after it, the same tentacles will fatally embrace it. When the anemone feeds; so will the clown anemone fish. Thus, it is in the fish's best interests to turn itself into live-bait to allow the anemone to catch a meal.

But why does the anemone not sting this fish? Initially it was thought that the anemone's stinging cells discharged on contact alone. Now we know that the stinging cells discharge only on contact with some select material. The slime on the scales of the clown anemone fish inhibits the stinging cells...giving it some sort of diplomatic immunity.

Much of how these two unlikely species become 'fast friends' comes from direct observations. When a sea anemone and a clown fish are first placed in an aquarium, the fish swims fearlessly towards it and circles the anemone till it is close enough to nibble the anemone. It does so a few times and touches the tentacles once or twice. Normally, behaviour like this would have elicited the firing of all the stinging cells and resulted in the death of the clown fish. However, this is not the case although the fish does get stung a little. It swims away but returns again and again. Then finally, it swims deep into the anemone's tentacles. The tentacles ignore it for the rest of its life.

Interestingly, the friendship is decidedly individualistic. If a clown fish living with one anemone is removed and placed with another anemone, it is attacked, even killed. On the other hand, a clown fish may raise a family among the tentacles of its friend; with the father guarding the offspring till they find anemones of their own. So close is this friendship that marine aquaculturists recommend keeping an anemone with a clown fish even in the artificial environs of a marine aquarium at home.

Some goby fish live happily between the toxin containing spines of Sea urchins such as *Astropyga radiata*. Obviously nothing less than an unusually determined predator with a suicidal bent of mind will ever attack them.

These 'friendships' are noteworthy as these have sprung up between a vertebrate and an invertebrate.

However, commensal relationships may exist between two invertebrate species too. For example, the imperial shrimps (*Periclimenes imperator*) often use the large sea cucumbers (particularly *Stichopus*) as HOHO (Hop On Hop Off) buses to reach rich feeding areas. Once there, they hop off and when through with feasting, simply catch another 'bus' to ride on elsewhere. These shrimps also ride the large colourful, shell-less mollusc *Dendrodoris*, which, though slow moving, are venomous and given a wide berth by potential predators.

Hermit crabs, despite being called crabs, lack the characteristic hard shell on their bodies. These retiring little creatures therefore hunt for empty mollusc shells to use as a shelter. They change the 'house' as they outgrow it, in time and always they carry their temporary homes about wherever they go. However, this borrowed protection is not deemed enough, so they mount heavy artillery on the roofs in the shape of stinging sea anemones. When the hermit crab changes 'houses,' it is faced with the necessity of taking along its protectors.

However, usually anemones remain attached to a single spot all their lives; and their grips on a chosen base is grim. The hermit crab massages the anemones with its claws till the anemones relax and their grip loosens somewhat. The Hermit crab then picks them off and places them on the roof of the new home. This association may not be as one sided as it may appear at first glance. Since Sea anemones remain attached to a substrate all their lives; they may suffer if the area becomes poor in potential prey. Transportation by the Hermit crab expands the anemone's range. Besides the anemone is not averse to 'stealing' some of the hermit crab's food by means of its tentacles that spread like an umbrella of sorts above the hermit crab. This association therefore may be one of symbiosis rather than commensalism.

Doctor Fish

Certain fish species, particularly those that inhabit reefs, display equally astonishing behaviour to mutual benefit. The cleaner wrasses and the neon blue goby (*Elacatinus oceanops*), in particular are invaluable to almost any marine fish harbouring parasites because they pick off and eat the parasites. Almost 200 species of coral reef fish depend on them to keep them free of parasites that latch on.

Mother Nature has equipped these fishes with well for the job. These doctor fish have pointed snouts and tweezer-like teeth with which they probe their client's bodies. They probe their client's bodies and remove parasites and fungi. They also clean wounds by nibbling away the dead flesh surrounding it...and once in a while, they 'cheat' by nibbling the tasty mucus on their client's bodies. This service rendered assures them of decent meals. Clients burdened with external parasites have been known to patiently 'queue up' for their services. Often 'client fish' undergo a colour change. This may be as visual clue that attracts the attentions of the doctor fish, or it

may be a trick that makes the external parasites more visible and so easier to be 'cleaned by the doctor.

The Bluesteak cleaner wrasse known as *Labroides dimidiatus* in scientific circles is an important and highly sought after member of the piscine community, throughout its range in the Indo-Pacific Ocean, Pacific Ocean and the Red Sea. It fearlessly swims into the mouths and gill chambers of fish such as the fierce Barracuda (*Sphyraena sp.*) also known as the 'Tiger of the sea,' which if it so wished, could consume many of its tiny benefactors in a gulp. It never does. Even the much larger groupers merely wince a little if the cleaner wrasse's surgical skills are below par at times. Swimming nonchalantly inside the mouth, darting between the razor-sharp teeth, the wrasse services its clients. Interestingly, the wrasse constantly vibrates its fins while inside the mouth of a client. Scientists say that this could be Dr. Wrasse's subtle reminder to the client not to close its mouth.

Cleaner-Wrasse in action

The great dependence that many coral fishes have on the cleaner wrasse was demonstrated in the seventies when a researcher removed all the cleaner wrasse from a small area of the reef for a short period. Both, the variety and the number of individuals in a species of coral fish, plummeted, and did not recover till the cleaner wrasses were reinstated. But the wrasses are not the only experts in the field. Barber fish deserves mention too.

William Beebe, an American marine zoologist, first observed the curious cleaning behaviour of the Barber fish in 1928, in the waters near Haiti. Barberfish, *Johnrandallia nigrirostris* has a small protractile mouth with brush-like teeth. Its body is silvery-yellow with black bands on the snout, forehead, and along base of the dorsal fin. It has Zorro-like mask around its eyes that gives it a rather dashing look. These fish are common in rocky areas and around coral reefs and swim to depths of 40m. The Barberfish *Anthias sacer* is also known as surgeonfish because of the lancet-like spines on the tail. Mexican fisherfolk call the fish *El Barbero* (the Barber) because it 'manicures' other fish.

The fish that requires the services of the barberfish not only visit them but also cooperates in every way. It raises the gill cover on one side and holds it in position to facilitate the movements of the barberfish. Once the barberfish swims over to the other side, the 'client' fish raises its gill cover on the other side. Most customers queue up for their turn to be groomed but very big fish, such as sharks, may have an entire team of cleaners all to themselves. The huge sunfish, with its disc-like body, may weigh up to 1 tonne. Obviously it needs the services of an entire team of barber fish.

Indeed, fish in need seem to deliberately seek out the cleaner fish. Those living in the open ocean may sojourn to more shallow waters to seek out the cleaners, which maintain 'service stations'...much like a doctor's chamber. Most cleaning

stations are located about 20m under the water. Like real estate on land, locality is everything underwater too. The availability of space and nearest competing station determines where a doctor may set up the cleaning station, which is actually divided into two distinct spaces. The first is the work station proper. There is a larger area nearby where the doctor fish dances from time to time, flashing its colours. This action may be compared to a “commercial break” when the fish advertises the fact that it is available for consultation.

Interestingly, most doctor fish are blue and yellow in colour. Scientists have determined that this is extraordinarily effective as a combination because blue affords the greatest contrast against the coral reef and yellow has the highest contrast against blue water. Obviously the colouration of the cleaner fish is its first line of advertisement. Commendably, although many different species gather at the service station there is little, if any, aggression while they are there. The client fish may actually actively defend the cleaning station, and the cleaners, from attacks by potential predators.

However, as if to show that exemplary behaviour is always in short supply, researchers say that the doctors sometimes play favourites. They usually have a preference for certain fish species such as Parrotfish. Apparently, the sort of parasites that are removed plays an important role in whether the ‘doctor’ will service the client first...after all the parasite that is removed is the ‘doctor’s breakfast, lunch and dinner. Like us, the Cleaner Wrasse has its favourite food item too and it gets bored of a diet with no variety.

Redouan Bshary from the University of Cambridge (UK) and Manuela Wurth from the Technical University in Munich, studied the cleaner fish in the Ras Mohammed National Park, Egypt. They found that cleaner fish stroke their clients’ fins to cement the relationship. If, for example, they’ve accidentally bitten too vigorously in the course of their duties, they pet

their client(s) even more. They also caress their clients to persuade them not to swim away, or visit other cleaners. The caresses work to prevent the clients from turning on their benefactors. Bshary and Würth claim this is the first inter-species “cuddling” seen in non-mammals.

A Quack Fish

This ‘trust’ that the piscine client’s have in the cleaner fish is open to abuse. It also has a human parallel. A barber called Sweeney Todd apparently used to entice customers into his chambers, lull them with his skill and murder them. Something akin to this happens in the piscine world too. Pseudo barber fish that mimic the looks, but not the actions, of the true barbers exploit the barber fish’s well-earned popularity. Such look-alikes lure client fish to their death. These are the piscine versions of Sweeney Todd up to fishy business! The False cleaner or mimic blenny, *Aspidontus taeniatus*, superficially looks like the cleaner fish because it is blue above, with pale undersurface and has a black stripe running from the snout to the tail fin. But looks can deceive. These fish are like wolves in sheep’s clothing...because they do not hesitate to take a bite out of the flanks of the ‘patients’ that mistake them as doctors. They do not feed on the parasites on the bodies of other fish but on healthy scales and mucus covering the client fish.

Camouflaged to Perfection

Some shell-less molluscs can change their coloration by altering their diet. Their skin stores pigments from the corals that form their diet. Soon the animal becomes the same colour as the coral. Since these molluscs live near coral reefs the colouration provides the perfect camouflage. The skin of the cuttlefish is covered with specialized cells that reflect light in many different colours enabling it to blend into its background.

Photosynthetic Partnership

Corals harbour algae. In return of the hospitality, corals claim a hefty 80 per cent or so of the food produced by photosynthetic algae. Undeterred by this unfair rental policy, the algae goes on to produce a chemical that shields them both from the damaging UV radiation of the Sun! If only, all tenant-landlord relationships could benefit from the example set by these invertebrates!

Certain jellyfish also allow photosynthetic algae to take up residence in their tissues. The association brings about a marked change in jellyfish behaviour as every morning it moves to follow the Sun. As a result, observers have reported “a wall” of jellyfishes that tracks the sunlight as it moves over the water. Giant clams also provide safe refuge for algae. Some clams even have strategically placed transparent pouches that act like lenses, focusing sunlight on the resident algal colonies.

Seaslugs love coral too...as lunch or dinner, mostly. However, by some mechanism not clearly understood as yet, they manage to segregate the algal population from the ingested coral. The algal population is then transferred from the tummy to the tentacles. The translocation does not seem to hurt the algae in any way. Soon, these cells are happily carrying out photosynthesis, apparently oblivious to the fact that they have changed hosts. An Australian seaslug makes the captive algae so comfortable that it undergoes a population explosion. The resultant spike in photosynthetic activity more than meets the Seaslug's energy demands and from that point onwards, it rarely eats corals again. Quite a sustainable way to meet energy demands, wouldn't you agree?

Mimic par Excellence

Octopus can change the colour and texture of its skin to avoid being detected by predators. However, the first prize

for superb blending-in skills should undoubtedly go to the mimic octopus *Thaumoctopus mimicus*, discovered in 1998 in a muddy estuary in Indonesia. It is typically brown and white striped. The amazing fact is that it can appear deceptively similar to any of a variety of different animals by bunching up or elongating its arms.

Mimic Octopus

To take on the appearance of a sole fish, it pulls close all of its arms together to form a leaf-shaped wedge. It then undulates its arms to give the appearance of a Sole fish swimming by. To look like the lionfish (*Pterois* sp.), it swims with its tentacles spread wide and trailing from its body. It changes its colour to imitate the yellow and black bands of the poisonous sea snake. Then it hides two of its tentacles in some crevice while it waves the other arms in opposite directions. ..as if these are two different snakes. Scientists believe that it is capable of mimicking sea anemones, stingrays, mantis shrimp and the stinging jellyfish. Incredibly, it has been observed to mimic the banded sea snake when attacked by damselfish defending their territory. The banded sea snake is a predator of damselfishes! Mark Norman, Julian Finn of the University of Tasmania, Australia and Tom Tregenza, University of Leeds, England have published a research paper on this species.

Mark Norman of the Melbourne Museum, Australia, pointed out that “...*this animal stood out as it was the only one we’ve encountered that goes beyond camouflage to take on the guise of dangerous animals.*” It is incredible indeed that the octopus has the presence of ‘mind’ to instantly arrive at a ‘decision’ about the disguise to take on when faced with attacking damselfish.

Electrifying Presence

The electric ray, also goes by the names of torpedo fish, numbfish, or crampfish. Whatever the name, its claim to fame is that it is one of the few species that has the ability to shock—literally so- because they can generate electricity!

There are many species that are collectively called electric ray and although most live in shallow water, *Benthobatis* is comfortable at depths of 1000 m and more. The pacific electric ray *Torpedo californica* is found in the waters of the northeastern Pacific Ocean up to a depth of 200 m. It can generate up to 45 volts of electricity, usually to stun and capture prey but also for self-defense.

Communication at Sea

Killer whales live in cohesive, social units called pods, which may include five to 100 individuals. A single matriarch rules the pod. The most fundamental social unit in a pod is the maternal group. A maternal group consists of a mother and her offspring (but not adult daughters with offspring of their own). One or more maternal groups may travel in a sub pod. Above the pod level is the clan. A clan shares similar dialects and pods that make up the clan in an area are thought to be related. Finally, at the top of the killer whale social set-up is a community. A community is made up of several pods. Pods from one community do not travel with pods from another, even if their ranges overlap. In killer whale hierarchy, a female

establishes her dominance by slapping her tail against the water, by head-butting, jaw-snapping, tooth scratching and biting. Apart from these obvious displays, whale communication can be pretty sophisticated too.

Humpback-Whale

Humpback whales (*Megaptera novaeangliae*) can produce moans, grunts, and shrieks. Some of these sound waves are of high frequency. They also emit low frequency sound waves, which can travel through water, without losing energy. Researchers believe that some of these low frequency sounds can travel more than 15,000 km at certain depths of the ocean. They have noted that whale songs sound very similar to the sounds of hoofed animals, such as elk and cattle....and even elephant. Male Humpback whales are known to communicate by singing songs that sound eerily soulful to human ears. Every year they have a haunting new song. These songs are easily the longest and most complex of any sung in the animal kingdom. Sound is a form of territorial display to warn intruders. However, as these songs can usually be heard during the

winter breeding season it is speculated that Humpback whales sing to attract females or to notify other whales that they are in the area.

The most amazing part of humpback whale songs is that the whales create themes. They may repeat the same song for hours, broken only by pauses for breathing. All male humpbacks in the same region sing the same song. That 'cultural influences' exist in whale society came to light when some humpback whales off Australia's east coast were found singing a new song. The top of the pops was the song of the humpbacks from western Australia-it was an Indian Ocean song! Scientists later conceded that it was possible that the song came from a few Western whales that went astray during their migration and ended up on the other side of Australia.

There is emerging evidence that cuvier's beaked whales use echolocation to forage selectively—ignoring echoes from certain targets before selecting one to catch. Individuals feeding close by keep 'acoustic tabs' on each other. They listen for each other's clicks even as they go about foraging. Interestingly, they appear to use their ability to echo-locate only at the deepest parts of their dives. Researchers think that judicious use of this ability helps the beaked whale to avoid detection by killer whales and white sharks that swim above them.

Underwater communication using sounds has been documented for dolphins too. After World War II, when bottlenose dolphins (*Tursiops truncatus*) were first kept in captivity, keepers were startled to discover that they had a large 'vocabulary' of sounds. Their sounds were analyzed in 1965 by T.G. Lang and H.A.P. Smith of the US Naval Ordnance Test Station. The sounds that dolphins make have been described as: whistles, squawks, clicks, quacks, creaks, singing notes and wailing. Much of dolphin communication is, however, in the ultrasonic range and so, inaudible to human ears. Dolphins try to locate each other by echo-locating clicks. Then

they talk in grunts. In the long association between humans and dolphins, certain empathic individuals have learnt the art of communicating across the species divide, and dolphins approach them when summoned.

Socrates apparently went on record that that the deep sea was a lifeless desert where “*nothing is in the least worthy to be judged beautiful by our standards...*” We are glad he was wrong, for once.

7. 'SEA' IN A NAME

*What's in a name? That which we call a rose by any other name
would smell as sweet.*

William Shakespeare

There are many plants, animals, and at least one defined human population, that bear the word 'Sea' as part of their name, although they may or may not all be strictly marine in nature. So in a manner of speaking the names are a bit of a misnomer.

Sometimes, animals are given names suggesting that these are vegetables. And although the poet says, "What's in a name?" some names are clearly more desirable than others. This leads to a situation where more than one species share the same common name. The name Sea Potato, for example has multiple species staking its claim to it.

Plants with the term Sea in their names

Seagrass

Seagrasses are the only flowering plants in the sea. Although these plants do not belong to the family to which terrestrial grasses belong, these are still called 'grasses' because their leaves are long and narrow resembling the blades of terrestrial grasses.

Sea Wrack: This is also known as eelgrass, which correctly indicates that this is a seagrass species. While welgrass is a common name for all the species that are classified under the genus *Zostera*, it is *Zostera marina* that is specifically referred to as sea wrack.

Sea Lyme Grass: *Leymus arenarius* is a sand-loving species of grass. The Inuit use it for weaving baskets. In Europe, the stems are used for roof thatching. It can also be woven into a coarse fabric. Seeds are edible and because its roots can stabilize sandy soils, it is used for erosion control.

Seaweeds: Seaweeds are algae that generally grow near the shore and in shallow waters where light penetrates well. There are about five to six thousand seaweed species, worldwide. It is rather judgemental on the part of humankind to label these marine algae, as weeds, which by definition are something undesirable or unwanted. Seaweeds are useful to mankind. They are not used just as food but also provide valuable extracts that are used as stabilizers, gelling agents or emulsifiers, in products ranging from cloth dyes, toothpastes, salad dressings, flavoured drinks, cosmetics, pizza toppings and pet food to name just a few. Alginates, derived from the cell walls of brown algae, are used in beer, frozen desserts, pickles, adhesives, ceramics, explosives, paper and toys. Agar jelly extracted from selected species of seaweeds is used as a growth medium for culturing microbes for medical testing. Commercially important seaweeds are cultivated, rather than collected.

Sea Balls: These are a stalk-less brown seaweed called *Leathesia difformis* that are often washed ashore. The rounded 'ball' is solid when the alga is young but as it matures the 'ball' become hollow and somewhat indented in many places as if it has been squeezed by giant hands. As it ages, the algal body acquires the appearance of a small leathery brown tennis ball. The texture is rubbery and the origin of the common name is quite evident when one catches a glimpse of this alga.

Sea Comb: This is profusely branched, attractive, red seaweed that is called *Plocamium cartilagineum* in scientific circles. It grows up to 30 cm in length. The tips of its fronds curve inwards and ultimate branching occurs only to one side.

This gives it a distinctive feathery or comb-like appearance hence, the name. It is confusing to say the least, but animals belong to Phylum Ctenophora are also called Sea Combs.

Sea Bamboo: This is the Atlantic Ocean variety of a giant seaweed species called *Ecklonia maxima*. Like terrestrial bamboos, this one grows at a phenomenal rate too. It is harvested both as an agricultural supplement and as food for the cultivated, edible snail, Abalone.

Sea Kale or Sea Cabbage: This is a salt-loving perennial plant in the genus *Crambe* that grows wild along the coasts of Europe, from the North Atlantic to the Black Sea. *Crambe maritima* with its abundant white flowers, is an example. Sea Kale is eaten in Europe.

Sea-otter's Cabbage: This is a fanciful name for a species of kelp that grows to gigantic sizes. It is found in the Pacific Ocean and scientists call it *Nereocystis lutea*.

Sea Parsley: Commercially grown variety of the alga *dulse* with frilly outgrowths.

Sea Lace: This is a brown seaweed typically found in the inter-tidal zone. It is scientifically called *Chorda filum*. The brown colour is due to the brown pigment fucoxanthin. This bootlace-like Seaweed remains attached to the sea floor, by a holdfast while the thin, long and slippery fronds wave in the water. The fronds can reach six m in length. These fronds are unbranched, flexible, covered with small hairs and very tough. Sea Lace is also called 'mermaid's hair' or 'dead men's ropes' and actually used like rope. In Japan it is relished as *Tsuru-mo*. In Scotland tender fronds are harvested and used in soups or salads. Sea Lace is also used in the manufacture of soda-ash for soap.

Sea Moss: The alga *Gracilaria* is sold as a salad vegetable in the West Indies as sea moss. It is reputed to have aphrodisiac properties and is also used as a base for a non-alcoholic drink.

Sea moss

Sea Purslane: Scientists call this plant *Atriplex portulacoides*. It grows on the sand dunes on the sea coasts up to the high tide mark. The leaves are thick and fleshy. The stems are succulent, reddish-green in colour and branch profusely. The pink flowers are small but showy. These plants help stabilize the sand dunes by holding on to the grains of sand. This plant is often eaten in salads as it is naturally salty in taste.

Sea Rocket: This plant is a distant cousin of the radish. The different kinds of sea rockets get their name from the place where they grow. Scientists call the European searocket, *Cakile maritime* and the American sea rocket, *Cakile edentula*. Sea rockets grow close to the coast, on sandy beaches and

above the high tide line. They have fleshy leaves and bear mauve to white flowers.

Sea Lettuces: These are species belonging to the genus *Ulva*: a group of edible green algae which grow along the coasts of the world's oceans. The word "*lactuca*" means lettuce in Latin; so people usually mean *Ulva lactuca* when they refer to sea lettuce. Individual strands of *Ulva* can grow to be more than 400mm in size. Some algal species belonging to the genus *Monostroma* are known as slender sea lettuces.

Sea lettuces are eaten by people in Scandinavia, Great Britain, Ireland, China, and Japan and also by a number of different sea animals. It is high in protein, soluble dietary fibre and many vitamins and minerals, especially iron.

Sea Lavender: These plants belong to the genus *Limonium*. Interestingly, although these plants bear the prefix 'Sea'; they are not really marine. Many species of sea lavender flourish in saline soils, and are common near coasts and in salt marshes. These bear clusters of small lavender coloured flowers, which give them their name.

Sea Oats: This is a tall grass that grows on sand dunes and on beaches. It has good tolerance for seawater spray. Scientists call it *Uniola paniculata*.

Sea Pea or Sea Vetchling: This is a flowering plant that is common on sandy beaches. Its roots help to bind the sand grains. The flowers are pink to purple in colour. Its pods are like those of the common pea but sea pea is not edible. Scientists call it *Lathyrus japonicus*.

Sea Thrift or Sea Pink: This is a drought-tolerant poisonous garden plant that is scientifically called *Armeria maritima*. This plant can grow in sandy soils and under saline conditions too. It bears flowers that are white to pink in colour.

Sea Milkwort: Scientists call this plant, *Glaux maritima*. However, despite the name, it is not a marine plant although it is common along seashores, particularly around the Baltic Sea.

Sea Mango: This is an evergreen coastal tree that Scientists call *Cerbera manghas*. It has glossy green and leathery leaves. It bears white fragrant flowers. Sea Mango has medicinal properties.

Sea Fig: This is a succulent plant which stores water in swollen leaves. It bears bright magenta flowers. It grows in coastal areas, sand dunes and beaches. Scientists call it *Carpobrotus chilensis* and ice plant is another common name for it.

Sea Grapes: These are edible green algae, scientifically named *Caulerpa lentillifera* and *Caulerpa racemosa*. It is likely that these got their names because of their grape-like appearance. These grow on sandy or muddy sea bottoms and are also cultivated as 'green caviar'-a huge culinary compliment, because caviar, or the egg of the Sturgeon fish, is a greatly prized delicacy in many parts of the world.

Sea Plantain: This is also known as seaside plantain or *Plantago maritima*. It is a herbaceous plant with a dense rosette of stem-less leaves. The flowers are small, greenish-brown and produced in spikes. This plant can tolerate saline ocean spray and marsh-like conditions. It grows in coastal areas.

Sea Holly: Two totally different plants lay claim to this common name. One is *Eryngium maritimum*, a species native to most European coastlines and which bears blue flowers. The second is *Acanthus ilicifolius*; also known as *Hargoza* in Hindi. It is a mangrove plant. This plant produces a cluster of flowers which appear in neatly organized spikes at the tips of the branches. Ripe pods explode to propel the seeds far away.

Sea Rose: This is a terrestrial, evergreen plant that has lush green leaves. Its stems bear small white hairs which give them a velvety feel. The deep pink flowers are large and showy, borne either in clusters or singly. Scientifically it goes by the name *Orphium frutescens*.

Sea Rush: These are terrestrial plants that grow in coastal salt marshes, saline swamps and along the margins of salt lakes in Australia and New Zealand. Scientifically these are named

Juncus kraussii. The leaves and stems taper to sharp points and are tough, with pithy centres. It bears clusters of flowers. Animals find this plant distasteful.

Sea Asparagus: It is a bushy plant with succulent leaves that grows near the coast. Scientifically it is called *Salicornia virginica*. It is edible and has a salty taste and so, is often served as sea vegetable. *Salicornia* is poised to earn prominence as an edible-oil yielding crop, which can be raised using seawater. An improved variety of *Salicornia* has been developed, which is highly drought-resistant and salt-resistant. This is being grown in many parts of the world, including India. *Salicornia* appears to have a good future as a feedstock for biodiesel and other energy products too. Approximately 30 percent of *Salicornia* seed per weight is oil. Apparently, *Salicornia* oil is very similar in quality to safflower oil. After extraction, the seedcakes can be used as a protein feed for livestock, so nothing need be wasted.

Sea asparagus

Sea Beans: These are seeds of plants belonging to the Family Fabaceae, which not only includes beans but also many

species of tropical vines. Many of these vines are climbing woody vines called lianas which produce hard, marble-like seeds. These seeds are known as “Sea Beans” because they are carried into the ocean by the rivers. An example of a vine, the seeds of which are called sea beans is the woody vine *Dioclea*. The seeds of *Entada rheedii* are known as the Snuff Box sea bean. The totally unrelated *Salicornia* is also called sea bean.

Sea Onion: These are three different terrestrial plants that grow from bulbs, much like onions do. The scientific name of the first plant is *Bowiea volubilis*. It bears greenish flowers on a very long stalk. A Mediterranean plant cultivated for its bulb that yields a powder used medicinally, and as a rat poison, is the second plant that goes by the same name. Scientists call it *Urginea maritima*. The third is a small bulbous European plant having fragrant blue flowers. Its scientific name is *Scilla verna*.

Sea Squill: Another name for *Urginea maritima*.

Seabuckthorn or Seaberry: This is a terrestrial plant belonging to the genus *Hippophae* that bears berries with medicinal properties. In 2010, India launched the ‘National Mission on Seabuckthorn.’

Seabuckthorn Hippophae rhamnoides

Animals with the term Sea in their names

Perhaps the most abiding myth involving an animal with the term 'sea' in its name is that of the sea serpent. It is supposed a monstrously huge serpent that inhabits the depths of the oceans. However, no evidence of such a sea serpent has ever been found although the Oarfish (*Regalecus glesne*) –a species that holds the record for being the longest bony fish (over 17 m) with its snakelike body has sparked many reports of sea serpent sightings.

Sea Snakes

All known sea snakes are considerably smaller than the gigantic mythical sea serpent. All sea snakes are venomous and have short fangs. Being venomous does not seem to have helped them much since they are highly regarded as food wherever snake flesh is eaten. Sea snakes themselves eat fish, especially eels, molluscs, prawns, and fish eggs.

Sea Turtles: Together with their cousins, the saltwater crocodiles, sea snakes, and marine iguanas, sea turtles are the only seawater-adapted reptiles that are alive on Earth today. The eight species of sea turtles are found in warm and temperate seas. They are champion swimmers and are known for their long migrations.

Sea Eagle: Any of the many fish-eating eagles that live near the sea. The term is especially used for the White-tailed eagle *Haliaeetus albicilla*.

Sea Pie or Sea Pyot: The oyster catcher, a bird belonging to the genus *Hæmatopus* has been given this name. As its other name attests it likes to hunt oysters and so, frequents seashores.

Sea Devil: Many fishes lay claim to this name. The manta ray, *Manta birostris*, which lives in the tropical seas, usually around coral reefs and the monkfish *Lophius piscatorius* found

in coastal waters of the northeast Atlantic Ocean, are both referred to as the sea devil. The deep-sea anglerfishes in the Family Ceratiidae are equally strong contenders for this name.

Seahorses: These are bony fishes that really look a lot like horses; hence the name. Even Scientists agree that these two animals look similar. They have named these animals *Hippocampus*. The word "*Hippocampus*" is derived from two words in ancient Greek: "*hippos*" meaning horse and "*kampos*" meaning "sea monster." The word therefore literally means horse-like sea monster, an obvious reference to its equine looks. There are about 40 species of seahorse that belong to the genus *Hippocampus*.

Seahorses vary in size. The pygmy seahorse (*Hippocampus bargibanti*) is less than 15 millimeters in length, while the Pacific seahorse, *Hippocampus ingens*, one of the largest of the 34 known species of seahorses in the world, can grow to an impressive 30 cm in length. Seahorses are strange fish. Despite being fish; these do not have scales. Instead they have a thin skin stretched over a series of bony plates arranged in rings. Each species has a definite number of rings. Unlike other fishes, Seahorses swim in the upright position and may remain stationary for long periods by twisting their tails around a support. Seahorses like shallow tropical and temperate waters; preferably sheltered areas such as Seagrass meadows, coral reefs, or mangroves.

Seahorse

Seahorses adopt dull patterns to camouflage themselves but during courtship, often come forward in colourful avatars. The male seahorses brood the young. They carry the eggs in pouches that are reminiscent of those that kangaroos have! Seahorses are becoming quite rare these days but are still used in traditional medicines in many parts of the world; particularly in Indonesia, Philippines, and China.

Sea Dragons: Cousins to the seahorse, these gentle marine fish are quite unlike the fire-breathing dragons of story books despite their perceived resemblance to it. The leafy sea dragon or glauerts sea dragon goes by the scientific name *Phycodurus eques*. A related species is the more colourful but smaller, weedy sea dragon (*Phyllopteryx taeniolatus*). Sea dragons are mostly found in waters up to 50 metres deep. They are common along the southern and western coasts of Australia where they hide among rocks and seagrasses.

Sea dragon

The leafy sea dragon is about 20–24 cm long. It has a long, pipe-like snout that it uses to feed. Although it feeds on plankton

and small shrimps, the leafy sea dragon is literally, toothless. It is a master of camouflage. The long leaf-like protrusions on its body make it look like a raggedy piece of seaweed. As if this were not enough, the leafy sea dragon can also change colour to blend in; but this ability depends on its diet, age, location, and stress level. Male sea dragons could be role models for gender equality! They carry and protect the eggs, which the female lays in a pouch under its tail.

The leafy sea dragon is the official marine emblem of the state of South Australia. A biennial Leafy Sea Dragon Festival, first begun in 2005, is also held in South Australia.

Sea Porcupine: The body of the fish *Diodon* spp. is covered with spines, which makes it resemble a porcupine; hence the name.

Sea Moths: This is the common name for six species of fish that have large pectoral wings that rather resemble wings. *Pegasus volitans* is the scientific name of one species of sea moth. Strangely enough sea butterflies are not fish!

Sea Bass: This is the common name shared by many edible marine fish. European sea bass is *Dicentrarchus labrax*.

Sea bass dicentrarchus labrax

Sea Bream: *Archosargus rhomboidalis*, more commonly known as the Western Atlantic sea bream, is an edible marine fish. It also goes by the names brim, tropical sheepshead, chopá amarilla and salema.

Sea Purse: Strictly speaking this is not an animal... just the envelope containing fertilized eggs of certain sharks and skates. Sometimes this is also called Mermaid’s purse. The seed of an Asian plant that floats to places as far away as USA is also called sea purse. It is often used to make exotic ornaments.

Sea Otter: This is a marine mammal that scientists have named *Enhydra lutris*. Unlike most marine mammals the sea otter has a thick coat of fur. It is smart enough to use rocks to break open mollusc shells; this makes it one of the few animals that can use tools.

Sea Cows: These are large herbivorous marine mammals with cylindrical bodies, paddle-like tail and rounded front flippers. These are also called Sirenians because they belong to a group called Sirenia. There is a school of thought that holds that the mythical sirens of Greek folklore, who allegedly mesmerized sailors with their songs, were actually sea cows. Actually, from far, these animals do resemble a typical ‘mermaid’—albeit one with whiskers! One supposes that the sailors had really been away from land for a very long time indeed to have been convinced they saw bewitching sirens when what they had actually seen were these animals and their relatives. Dugong (*Dugong dugong*) and the Manatee (*Trichechus spp.*) are examples of sirenians.

Sea Leopard: The leopard seal (*Hydrurga leptonyx*) is the second largest species of seal in the Antarctic region. It has been given this name in appreciation of its skills as a predator. There is another resemblance. The leopard seal has black spots on its whitish throat that are reminiscent of the leopard. The name *Hydrurga* means “water worker” and *leptonyx* is the Greek word for “small clawed.” The sea leopard is a large and

muscular animal with a dark grey back and light grey undersurface. Bull leopard seals can grow to 2.5–3.2 m in length and weigh between 200 and 453 kg; the larger females can reach 3.4 m in length and weigh between 225 and 591 kg. The Leopard Seal is a shallow water hunter, and does not dive deep. Its teeth pattern allows it to sieve krill from the water and it also hunts fish and penguins.

Sea Lions: These are marine mammals that have long torpedo-shaped bodies covered in short coarse hair. They have long, leathery and nail-bearing flippers on their limbs which are used for locomotion. They have external ear flaps. The steller's sea lion (*Eumetopias jubatus*) is named after the German naturalist Georg Wilhelm Steller who first studied these animals. The California sea lion is named *Zalophus californianus*. Sea Lions dive into the waters in search of food but usually remain underwater for not more than four or five minutes.

Sea Wolf: The Kiler whale *Orcinus orca* is given this name because it hunts in groups just like the packs of wolves do on land.

Sea wolf killer-whale

Sea Elephants: The elephant seal is called a sea elephant because it has a nose-like structure the proboscis that reminded early observers of the elephant. It is also quite huge in size with males growing up to 2300kg in weigh. They make loud sounds much like the trumpeting elephants, during the mating season. There are two kinds of elephant seals: northern elephant seal or *Mirounga angustirostris* and the southern elephant seal *Mirounga leonina*.

Most inexplicably, some simple pelagic sea snails with a transparent body are also called sea elephants.

Sea Orange: This lowly animal is a sponge that belongs to phylum porifera like all sponges do. It is quite aptly named because it is round like an orange and coloured yellow or orange too. Its surface has small round and spiny outgrowths. Scientists call it *Tethya aurantium*

Sea orange tethya-aurantium

Sea Worms: Most sea worms, as cousins to the terrestrial earthworms, belong to the Phylum Annelida too. They also

look a lot like the worms on land, which is actually not saying a lot about their looks. However, tube worms that are found deep under the sea live inside hard or leathery tubes with only their 'gills' waving about from the open end of the tube. The magnificent feather duster tubeworms (*Sabellastarte magnifica*) bear feathery tentacles on the top to filter nutrients from the water. When the animal is disturbed, it quickly retracts these into the tube. The tentacles of the christmas tree worm (*Spirobranchus giganteus*) are ornate and brightly coloured; hence the name. These worms are found in the waters of the Caribbean sea and the Indo-Pacific Ocean. The large-eyed feather duster worm (*Potamilla reniformis*) grows inside leathery tubes and their feathery gills are usually orange-red to reddish-brown in colour with white tips. The orange fireworm (*Eurythoe complanata*) earned its name because it has bristles that can deliver painful stings. These grow under rocks and on coral reefs. The red-rim flatworm (*Pseudoceros splendidus*) is unusually flat in shape and its bright colour advertises its unpalatability to would-be predators that do not know any better. These worms exude foul-tasting mucus that no predator wants to taste twice.

Tube worm

Sea Louse (plural Sea lice): These belong to the Phylum Arthropoda, which makes them relatives of insects and crabs etc. Sea lice, like the lice found in hair and body of infested individuals and animals on land, are also parasites. These feed on the mucus, epidermal tissue, and blood of host marine fish and are often represent a threat to fisheries.

Sea Slater: This marine arthropod is a relative of the terrestrial woodlice. It has a flattened, oval-shaped body that is grey to olive in colour and twice as long as it is broad. It has long antennae, seven pairs of walking legs and two projections at the tip of the abdomen, known as uropods. The black eyes are very large and similar to the compound eyes found in insects. Scientists refer to it as *Ligia oceanica*. It is also called **sea roach**.

Sea Monkeys: These tiny shrimp-like organisms belong to Phylum Arthropoda and scientists call them *Artemia salina*. Sea monkeys can colonize waters that are so salty that no other non-microbial organism can survive in it. They are also found in salt lakes and salt evaporation flats. This ability has earned them the name brine shrimp. Not only are the adults resilient, but their eggs too can survive for many years. Hobby shops abroad often sell “*Artemia* growing kits” containing eggs, salt, food etc., and the Brine shrimps can be cultured in salt-water aquaria.

Sea Ears: One of the many common names for the tasty sea snail, Abalone (*Haliotis spp.*). Like all snails; sea snails too belong to Phylum Mollusca. Abalone shells are actually ear-shaped, with two to three whorls; hence the name.

Sea Slugs: These are sea snails without the characteristic outer shells that we associate with the term ‘snails.’

Sea slug

Sea Hares: These are sea slugs. Although these are invertebrates, they share their name with hares which are mammals, because the two long projections on their heads reminded the first observers of rabbit ears! Sea hares are usually large and bulky. The largest, *Aplysia vaccaria*, can reach a length of 75 cm and weigh up to 2 kg. Sea Hares are hermaphrodites; each animal is both male as well as female.

Sea hares feed on algae and this affects their colouration. For example, those that feed exclusively on red seaweeds show red colouration. Since they prefer to live in Seaweed beds in shallow water, the colour that they adopt is effective camouflage. When faced by a predator, Sea hares release ink from their ink glands. This ink, supposedly toxic, not only provides cover, but also confuses the predator's sense of smell. Interestingly, the colour of the ink may be white, purple or reddish, depending on the colour of the pigments in the animal's seaweed diet. Their skin also contains a toxin that makes them unpalatable to predators. However, although predators may give the sea hares a wide berth, researchers do

not. *Aplysia californica* is greatly valued for its large nerve cells that are perfect for the study of nerve impulse.

Sea Lemons: These are the sea slugs *Archidoris pseudoargus/Anisodoris nobilis*. The body is oval in shape and the mottled colouration may vary greatly, ranging from yellow, pink, green, white, brown and even, brilliantly- red. The upper surface of the body is covered in protuberances called tubercles.

Sea Butterflies or Sea Angels: These are a type of sea snails. The naked sea butterfly is scientifically named *Clione limacine*. It can be found up to a depth of 350m. The totally aquatic lives of these snails have led to some changes in their bodies, which have resulted in the name sea butterflies. Many of these snails have lost their shells and the muscular foot on which they move form of two wing-like lobes which beat rhythmically to allow the snail to ‘fly’ through the water. Sea butterflies play an important role in the food web, particularly at high latitudes.

Sea Anemone: Anemones belong to Phylum Cnidaria and are closely related to corals and jellyfish. These are water dwelling, predatory, stinging polyps. Anemones have an adhesive pedal disc (foot) that helps them to hold on to a rock or the reef. They have a cylindrical body, and an entire array of tentacles surrounding the central mouth. The tentacles are triggered by the slightest touch and instantly fire a harpoon-like filament into their victim simultaneously injecting a toxin that affects the nervous system of the prey; paralyzing it. Then the tentacles guide the ‘unresisting’ victim into the mouth. There are more than 1,000 sea anemone species found throughout the world’s oceans at various depths. These animals may be dull or brightly coloured. Some are as small as 1.25 cm; others as large as 1.8 m across.

The sea-fan anemone is pink, orange, red or fawn-coloured with streaks of white. It is small in size with up to 80 irregularly arranged small tentacles around its oral cavity.

It usually occurs attached to **sea fans**, hence the common name sea-fan anemone. Scientists call it *Amphianthus dohrnii*. Its scientific name was coined from the Greek word “*amphi*” meaning “*near*” and “*athus*” meaning flower. *Amphianthus* thus means “flower-like” and it really does resemble a beautiful flower.

Sea Nettles: Despite the name, these are not plants but animals belonging to the Phylum Cnidaria. Like all Cnidarians, these are armed with deadly stinging cells. So brushing against them as they swim past can be as nasty as a brush with the nettles on land. Sea nettles have a distinctive golden-brown bell that can grow up to 30 cm in diameter. The arms surrounding the oral cavity are white and the long, thin tentacles bearing the stinging cells are maroon. Sea Nettles are good swimmers. Scientists call Sea Nettles *Chrysaora fuscescens* and *Chrysaora quinquecirrha*.

Sea-nettle

Sea Wasp: This is a jellyfish and a member of the phylum cnidaria. The term sea wasp is usually used for *Chironex fleckeri*. It is commonly encountered in coastal waters from northern Australia and New Guinea. It is perhaps the most lethal jellyfish in the world with venom enough in its 3m long tentacles to kill 60 adult humans. Sea turtles, however, can feast on them because their leathery skins are impervious to the lethal darts. The Jellyfish *Carybdea alata* also shares this name.

Sea Pansy: The scientific name of this Cnidarian is *Renilla reniformis*. The Sea pansy is not actually one single animal; but an assemblage of “polyps” with different forms and functions. A single, giant polyp forms the anchoring stem called peduncle; which can be distended to attach the colony more firmly to the substrate. Then there are the many anemone-like feeding polyps which secrete sticky mucus to trap the tiny organisms suspended in the water. Hard spicules of calcium carbonate on its body give rigidity to it plus, the colour purple. The Sea pansy emits light when disturbed.

Sea pansy renilla

Sea Pen: Sea pens are soft corals that look remarkably like old-fashioned quill pens. Some can grow to be quite big. For example, the Tall Sea pen (*Funiculina quadrangularis*) can reach

2m in height. The orange sea pen (*Ptilosarcus gurneyi*) is quite brightly coloured, as its name attests. Sea pens emit a bright greenish light when disturbed.

As with all corals, sea pens are colonial animals with multiple polyps. The polyps are specialized to carry out specific functions. For example, one polyp develops into a rigid, erect stalk called the rachis. It loses its tentacles but develops a bulbous structure at the base, rather like a “root.” The other polyps branch out from this central stalk. Some go on to form water intake structures. These are called siphonozooids. Others form feeding structures and are called autozooids. The zooids are armed with nematocysts or stinging cells.

Sea pens are rarely found above depths of 10 m but may be encountered at depths of 2,000 m or more. However, although “rooted”, Sea pens are able to re-locate and re-anchor if the need arises; particularly if it has to ‘flee’ Sea Urchins that feed on it.

Sea Whip: This is the coral species *Muricea muricata*. Its name comes from the elongated finger-like or whip-like shapes that it assumes. These corals are usually pale yellow in colour.

Sea Fan: These are members of the Phylum Cnidaria and go by the scientific name *Gorgonia flabellum*. Sea Fans are very closely related to **sea whips** and can be red to yellow and also, purple. The main difference between Sea Whips and Sea Fans is that Sea Fans are more flat or fan-like appearance instead of being thin and whip-like. These are very common in the Caribbean region.

Sea Mats: These are soft corals and like all corals, are composed of small polyps with short tentacles. These polyps are connected at the base in a continuous mat. *Palythoa toxica* and *Palythoa tuberculosa* are toxic in nature. A group of marine invertebrates called Bryozoa are also called sea mats.

Sea Spider: Sea-spiders are completely unrelated to terrestrial spiders, although there is strong superficial similarity. Sea spiders are exclusively marine and mostly live on sea bottoms. Male sea spiders carry the fertilized clutches of eggs till these hatch and sometimes, carry the larval stages too.

The bright red, giant sea spider *Colossendeis* is the largest of all Sea Spiders with leg spans as wide as fifty cm. It usually lives at depths of about 5,000 m although in Antarctic waters it may be found in more-shallow depths. It strides over the soft ooze of the sea bed on its very long legs. It sucks out the juices of other invertebrates by means of its feeding tube or proboscis. The species *Nymphon gracile* is found in the intertidal and sub-littoral zones near rocky shores.

Sea Cucumber: These are also called **sea apples**. The common names are misleading because despite the terms ‘cucumber’ and ‘apple’ in their names, these are not members of the Plant Kingdom. They are marine invertebrates that belong to the Phylum Echinodermata—a group that has the distinction of being totally marine. No Echinoderm is found in freshwater or on land.

Sea cucumbers have a leathery skin and an elongated body. They have somewhat bone-like calcified structures just below the skin. Sea cucumbers are found in great numbers on the deep sea floor, where they often make up the majority of the animal biomass. According to an estimate, at depths deeper than 8.8 km, sea cucumbers comprise 90 per cent of the total mass of the larger animal lifeforms. These scavenging animals even form large herds that move across the ocean floor. The strawberry sea cucumber (*Squamocnus brevidentis*) is so abundant, in Fiordland, New Zealand that this underwater site has been named strawberry fields in their honour. The name comes not only from the fact that there may be up to a thousand individuals per square meter but from the fact that these animals contract their extremely plastic bodies into a “*strawberry blob*” when disturbed.

Sea cucumbers extract oxygen from water in a pair of 'respiratory trees' that branch off the cloaca just inside the anus. Thus it may be said that 'breathe' by drawing water in through the anus and then expelling it. Gas exchange occurs across the thin walls of the tubules, to and from, the fluid of the main body cavity. The respiratory trees also act as excretory organs throwing out particulate waste along with nitrogenous waste such as ammonia.

The anatomical peculiarities of sea cucumbers have had strange consequences because it has attracted many unrelated species to it and led to bizarrely intimate associations. A variety of fish, most commonly the pearl fish, polychaete worms and crabs have evolved a strange relationship with sea cucumbers. They enter the sea cucumber's body via the excretory opening or cloaca and live there. They use the body of the sea cucumber as a cave for protection from predation and as a source of food. For example, the emperor shrimp (*Periclimenes imperator*) is quite at home inside the sea cucumber, *Bohadschia argus*. The sea bed is such a nutritionally-poor habitat, that these animals have developed a way to capture immediately any nutrient that is passing out of their host's body via the anus.

Sea cucumbers are used in Chinese cuisine as *Hoi sam*. In Indonesia and Malaysia it is believed that certain species; known as *Teripang* and *Gamat* respectively, have healing properties.

Sea Pig: The term is used for three species of sea cucumber namely *Scotoplanes angelicus*, *S. globosa* and *S. mutabilis*. Sea Pigs live on deep ocean bottoms, specifically on the abyssal plain in the Atlantic Ocean, Pacific Ocean and Indian Ocean, typically at depths of over 1000 m. Some species of marine mammals such as porpoise or dolphin or dugong are also called sea pigs.

Sea Stars: They are also known as starfish; a name that refers to their star-shaped body with five arms. However, they certainly are not fish, but echinoderms that are relatives of the sea cucumbers. About 2,000 different species of Sea Stars populate the world's oceans. The greatest variety of is found in the tropical Indo-Pacific Ocean; ranging from the inter-tidal regions to abyssal depths.

Seastar

These iconic animals play important roles in the ecosystem. In ecology, a keystone species is a species that exerts an impact on its community that is both strong and disproportionate to its abundance. The ochre sea star (*Pisaster ochraceus*) is considered to be a keystone species. The crown of thorns starfish (*Acanthaster planci*) is a voracious predator of coral.

Sea Urchin: This is another Echinoderm, and a cousin to both, sea stars and sea cucumbers. It is also called,

“hedgehog of the sea” because it rather resembles a hedgehog. The word “*urchin*” is an archaic word for the round spiny hedgehog.

Sea urchin

Sea urchins are spherical in shape and covered with long spines. The spines may be solid or hollow and filled with poison, depending on the species. These are used for locomotion and for protection. Most sea urchins are about 5 to 10 cm in diameter, including the spines. These feed on seaweed and are usually found on the ocean bottom; especially, near rocky shores. Sea urchins are such voracious feeders that they can reduce entire forests of kelp to what are known as Urchin-barrens. Sea urchin eggs are used as food in many Asian and European countries.

Sea Biscuit and **Sea Dollar** are alternative names for the burrowing sea urchin. The term sand dollar comes from the shape and colour of the dead animals that wash up on the beach. Sand Dollars reminded people of large silvery coins such as the old Spanish dollar coin; hence the name. *Echinarachnius parma* is the common sand dollar, and it is

widespread in oceans of the Northern Hemisphere; from the inter-tidal zone to considerable depths. The ‘fatter’ *Clypeaster rosaceus* is called the Inflated Sea Biscuit. In Spanish, this is called “*galleta de mar*” or **Sea Cookie**.

Sea Lily: The sea lily is an echinoderm that rather looks like a stem or stalk of a plant that is rising up from the bottom in which it is rooted. Scientists call them Crinoids. Sea Lilies have feathery arms arranged around a central opening or mouth. The arms are covered with rows of feather-like appendages, called pinnules that help trap the plankton in surrounding waters. The feathery arms of these plant-lookalikes then guide it to the mouth. Sea Lilies like deep waters. The Japanese sea lily, *Metacrinus rotundus* is usually found at depths of 210–270m but it also occurs at depths of only 160m in Suruga Bay near Tokyo, making it the shallowest species recorded.

Sea Squirts/Sea Violets: These animals belong to Phylum Urochordata. Members are also called tunicates because of a rubbery tunic that encases the body. These, rather insignificant looking animals, are found all over the world, usually in shallow water. Sea squirts are globular or cylindrically-shaped and remain firmly attached to the substratum. They have a leathery ‘bag-like’ body. Sea squirts range in size from 0.025 to 18 cm in diameter. The adult sea squirt has two ‘siphons’ on the top of its body. One siphon draws in sea water and the other expels it. When disturbed, it contracts its siphons, squirting out two streams of water—a habit that earned it, its name. Under normal circumstances however, the siphons set up a cycle that draws sea water into the animal’s pharynx where plankton is ingested, while the water is expelled.

Sea Pork: These tunicates are called *Aplidium stellatum* in scientific circles. Sea pork got its name because after death, the rubbery tunic bleaches to white, resembling salt pork. Sea pork forms large colonies. It likes to inhabit regions from the low tide line to depths of about 9m.

Sea Liver: Similar to sea pork, *Eudistoma hepaticum*, as it is known scientifically, has a softer tunic. Its tunic is also more slimy as compared to that of the cartilaginous tunic of sea pork.

Sea Peaches: These are tunicates too and commonly found in the northern Pacific Ocean and the Bering Sea at a depth of 40 to 100 m. The sea peach is typically barrel-shaped, growing to a height of 18 cm, and its body is attached directly to the substrate. *Halocynthia aurantium* is an example. Its 'tunic' is red to orange in colour and may be either smooth or wrinkled with two siphons on top.

Sea peaches

Sea Vase: Scientists call this tunicate *Ciona intestinalis*. It has a cylindrical body with a thick gelatinous tunic and grows

up to 15 – 25 cm. in size. The colour varies. It may be white or yellowish- green with orange marks around the siphons. It likes hard substrata to which it attaches firmly but it sometimes grows on Seaweeds too. It can inhabit depths up to 500 m.

Sea Pineapple: The sea squirt (*Halocynthia roretzi*). It is cultivated in Japan and Korea . When eaten raw, *Lonely Planet* described it as tasting like “*rubber dipped in ammonia*.” The flavour is because of a compound called cynthiaol.

Sea Walnut: This is any species belonging to the genus *Mnemiopsis*; although it is *Mnemiopsis leidyi* that has a shape somewhat like that of a walnut. These gelatinous, planktonic invertebrates are classified under phylum ctenophora or comb jellies. Sea walnuts are found in the open seas as well as in coastal waters; often in huge and dense swarms. They are bioluminescent, producing a bright bluish light.

Sea Gooseberries: These bio-luminescent, planktonic animals also belong to the phylum ctenophora. There are about 90 species of sea gooseberries. Most are small, from 3mm in diameter to 15mm. These have gelatinous, transparent, and roughly rounded or pear-shaped bodies and two feathery, long, trailing tentacles with sticky heads but no stinging cells on them. These are used to catch prey. The sea gooseberry *Pleurobrachia pileus* is an example.

Sea Potato: Many unrelated species, including the brown alga *Leathesia difformis* that is also called **sea ball**, lay claim to this name.

The animal *Styela rustica*, a member of the phylum urochordata is found in the bering sea. It is also called sea potato because it has a dark brown, potato-shaped body. It reaches a maximum height of about 10 cm and usually grows in clumps attached to a hard substrate.

The yellowish-brown Heart Urchin or *Echinocardium cordatum* is also known as a sea potato. This is because its outer covering looks rather like a potato.

The Bajau Sea Nomads

The ethnic group known as the Bajau has lived at sea for centuries. They sail a tract of ocean between the Philippines, Malaysia and Indonesia using traditional, hand-hewn *lepa-lepa* boats, which may or may not boast of a rudimentary engine. Skilled divers, they often deliberately perforate their ear drums to avoid rupturing them on deep dives. They wear hand-carved wooden goggles with glass lenses and use spear guns innovatively designed from odds and ends such as boat timber, rubber from worn-out tyres and scrap metal to hunt fishes. To them, the ocean is a living entity and spirits live in and animate the currents and tides.

They have also been called sea gypsies because of their nomadic life style.

It is being recognized that deeply entrenched knowledge such as theirs are repositories of ancient human wisdom and can be put to great use in modern conservation efforts.

The word 'Sea' as a prefix to the name of a plant or animals is an instant trigger that conjures up visions of a lovely blue expanse of water with these lifeforms languidly riding the silver crested waves; undulating underneath or knifing through it without even leaving a wake! It conjures up visions of an environment that we can enter only occasionally and that too, for limited periods. It fills us with a sense of wonder. No wonder Katherine Patterson said, "*The name we give to something shapes our attitude to it.*"

8. WEALTH FROM THE DEEP

Ratnagarbha: Womb of Gems.

Ratnakar: Treasure trove of Gems.

Other names, in India, for the oceans.

In Hindu mythology, the churning of the oceans brought forth wondrous gifts. It now seems that there is more than just a tiny kernel of truth in the story, and it could come literally true if scientists and technologists finally manage to mine the ocean depths.

The sea waters are enormous reservoirs of different minerals, oil, gas and even uranium and gold! So, in the marine depths lies a veritable treasure trove just waiting to be recovered.

Seawater: Reservoir of Dissolved Chemicals

Everyone knows sea water is salty. It is salty because it contains about 5×10^{16} tonnes of mineral matter, 85 per cent of which is sodium chloride—the table salt we use everyday. Sea salt is used in many traditional cuisines. Human beings first learnt to extract salt from sea water in China, as early as in 2,200BC. In addition to Sodium chloride, Magnesium oxide is produced from solar salt bitterns in India.

In the last couple of decades attention has been focused on the '*hot brine deposits*' in the Red Sea. As early as in the 1880s water from about 600 m deep in the Red Sea was sampled by scientists on board the Russian ship *Vitaz*. It was found to be warmer than expected. Over half a century later, the Swedish ship, *Albatross* confirmed that water in the deep Red Sea was warmer than normal and unusually salty too. In 1964, the British research ship *Discovery* recorded that deep Red Sea

waters were at temperatures of 44 degree Celsius. The next year, the *R/V Atlantis II* collected sediments ...the thermometer registered 56°C! The 'hot brines,' as the waters came to be called were thought to have formed when the Sun's heat caused surface waters to evaporate –leaving behind very salty and denser waters that sank to the bottom. However, the mystery of the high temperatures remained unexplained.

Whatever, the reason behind the heating up of the water, it soon became clear that the hot water not only dissolved salts from the rocks but also leached out heavy metals. In the process, the water becomes saturated with various metals. Further, analyses revealed that the red sea sediments contained brilliantly colored layers rich in copper, iron, manganese, zinc and other metals. The saturated brine releases zinc as sulphides and Iron as carbonate. Thus the highly saline waters, high temperatures and rich mineral content have created conditions where accumulations of bottom sediments containing oxides and sulphides of iron, manganese, zinc and copper are taking place. The process appears to have been facilitated by the transfer of heat from the Earth's interior along lines called 'fracture zones.'

Gold from Seawater?

Popular perception has been that large amounts of gold have been washed into the oceans by the rivers that flow into it. Thus, over millennia, huge amounts of gold have ended up in the salty water; and just await extraction. However, a report in the 7th July 1990 issue of *New Scientist* rather lays to rest the speculation that large quantities of gold could be extracted from sea water. According to geologists Kelly Kenison-Falkner and John Edmond, Massachusetts Institute of Technology, USA, there definitely is gold in the oceans; but not as much as people think. They should know. They have analysed samples from the world's oceans and found that in the Atlantic

Ocean and north Pacific Ocean there is just 1 gram of gold for every 100 million tonnes of sea water.

But there may be hope yet.

As Scientists learn more about extremophiles, the range of biochemical activities these microbes appear to be capable of performing, seems straight out of Ripley's *Believe it or Not* books. Derek Lovley, Microbiologist at the University of Massachusetts, USA, has found that many such microbes derive energy by breathing in dissolved forms of toxic metals, such as uranium and cadmium, and converting them to solid form. Some extremophiles also breathe in dissolved Gold and breathe out solid gold! "*They use metals like we use oxygen,*" says Lovley. "*It is the way they get energy.*"

This is apparently how some gold deposits such as those in southeastern USA, were formed near hydrothermal vents, millions of years ago. Lovley and his colleagues have actually demonstrated that this could be so. They placed some extremophiles in a gold solution similar to that found in hydrothermal vents. Imagine the excitement in the laboratory when these microbes rapidly converted the gold from the dissolved form to the more valuable metallic form. Lovley has admitted that people have asked him many questions about the process. Obviously, they are curious about the feasibility of commercial application of the process. However, if you are planning to go to the nearest pet shop to order an aquarium full of these microbe, let me advise patience. Apparently, despite dissolved gold being present in seawater, the microbes aren't the easiest, or the most economical way, to mine it. "*The cost in pumping the water would be more than how much Gold you could recover,*" Lovley points out. "*The Gold particles deposited by the microbes are so tiny it would take about a million microbes to produce a gram of solid gold.*"

Despite the less than encouraging words, the gold industry has already spotted an opportunity. Paul Bateman, Executive Director of The Gold Institute, Washington, D.C. USA, was

quick to point out that, at some future date when research has progressed some more, these microbes might be commissioned to recover gold particles that would have otherwise been lost in the processing. Let's hope that day comes soon and the world's insatiable thirst for Gold is somewhat quenched.

Iron –A Microbial Gift?

Lovley has also shown that huge accumulations of magnetite created by microbes during pre-historic times are now important deposits of iron ore. Interestingly, a reddish brown matter was found on the seafloor on Loihi Seamount; an active underwater volcano near Hawaii. Examination revealed it to be Iron oxide-more familiarly known as rust.

Research revealed that this deposit was courtesy, microbes that live by oxidizing Iron directly from solid seafloor rocks. This discovery has catalyzed the setting up of the FeMO (Iron-oxidizing Microbe Observatory Hawaiian Islands).

The implication of this finding is that such microbes may be involved in large-scale geochemical changes on Earth. Interestingly, one of the first things that FeMO found out was that the mid-ocean ridge was fertile habitat for iron microbes. Scientists at the WHOI have begun sequencing the genomes of these microbes. They think that these microbes are primitive microbes that have persisted from the early days of Earth. If this is indeed so, then their genes/enzymes/metabolic pathways etc. will help unravel ancient secrets about how life may have developed on Earth.

Biologist Carl Wirsen (WHOI) and others, have found similar evidence of Sulphur-oxidizing bacteria that used solid minerals as their only source of energy. Such microbes are actually situated in the "Land of Plenty" under the sea because sulphur and sulphides are plentiful here. The discovery of microbes capable of 'feeding' directly off the minerals in the rocks on the seafloors has led to new field of study. It is called

named Geo-microbiology. The name clearly shows that geology and microbiology are equally important in this field.

Incredible facts about the contributions by the so-called insignificant, and certainly invisible, microbes are coming to light. They most definitely deserve our thanks for having played such a significant role in laying down reserves that are being exploited today.

Trace Elements in Seawater

Uranium is present in seawater but only in trace amounts of about three micrograms per litre of seawater. However, given the large volume of seawater, the total amount of uranium works out (roughly) to a whopping four trillion tonnes. The optimistic are sure that it may be feasible to extract it. Laboratory-scale operations to do so reported success in the 1990s. Most of the processes used Titanium hydroxide beads that selectively took up uranium from the waters.

Seawater also contains 65 parts per million (ppm) bromine, which translates into roughly 100 trillion tonnes of elemental bromine. In addition, Dead Sea contains an estimated 1 billion tonne of Bromine. Bromine available for extraction usually occurs as bromide; particularly in brine or saline deposits left by evaporation of seawater by the Sun's heat.

Bitterns or the left-over concentrated solution of salt that has crystallized out of sea water, are very rich in bromine. In India, the technology for manufacture of bromine has been developed at Central Salt and Marine Chemical Research Institute, Bhavnagar, which is a laboratory of the Council of Scientific and Industrial Research.

Marine Deposits

Marine mineral resources are of three types: Offshore rock deposits; deep oceanic mineral deposits and shallow mineral deposits.

Offshore rock deposits: These include gas, oil and coal deposits. Much of the world's oil and gas deposits are located offshore. Interestingly, oil and natural gas, even if found on land are of marine origin: having been formed millions of years ago from the remains of organisms whose dead bodies collected in shallow pockets at the bottom of the oceans. Over time, sediments covered them. Conditions prevalent at that point of time contributed to transform the remains into oil and gas and changed the sediments into hard rock. As time went by, enormous pressure exerted by the layers of sediments on top "squeezed out" the oil. Sometimes, on its upward journey it was met by a layer of impermeable rock that effectively 'sealed' it into pocket.

Offshore marine deposits also include ores rich in metals, Sulphur and potash. These deposits can extend hundreds of km and reach down to depths of thousands of m under the sea. These are mined by using techniques that are essentially similar to those used to drill deposits on land.

Certain clues guide offshore prospecting. For example, heavy minerals are most likely to occur close to the shore. Seaward extension is unlikely to extend eight km for tin and 15 km for gold.

Deep oceanic mineral deposits: These are found at varying depths under the open oceans. Deposits of sulphides are found as clusters of 'chimneys' at enormous depths. These 'chimneys' build up around seafloor hot springs where there is magma upwelling beneath volcanic seamounts. The magma cools, solidifies and creates new areas of sea floor. This creeps on either side of the submerged mountain range at the slow rate of a few cm per year! This is called seafloor spreading.

When cold and heavy seawater comes in contact with the hot magma it gets heated. It then expands and rises; dissolving metals present in the volcanic rocks. It also precipitates other metals in the seawater. This leads to deposition of metals such as copper, iron, zinc, silver and gold as sulphides at depths

of 1–4 km. Already a hundred such sites have been identified on seafloors. Additionally, crusts rich in iron and manganese occurring together are found in many seamounts at depths of 1000–2000m. Cobalt- rich ferromanganese crusts have also been found at water depths of 400–4000m; the richest of these crusts lie in waters around the island nations of the Western Pacific Ocean. It is important to remember that only about 5 per cent or so, of the Earth's seafloor has been mapped so far. Perhaps greater wealth lies undiscovered!

Polymetallic nodules

Deep oceanic deposits also include, what are called, polymetallic nodules. Polymetallic nodules get their name from the fact that these are rich in metals. These nodules were first dredged up from the ocean depths during the *Challenger* expedition under the supervision of Sir C. W. Thompson. However, it was not till 1965 when John Mero wrote the book entitled, *The Mineral Resources of the Sea* that active interest was catalyzed about exploring the economic feasibility of exploiting these nodules in the future for sourcing metals such as nickel, copper and cobalt.

Polymetallic nodules on sea floor

The texture of polymetallic nodules varies from smooth to knobby. Some nodules are soft and can be crushed between two fingers; these have less than two per cent calcium carbonate content. However, calcium carbonate content of more than five percent enables these to withstand light blows of a hammer. These irregularly shaped, potato-like nodules are rich in manganese and other strategically important metals such as nickel, copper and cobalt. These also contain iron, lead, zinc, and aluminum. Manganese nodules appear black to brown in colour. It is reddish if Iron content is high.

These nodules are found in all oceans, at depths ranging from 4000–6000 m. However, the Pacific Ocean seems to be particularly rich in polymetallic nodules. In the Northern Pacific Oceans, Copper, Nickel and Cobalt make up 3 per cent of the nodules while Manganese makes up 25–30 per cent.

Microscopic examinations of cross sections of these nodules show that the nodule 'grows' around a central nucleus or seed—very much like a pearl does. The 'seed' may be a tiny grain of basaltic material or clay. It may even be a shark tooth or remains of a dead animal. Of course when minute bits of iron from sunken ships and bomb shells are found inside the nodules it does indicate rather recent origin.

India is among a small group of nations to have explored the possibility of mining the seabed for polymetallic nodules. As early as in 1981, the National Institute of Oceanography, Goa, used the research vessel *R.V. Gaveshani* to collect nodules from the Seychelles Basin in the Indian Ocean.

The International Seabed Authority is empowered to regulate deep seabed mining. It places special emphasis on ensuring that the marine environment is protected from any harmful effects which may arise during exploration and mining activities. One of its first priorities was the formulation of the regulations for prospecting and exploration for polymetallic nodules to ensure environmentally sustainable development of seabed mineral resources.

Under an Agreement, India has been allotted an area of 1.50 lakh sq km in the central Indian ocean basin by the International Seabed Authority to conduct its explorations. India is among the four recognized regional pioneers in this field, the others being France, Russia and Japan.

Shallow mineral deposits: These deposits are placed towards the near shore zone, and apart from oil and gas, comprise of sands of titanium, rutile, zircon, ilmenite, magnetite and monazite. These deposits also include carbonates and phosphorites. In addition, marine deposits of sand and gravel are mined to meet construction needs where terrestrial resources are inadequate. Industrial sand and gravel are used to make glass.

The International Seabed Authority has reported that sand and gravel, “... *are the marine minerals with the highest annual production value.*” Industrial sand and gravel are produced all over the world. The world’s sand and gravel resources are very large. Still, mining and processing these resources may be expensive. It makes economic sense to mine areas close to the area of consumption so that transportation charges are minimized. In the Indian context, the Lakshadweep Islands have the richest potential for sand and gravel to be mined. Of course, care has to be taken not to adversely impact the environment while doing so.

Calcareous sand has an increased amount of calcium carbonate. This comes from rich accumulations of sea-shells from long dead molluscs, and even coral.

Mineral sand is rich in minerals such as rutile, ilmenite, zircon and monazite. Beaches rich in such sands are found in of peninsular India, Australia and parts of USA.

Precious Coral

Corallium grows in tropical and subtropical waters; five of these species can be found in the Atlantic Ocean. The Red

coral of commerce, *corallium rubrum*, flourishes in the Mediterranean Sea. *C. rubrum* is a slow growing species that grows just a few cm every year. Unfortunately, it has been intensively harvested for centuries, and now, most commercially viable *corallium* beds are seriously depleted. This happened because each time a new *corallium* bed was discovered, it triggered a “coral rush,” and resources were overexploited.

Coral jewelry

Precious coral is mined from the oceans in many parts of the world. It has long been recognized that the areas around the Lakshadweep and Andaman & Nicobar Islands are promising in this regard.

Pearls from the Sea

Saltwater pearls grow in pearl oysters, which live in oceans. Ptolemy described pearl beds in the Persian Gulf in 307 BC and Marco Polo described the pearl beds of Ceylon (Sri

Lanka) in 1294. Despite being basically just Calcium carbonate, large and lustrous sea pearls have always been in high demand and commanded high prices. Cleopatra is said to have crushed one pearl earring into her wine and drunk it to win a wager with Marc Anthony, who astounded by what she had done, simply conceded defeat.

Pearl-oyster with pearl.

The formation of a natural pearl begins when a foreign substance slips into the oyster between its tissue and the shell and sets up irritation...like we feel when a sand particle gets into our eye. The oyster's body secretes a shining substance called nacre to cover up the irritant. Layers of nacre eventually form a pearl. Natural pearls are extremely rare. It is reported

that just about one in every 2,000 oysters opened may reveal a pearl—that too, a small and irregular one. Just how prolific pearl oyster beds used to be can be estimated from the fact that in 1905, over eighty million specimens of *Pinctada radiata* were fished in Ceylon in just six weeks.

Of course, this sort of over-fishing is unsustainable and so, it was a blessing indeed when a method was fine-tuned to 'culture' pearls by artificially introducing the irritant into the oyster's body. Mabé pearls are cultured pearls that form on the oyster's shell rather than in its soft tissues. Japan led the pearl-farming revolution.

Even the shell of the Black-lipped pearl oyster (*Pinctada margaritifera*) is used to make jewelry. These pearl oysters occasionally produce pearls that are grey with green, blue or pink overtones. The Akoya Pearl Oyster (*Pinctada fucata*) is much valued for the iridescent mother-of-pearl that lines its shell. Silver-lipped pearl oyster/Gold-lipped pearl oyster / White-lipped pearl oyster (*Pinctada maxima*) produces pearls of exceptional quality. It is also the world's largest pearl oyster. Another pearl producing species is the *Pinctada mazatlanica*. Abalones (*Haliotis* sp.) are not only valued by chefs and gourmets but also by those who appreciate coloured pearls. Abalones produce exquisitely coloured natural pearls in shades of turquoise, rose, green and cream.

Byssus Threads

The Noble Pen Shell (*Pinna nobilis*) spins a fine, silky byssus thread which after processing, can be made into high-quality garments. Before sericulture took over in a big way, the byssus industry based in Italy produced durable and attractive garments made of byssus 'silk.' However, a single shell produces only about one gram of usable byssus thread—it seems unlikely that natural byssus will ever meet global demands again!

Diatomite Mining

Diatoms

Diatoms are algae. There are about 60,000 species known at present, although scientists say that the total number of species could easily be anywhere up to 6,000,000. The name Diatom comes from a Greek word '*diatomos*' meaning 'cut in half'. The name is an apt one because diatom shells have two overlapping, symmetrical halves, which gives it the appearance of having been cut into half. Under the microscope the shells of the diatoms appear very beautiful and so, the group has earned the name, "Jewels of the sea."

Diatoms are single-celled organisms, some of which live in big groups or colonies. Diatoms are very abundant and provide food for many aquatic animals. When they die, their shells are not degraded but accumulate on the seafloor. Over time, these shells have formed thick layers of what is known as diatomaceous earth or diatomite. Diatomaceous earth is white to cream in colour. It is very porous and is used in filtering devices to filter a wide range of products such as wine and grease. Diatomite is also a mild abrasive and is used in toothpaste and metal polishes. It is also used in paper, paint, brick, tile, ceramics,

plastics, soaps, detergents and other products as a filler to increase the volume of a product. In addition, it is used as insulating material in furnaces and boilers.

Methane

Seeping of methane gas is apparently a widespread, natural phenomenon that had been overlooked till recently. With better technology becoming available, scientists have discovered that methane gas has collected in pockets beneath seafloor sediments. These are now labeled 'Cold Seeps. The seepage of Methane not only sustains microbes that serve as the base of the food chain but also has potentially dramatic implications on energy resources and global climate.

Methane solidifies under the immense pressure at the cold depths to form called methane hydrates. These reservoirs of methane hydrates can be tapped is a potential fuel. According to a report by the International Seabed Authority, *"If recovery techniques are perfected, estimated reserves could satisfy the needs of the world, for centuries."*

The words, "...*if recovery techniques are perfected...*" are crucial. Most of the world's reserves are sequestered in the deep ocean, presenting great challenges for commercial production. When broken, chunks of methane hydrate float upward. Higher temperatures and lower pressures decompose them, releasing Methane gas into the ocean.

Methane is a greenhouse gas that traps heat about 20 times more effectively than Carbon dioxide. The trapped heat warms the atmosphere. Within limits, this is a desirable natural phenomenon. However, suddenly "thawed" methane hydrate can catastrophically release huge amounts of methane into the atmosphere-accelerating the process of global warming.

There is also evidence that pockets of methane gas trapped beneath sediments have exploded to form "mud volcanoes," or may have triggered seafloor avalanches and tsunami waves.

So, companies interested in tapping this untouched reserve of natural gas must find ways to 'stabilize' it before transporting it to land. Methane hydrate is not uniformly distributed. Many deposits are spread thin over wide areas, making them very difficult to extract economically. The ecological impact of removing the life-sustaining methane gas from unique niches must also be taken into account as complex biological communities may be threatened by such an action.

Evidence suggests that serendipitous discoveries of Cold seeps and methane hydrate deposits are just the tip of an iceberg—much more remains undiscovered. However, it is clear that these play an important role in regulating ocean chemistry, sustaining marine life, and shaping seafloor geology.

Placer Deposits

Placer deposits, as the name indicates, are natural concentration of minerals 'placed' when minerals are freed by the process of erosion and washed down-slope into streams. The lighter matrix floats away in the water but the heavy minerals 'lag behind' and settle down. Over time, workable ore deposits are deposited.

Placer deposits

Two types of minerals form placers: The first are minerals that are more resistant to chemical and mechanical erosion. These are termed resistate minerals. The other type includes minerals that have high specific gravity. These are, rather unimaginatively, called heavy minerals. The minerals which are both resistates and heavy are the ones that turn up most frequently as placer deposits. This is the why gold and magnetite are common in placers.

How well the minerals will be 'placed' depends on its "settling rate." Settling rate determines just how concentrated the deposit will be. The settling rate depends on the grain size, grain shape, specific gravity, surface roughness and electrostatic charge. Larger grains, because they are heavier, settle faster than small ones. Thin, flat grains (such as flakes of gold) are washed away faster by the currents as compared to rounded gold nuggets.

Waves winnow away light minerals on the beaches and leave the heavy minerals behind. As each wave retreats, it washes light minerals back towards the ocean. As a result, heavy minerals, along with larger pebbles lag behind. These "lag deposits" form a linear band, parallel to the shoreline. If the land under these lag deposits subside, the deposits are submerged beneath the water, giving rise to offshore placer deposits.

Minerals that form placer deposits have high specific gravity, are chemically resistant to weathering, and are durable. Such minerals include gold, platinum, copper, cassiterite (tin oxide), magnetite (iron oxide), chromite (chromium oxide), ilmenite (iron-titanium oxide), rutile (titanium oxide), zircon, monazite, and precious gemstones such as diamonds and sapphires. Heavy-mineral concentrates known as black sands occur along the Kerala beaches.

Till recently, these solid deposits of minerals originating from the weathering of rocks on continents and washed down

to the seas primarily by rivers were commercially exploited. This is because such deposits were found in relatively shallow offshore areas. Sometimes, the marine placer deposits turned out to be quite valuable additions to the natural resources found on land. Till about the 1990s for example, offshore placer deposits of gold were mined intermittently in Alaska. Tin was mined off the coasts of Thailand, Indonesia and Myanmar. Diamonds are found off Namibia and South Africa in waters about 200m deep and about 100 km from the shore.

Exclusive Economic Zone

Under the United Nations Convention on Law of the Sea the Exclusive Economic Zone or EEZ is that portion of the oceans extending up to 200 nautical miles (about 370 km) in which coastal States have the right to explore and exploit natural resources as well as to exercise jurisdiction over marine science research and environmental protection. India thus has an EEZ of about 2.172-million square km all along its 7500 km long coastline.

The Chinese government has lodged the first application to mine for minerals under the seabed in international waters with the International seabed Authority. They are interested in mining a ridge in the Indian Ocean 1700 m below the surface and hoping to recover not only valuable metals such as gold and silver but also, copper, nickel and cobalt, which are used to manufacture mobile phones, laptops and batteries. They are also interested in the Sulphide deposits underwater.

The implications of large-scale mining of the ocean bottom have set alarm bells ringing in environment circles. Some have pointed out that any 'mistake' at such depths may not be easy to set right. Others have expressed concerns about disturbing established ecosystems we know little about. They have argued that plumes of sediment could perhaps block out light over large areas. This would hamper plankton growth triggering a

backlash on global climate too, not just the filter-feeding marine organisms that feed on plankton. In short, the world is poised on the brink of a decisive moment and the choice made now may well determine the course of destiny. Environmentalist and author, Charles Clover put it succinctly when he said, *"....At the mouths of these hydrothermal vents are some of the world's richest but least-known ecosystems, and the potential for conflict between commerce and conservation is huge."*

Richard Harrington of the Marine Conservation Society, UK has summed up the global concern about the long-term implications extremely well. *"Deep sea mining would take ... damage to a new level in the wider oceans. Conditions at this depth are normally very stable, and any mining damage would impact the environment for a very long time."*

9. ENERGY FROM THE WAVES

The story is about a little wave, bobbing along in the ocean, having a grand old time. He's enjoying the wind and the fresh air-until he notices the other waves in front of him, crashing against the shore. "My God, this is terrible," the wave says. "Look what's going to happen to me!"

Then along comes another wave. It sees the first wave, looking grim, and it says to him, "Why do you look so sad?"

The first wave says, "You don't understand! We're all going to crash! All of us waves are going to be nothing! Isn't it terrible?"

The second wave says, "No, you don't understand. You're not a wave; you're part of the ocean."

— Morrie Schwartz

The Oceans are restless. Even a casual observer cannot fail to be impressed by the relentless crashing of the waves on the shore. One cannot fail to marvel at the tremendous energy of the ocean waves.

The ancients were also awed when they saw the ruffled surface of the oceans and the enormous energy of the waves. In an attempt to explain the phenomenon, they spun a beautiful story. They said that the Creator reached down from the heavens to wash his mud-soiled hands after having fashioned the universe. The movements of the divine hands as the palms rubbed against each other led to the formation of waves...which still have not subsided. The modern explanation is not so beautiful; it is rather matter of fact. It says that waves are caused by the wind blowing over the surface of the ocean.

Waves and Rogue Waves

Waves may be gentle ripples. They may also be huge as when generated by massive chunks of ice breaking off and falling into the water or when a hurricane whips up the sea. Waves of colossal proportions are sometimes generated when an undersea earthquake triggers a tsunami. Coastal landslides can produce catastrophic tidal waves. And then, there are those waves that are often described as a “*wall of water*.” More commonly known as rogue waves, these arise seemingly out of nowhere. A rogue wave towers over the other waves occurring in the area at the time. The terms freak waves, monster waves, killer waves, abnormal waves and extreme waves sum up the sailor’s perception of these waves.

Interestingly, the ancient mariners had often described menacingly monstrous waves up to 30 m in height (approximately the height of a 10-storey building) – that appeared without warning in mid-ocean, often in perfectly clear weather. By all accounts, these waves moved against the prevailing current and wave directions. They described the waves as “*an almost vertical wall of water*” preceded by a deep trough that looked like a “*hole in the sea*.” A ship encountering such a wave had little chance of outrunning it and even less chance of surviving its onslaught.

The common man has a love-hate relationship with waves. We love to swim or float serenely in the gentle arms of the sea. We love to sail yachts, race boats and cruise on ocean liners. We love to use the ocean currents as highways to transport a multitude of products. We love sitting on the beach or walking barefoot on the warm sands. However, the brute power of the waves is awesome indeed. When these waves crash inland as a towering tsunami or when they are funneled up by a tornado; we have reason to fear them.

Scientists, on the other hand, view the waves as potential energy-generators for mankind’s escalating needs. They feel

that the energy latent in the waves just need to be tapped properly to generate clean power.

Energy from the Oceans

Two types of energy can be produced from the oceans: thermal energy from the sun's heat, and mechanical energy from the tides and waves.

The devices that harvest power from the waves can be installed in near-shore, offshore, or on far offshore locations. Wave energy technologies differ in their orientation to the waves with which they interact. They also differ in the manner in which they convert the energy of the waves into other energy forms, usually electricity. Many technologies have been devised to capture the energy from waves and some are even being tested at commercial scales.

Generating Power

The wave energy converters are devices that change wave energy into electricity. Those devices that extend in a perpendicular direction to the direction of the waves are called *terminator devices*. These devices are usually installed onshore or near-shore; although offshore floating versions have also been designed. The terminators have two components: a stationary component fixed to the sea floor and another component that moves in response to the wave. The moving component acts like a piston to drive a turbine. For example, the oscillating water column is a form of terminator in which water enters through a subsurface opening into a chamber with air trapped above it. The wave action causes the captured water column to move up and down like a piston to force the air through an opening connected to a turbine. The overtopping device is another terminator device. It includes a wall that collects the water from rising waves in a reservoir. The water is allowed to escape through an opening. In doing so it drives a turbine.

Attenuators are devices that are oriented parallel to the direction of the wave. The differing heights of waves along the long multi-segment floating structures cause flexing where the segments connect. This flexing is connected to hydraulic pumps or other converters.

A *point absorber* is a floating structure with components that move relative to each other due to wave action. The relative motion is used to drive electromechanical or hydraulic energy converters. These devices are not oriented a particular way toward the waves, but can “absorb” the energy from waves.

Specially built seagoing vessels have been built to capture the energy of offshore waves. These floating platforms funnel waves through internal turbines to generate electricity. The waves are then released back into the sea.

Motion-dependent Systems

Ocean wave energy can be captured from pressure fluctuations below the surface too. Especially designed wave power systems convert the motion of the waves into usable mechanical energy which then can be used to generate electricity.

Float or Buoy Systems can use the rise and fall of ocean swells to drive hydraulic pumps. The object can be mounted to a floating raft or to a device fixed on the ocean bed. The series of anchored buoys rise and fall with the wave and this movement is used to run an electrical generator. The electricity produced is transmitted ashore by underwater power cables.

Oscillating Water Column devices are those in which the in-and-out motion of waves at the shore enters a column and forces air to turn a turbine. The column fills with water as the wave rises and it empties as the wave descends. In the process, air inside the column is compressed and it heats up, creating energy which is transmitted ashore by electrical cable.

Tapered Channels rely on a shore-mounted structure to drive the waves into an elevated reservoir. Water flow out of this

reservoir is used to generate electricity using standard hydropower technologies.

Artificial Anaconda

A report that appeared in the May 2009 issue of the *New Scientist* describes an unusually innovative way of generating electricity from the waves. The device is a “rubber snake” filled with freshwater (to deter sea creatures from feeling at home inside the tube) and sealed at both ends to create a semi-rigid balloon that floats on the sea surface. The ‘artificial anaconda’ is anchored at one end. Waves exert pressure on the snake all along its length. This force is transmitted by the water inside the tube. This forces the artificial anaconda’s walls to expand outwards into the wave troughs where they are under less pressure. This creates “*bulge waves*” that travel along the anaconda’s length. When each bulge wave reaches the end of the snake it helps keep a turbine spinning to generate electricity.

Other than the turbine, Anaconda has no moving parts and unlike other wave power devices it needs only one tether to the ocean floor. That lowers construction costs and reduces the need for maintenance. Des Crampton, CEO of Checkmate Seaenergy, the firm commercializing the anaconda wave harvester, says an anaconda 200 m long could generate enough energy to power 1000 average homes. “*Anaconda captures more energy than all existing wave energy devices,*” he affirms.

Work on the concept began in 2007, the first full-size anacondas are expected to become operational in 2014.

Wave-energy feeding electrical grid

The Pelamis Wave Power Company was founded in 1998 by Dr. Richard Yemm, Dr. Dave Pizer and Dr. Chris Retzler. It has created innovative systems to generate renewable electricity from ocean waves; for example, the Pelamis Wave Energy

Converter. This is a technology that uses the motion of ocean surface waves to create electricity. The Pelamis Wave Energy Converter is made up of connected sections which flex and bend as waves pass; it is this motion which is used to generate electricity. According to the company's website (<http://www.pelamiswave.com/>) it is best described as, " .. a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints. The wave-induced motion of these joints is resisted by hydraulic rams, which pump high-pressure fluid through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all the joints is fed down a single umbilical cable to a junction on the sea bed. Several devices can be connected together and linked to shore through a single seabed cable."

Pelamis wave energy converter.

Pelamis was the world's first wave machine to generate electricity from offshore wave energy, and to deliver it to an established grid. It reached this milestone when it was connected

to the UK grid in 2004. The first generation or P1 machines were tested off the coast of Portugal in 2009. The second generation or the P2 machines started tests off Orkney islands in 2010. Roger Bright, Chief Executive, The Crown Estate, UK, announced, “... *Pelamis Wave Power ... to develop 50MW of wave energy power in Pentland Firth and Orkney Waters, the world’s first commercial wave and tidal leasing round....The 1.2GW of installed capacity proposed by the wave and tidal energy developers for 2020 shows the world that marine energy can produce meaningful amounts of electricity and offers a real alternative to conventional power production.*”

Harvesting Tidal Energy

Tides are the periodic rise and fall of the ocean’s waters. The periodic movement of large amounts of water represents untapped potential for the generation of energy. It has been suggested that energy can be generated from tides by creating a reservoir behind a barrage and then passing tidal waters through turbines in the barrage. The ebb and flow of the tides can be used to turn a turbine, or it can be used to push air through a pipe, which then turns a turbine. However, power is actually generated only when the tide is actually moving in or out, maybe for about 10 hours/day or so.

The Gulf of Cambay, Gulf of Kutch and the Sunderbans are attractive locations for generating energy from the waves.

Unfortunately, there are only limited sites where the tidal difference is greater than 4 meters, a necessary requirement. So, currently it appears that harvesting of tidal energy will only have limited application.

Drawbacks of Wave-energy Generating Technologies

Although technologies to generate power from the waves work well enough; the problem is that not all countries with

ocean-access can harvest wave power because the nature of the waves varies considerably from site to site. Wave-power rich areas of the world include the western coasts of Scotland, northern Canada, southern Africa, Australia, and the northwestern coasts of the United States.

Also, there are ecological considerations as construction of barrages affects ecosystems. For example, barrages affect fish migration. Fish such as salmon may swim up to the barrages only to die in the spinning turbines. Ecological damage may also occur due to accidental leakage of hydraulic fluids. Turbines generate noise. Generation of noise, both above and below the water surface may affect animals, particularly those that rely on echo-location.

Barrages may also affect the tidal levels, which in turn may affect navigation. Those who enjoy yachting or fishing also have reservations about the building of barrages which they view as impediments to their sporting pursuits.

The inherent problems in setting up these devices are the need for a suitable site, where waves are consistently strong. The systems have to be extremely robust to withstand conditions at sea. These also represent a possible collision threat for sea-faring vessels. Overhead transmission sights are 'eyesores' ruining the viewing pleasure of the tourists.

Ocean Thermal Energy Conversion

Ocean Thermal Energy Conversion (OTEC) aims to turn the solar energy trapped by the ocean into useable energy. OTEC systems use the ocean's natural thermal gradient that develops because the Sun's rays cannot penetrate, and thus heat up, the deeper layers of the water. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C, year-round, an OTEC system can produce a significant amount of power.

There are three types of OTEC processes.

Closed-cycle system: Here the heat transferred from the warm surface sea water is used to turn a working fluid into vapour. The expanding vapour drives a turbine attached to a generator. This produces electricity. Cold sea water passing through a condenser containing the vapour turns it into a liquid again, which is reused for the next cycle.

Open-cycle system: The warm surface water serves as the working fluid. It is vaporized in a near-vacuum at surface water temperatures. The expanding vapour drives a turbine attached to a generator, which produces electricity. The vapour is condensed back into a liquid by exposure to cold deep ocean water. The 'condensed vapour' gives fresh water that is good enough to drink. However, not all condensers keep the condensed vapour isolated from contact with salt water. A "direct contact" condenser, for example, produces more electricity, but the vapour is mixed with cold sea water and the discharged water is salty. It is returned to the ocean. It is a difficult choice indeed—having to choose between a system that has relatively lower yield of electricity but gives potable water as a by-product and a system which gives a higher electricity output.

Hybrid system: This uses parts of both open- and closed-cycle systems to optimize production of electricity and fresh water.

The OTEC concept owes its genesis to Georges Claude, a Frenchman who in 1930, designed and tested an OTEC plant. His patented invention generated 22 kilowatts of power. However, it consumed more than the amount it generated, partly because of the poor site choice in Cuba. His next attempt; a floating plant off Brazil, was damaged by a storm. The unfortunate inventor died almost bankrupt from his OTEC efforts.

In time, however, scientists have come to hold the view that Claude's concept was a sound one. "*OTEC is not affected by tides and waves. The solar energy stored in the seas is always available. Better yet, that 'fuel' is free as long as the sun hits the ocean,*" says Luis Vega, Director of the Kailua-Kona OTEC demonstration project at Hawaii.

Drawbacks to the OTEC system

Electricity produced by the OTEC system is more expensive than the electricity produced by currently used conventional methods using fossil fuels. The ecological concerns remain as construction of OTEC plants/pipes may cause damage to marine ecosystems. However, as technology advances, perhaps we can minimize damage to ecosystems and yet generate enough clean power to meet surging energy needs.

OTEC

Generation of electricity from the waves, which seemed a utopian idea not many decades back is slowly and surely emerging as a viable opportunity for sourcing clean energy. Wind energy is already a significant contributor in some countries. Wave energy therefore, ought not to lag behind because it is essentially just stored and concentrated wind energy. According to one estimate, Wave energy could play a major part in the world's efforts to combat climate change, potentially displacing 1 – 2 billion tonnes of CO₂ per annum from conventional fossil fuel generating sources.

Richard George Erskine, Director of Technology Ventures, has pointed out that, *“Fifteen years ago, who would have thought Europe would be producing 20,000 megawatts of the power it consumes from wind?...Maybe in 10 years time, wave power will also be a major energy supply source...A combination of technological improvements to make production less expensive and international incentives, like green certificates (the guaranteed sale of power based on renewables), can make this all very interesting.”*

Perhaps what we need is a new perspective when we look at the oceans, As Mariette DiChristina, Editor-in-chief, *Scientific American* rightly says, *“The world's largest solar collector absorbs an awesome amount of the sun's energy: equal to 37 trillion kilowatts annually - or 4,000 times the amount of electricity used by all humans on the planet. A typical square mile of that collector - otherwise known as the surface waters of Earth's vast oceans - contains more energy than 7,000 barrels of oil.”*

Once you look at the oceans like that, all vestiges of doubt about its powers to generate electricity vanish. What remains is our belief that we desperately need to do so!

10. ONE EARTH FOR ALL

When one tugs at a single thing in nature, he finds that it is attached to the rest of the world.

John Muir

The waters stretch blue and sparkling, till at the far end of vision the blue horizon merges with it, engendering the illusion of limitlessness. It is in these waters that lie the seed of natural phenomena such as hurricanes, cyclones and tsunamis that cause widespread destruction and lead to great human suffering. The other side of the coin is that these waters also bear the brunt of human folly and short-sightedness, as when the sea is treated as a dump or an open sewer.

Dirty beyond Belief

An African Proverb says, “*Filthy water cannot be washed.*” Yet oblivious to the wisdom contained in this, we continue to use the seawater as a “dump.” According to the environmental agency Greenpeace, domestic sewage, industrial discharges, urban and industrial run-off, accidents, spillage, explosions, sea dumping operations, oil sludge, mining, fertilizers, pesticides, waste heat sources, and radioactive discharges all contribute significantly to marine pollution. Metals such as mercury, copper, cadmium, selenium, lead and metalloids, such as arsenic, also contribute to the pollution load. Almost 80 per cent of pollutants contaminating the coastal waters and the deep oceans originate from the land.

Bird fouled with oil

However, pollutants and debris are also dumped in the sea from various sources such as wastes generated by offshore minerals and petroleum exploration & extraction. Cargo ships that wash out tanks or tankers that collide spectacularly, spilling gallons of oil are culprits too. However, despite the massive media coverage of oil spills upon marine environments the total quantities involved are given stiff competition by pollutants introduced from other sources.

Panel of Pollutants

Marine Debris

Most people think that marine debris is the junk they encounter on beaches-plastic bottles and such like. It is much more! Debris

is found throughout the marine environment. Coastal waters to the deep ocean; sea surface down to the benthos-no part of the sea is pollution free. Terms such as the 'Trash Vortex,' 'Asian Trash Trail' or 'Eastern Garbage Patch' have been used to describe the North Pacific sub-tropical gyre in the Pacific Ocean, where the waters describe a slow clockwise spiral.

An area, the size of Texas, USA, in the gyre just cannot be described in any other words. It is full of trash discarded by people worldwide. There is an estimated six kilos of plastic material for every kilo of plankton that still survives here. Some of the debris here was directly discharged in the sea but much of it is transported here by rivers, rain, wind, and sewer pipelines. The currents force the debris into the central area of the gyre where they remain, slowly spiralling, till they break up and sink.

So great has the problem of marine debris become that international conferences are being held to address the problem. The annual International Conference of Marine Debris aims to "...provide a forum for sharing research results, innovative approaches and challenges from around the globe, and equip participants to develop and implement locally relevant solutions to the impacts of marine debris....with all paths leading to the shared goal of moving forward, globally and locally, in combating the economic and environmental impacts of marine debris." It is high time indeed!

A Plague of Plastic

Plastic is an almost indestructible pollutant...be it on land or in the seas. This is because plastics are not normally broken down by the microbial decomposers of Mother Nature. Sunlight can only weaken and break down plastic; a process called photo-degradation. Photo-degradation is easy to spot at home in the plastic clotheslines that first fray, and then crumble, in the Sun. A similar process happens to the plastic debris at sea. It is broken into smaller and smaller pieces, finally forming what are called mermaid's tears or nurgles. However, plastic is not re-absorbed and recycled by natural ecosystems but have

the potential to persist for hundreds of years. Plastic debris dominates coastal marine debris because stuff thrown away on land, and those discarded at sea, converge at the interface of the land and the sea. According to one report, marine debris ranges from 4 to more than 48,000 items per km of shoreline.

Plastic-ocean-trash

The problem of plastic is not just one of plenty. That by itself might have been a manageable problem. The trouble is that discarded plastic stuff kills wildlife. For example, turtles mistake transparent plastic carry bags for jelly fish that they eat. Seabirds pick up plastic pellets and feed these to chicks, obviously unable to understand that these are inedible, even toxic. Animals become fatally entangled in plastic netting and lines. Marine mammals unable to surface will drown. A closeup of the Trash Vortex reveals many carcasses of marine birds and mammals and also, dead fish. Greenpeace estimates that over a million sea-birds and one hundred thousand marine mammals and turtles die annually because they have ingested plastics or become entangled in the choking debris.

Not all plastic floats, about 70% of the discarded plastic sinks to the sea floor. Dutch scientists surveying the North Sea bottom found 600,000 tonnes of it...smothering all the marine life underneath.

Plastic debris also acts as rafts transporting plants and animals to regions outside their normal range, where these species often become a nuisance.

Cauldron of Chemicals

The seas are increasingly becoming the final custodians of chemicals that are released on land. Be it chemicals intentionally dumped via industrial effluents or run-off from land, the seas are the final destination, often with tragic consequences.

The echoes of the tragedy that was enacted at the Japanese town of Minamata in the mid 1950s no longer resound in the general consciousness of the people. However, it taught mankind a lesson in environmental consciousness and must never be forgotten. Also must not be forgotten the pain and suffering of those who were directly affected.

Minamata was the first incident of mercury poisoning by food chain contamination on a large scale. It all began when a company that made fertilizers began to discharge the wastewater containing mercury into the bay without proper treatment. Microbial action turns mercury to methyl mercury a nerve toxin that builds up in the body. In the early days no one paid any attention to this possibility. Some of those who knew, kept silent; the few who spoke out were ignored.

By the early 1950s, dead fish were floating in the waters of the bay. Cats that ate the fish began to show tremors which

looked like a grotesque form of dance. Birds dropped dead from the skies. The dancing cats of Minamata hit the headlines. But people continued to fish in the bay. Then the true horror struck home...between 1953 and 1956, people started living terrible symptoms. They suffered convulsions, tunnel vision, blindness, madness and terrible pain. Children born to affected parents were affected too—many still live in pain, fifty years after the tragedy unfolded.

The words of Tsuginori Hamamoto, a former fisherman who was affected and later, a protest leader once said, *“If only I may live long enough to get out into the world, using my own body as an example, and demonstrate to everyone...what our Planet Earth would come to if we don’t stop industrial pollution and the decimation of our waters and air...but I fear I may crumble at any moment.”* It is a poignant statement, steeped in pain—something no human need repeat if only we pay heed to the message.

Today, Minamata city holds the Minamata disease victims memorial service annually on 1st May, *“to offer comfort to the souls sacrificed to Minamata disease, reflect on the environmental damage..., and to pledge commitment to environmental reconstruction.”*

Pollution of global waters continues unabated everywhere in the world, though. The results hit headlines with unfailing regularity. For example, it has been reported that in 2009, enormous amounts of Sea lettuce washed up on the beaches of Brittany, France. As the blades decayed, hydrogen sulphide, a toxic gas that smells of rotten eggs was given off. The stench was enough to cause a rider to lose consciousness and for his horse to succumb. A lorry driver who had worked without protective gear and transported three lorry loads of the rotting algae died at the wheels when his lorry crashed into a wall. Initially, it was thought that he had suffered a heart attack.

However, now there is growing suspicion that he might have been the first human victim of the noxious gas.

Minamata memorial

Apparently, the reason behind the explosive growth of the sea lettuce was excessive use of nitrates by pig and poultry farmers and the runoff of these chemicals into the sea. The torrent of nutrients led to 'blooms' of marine plants, some of which landed on the beach.

When too many nutrients are released into seas, bays, and estuaries, it can create an overabundance of plants and animals. These use up a major chunk of the available oxygen. When these die, the process of rotting further depletes the waters of oxygen. These nutrient-rich, oxygen-poor waters become dead zones, driving animals to migrate elsewhere or die. These dead zones in the seas can linger for months and show up in satellite images as black spots. Scientists believe that this may be the greatest threat to the health of the marine environment.

Another emerging problem is that of pharmaceutical products being flushed out into the sea and being taken up by marine creatures with undesirable consequences. For example, antidepressant drugs excreted by the body, and flushed into the waters, are altering shrimp behaviour and making them easier prey. Apparently, fluoxetine, a key ingredient of the sunshine pill prozac and sarafem somehow encourage shrimps to seek out well-lit waters instead of retiring to dark and safe corners. Bright light makes the shrimps more visible to predators and may compromise their safety. It is thought that fluoxetine makes the shrimp's nerves more sensitive to the mood-altering and sleep-influencing brain chemical serotonin.

In Tromsø, Norway, highly elevated levels of caffeine have been found in seawater...and in the animals recovered from there. We still do not know what a caffeine kick can do to the animals.

Most pharmaceutical and personal care compounds enter the water when people excrete them or wash them away during baths. Some are flushed or washed down the drain when outdated or unused drugs are discarded. Ecologists surveying waters around water treatment plants have already reported contraceptives, synthetic musk, painkillers and anti-inflammatory medicines. The fear that many other prescription drugs, particularly may also be inducing changes in aquatic

wildlife is not misplaced. These have been given the name emerging contaminants. Obviously, tighter drug disposal rules and more advanced technology for breaking down pharmaceutical products in sewage treatment plants are needed.

Sewage Savagery

Microbial decomposers can handle sewage or organic wastes...in limited amounts. In the past, undiluted sewage was dumped at sea without apology. In those good old days, the question of pollution was answered with a simple line: "...*the solution to pollution is dilution.*" And it seemed to work...the marine waters diluted the effluents and the microbes chomped away, with apparently negligible consequences for the ecosystem. What no one seemed to have noticed was that the volume of sewage was increasing in an explosive manner and yet, we kept up with the discharge. We soon overran the more-than-modest capacity of the oceans to diffuse the noxious nature of our wastes. The oceans began to turn into a gutter. Even today with better sewage treatment plants enough is dumped into the oceans to cause concern.

Radioactive waste

There are standard procedures for disposal of radioactive wastes. However, that these safeguards are not enough was demonstrated when in 1983, contaminated seaweeds washed up at Sellafield. The danger was enough to warrant closing large stretches of the beach. The other danger of disposing radioactive wastes in the oceans is the contamination of the marine food chain.

Greenpeace has been campaigning against the disposal of radioactive waste into the oceans since 1978, when it drew the world's attention to the routine practice of dumping radioactive waste from ships into the sea. It took fifteen long years for the international community to ban sea dumping of radioactive waste from ships.

Acidification of the Sea waters

Burning fossil fuel such as oil and coal releases carbon di oxide into the atmosphere. Carbon di oxide and methane are greenhouse gases that trap the Sun's heat and keep the atmosphere warm for us. However, too high a level of these gases can cause more of the Sun's heat to remain trapped; resulting in global warming. The carbon di oxide dissolves in the sea waters to produce carbonic acid; lowering the pH of the waters. A pH lower than 7 indicates an acidic solution.

As industrialization progressed, so did emissions of greenhouse gases. The oceans dissolved increasingly greater amounts of carbon di oxide. Today, the oceans are removing approximately 30–50 per cent all the carbon di oxide emitted.

Scientists have warned that the rise in carbon dioxide emission is whipping up a dangerous change in the chemistry of the oceans. At current rate of emissions, it is estimated that the *pH* of marine waters will fall by 0.4 units by 2100, which is more than what corals and other creatures can stand. This is actually a three-fold increase of the mean acidity of the ocean: something that has never happened in the past 20 million years. Of course, it will have far-reaching consequences. Any major die-off of marine species will affect all that depend on them for food. Human beings, as top predators cannot hope to escape unscathed, particularly from the backlash of a changed biology on Earth.

A recent research paper in the journal *Trends in Ecology and Evolution* calls ocean acidification, the “*evil twin of global warming*.” Prof. Ove Hoegh-Guldberg, ARC Centre of Excellence for Coral Reef Studies and the University of Queensland, Australia, who is one of the authors has gone on record that “*Evidence gathered by scientists around the world over the last few years suggests that ocean acidification could represent an equal – or perhaps even greater threat – to the biology of our planet than global warming.*”

The truth which we ignore is that marine food webs decrease atmospheric carbon dioxide through a “biological pump.” The cycle begins with the phytoplankton taking up carbon dioxide during photosynthesis. More the phytoplankton; more the carbon dioxide used up. Some estimate that phytoplankton consume carbon dioxide on a scale equivalent to forests. The carbon in phytoplankton enters the marine food webs when the phytoplankton is eaten by tiny zooplankton. The zooplankton is eaten, in turn, by other animals; some of which are deep divers whose carcasses sink to the ocean floor when they die. In addition, the carbon also moves downward with the sinking of faecal pellets and locked in the calcium carbonate shells of small marine creatures. Worldwide, this “biological carbon pump” transfers about 10 gigatonnes of carbon from the atmosphere to the deep ocean each year. Without the biological pump, there would be more carbon dioxide in the atmosphere and probably, faster global warming.

The ill-effects of acidification may not be easily evident to the casual tourist. But the creatures that live in the waters would have related their woe, readily enough, if they could. Scientists, such as Prof. Ove Hoegh-Guldberg, fear that acidification of waters will weaken calcium carbonate shells or skeletons making the animals more susceptible to predation and damage. Seasnails, corals and shellfish are all at risk.

If the waters become markedly acidic, certain plankton species may be unable to adjust. Plankton is the starting point of many food chains. If plankton disappears, the food chain will collapse; leading to the plummeting of populations of larger species. These are consequences in the foreseeable future; what will actually come to pass may be beyond our worst nightmare.

Oil spills

Oil spills are common during oil explorations and at drilling sites. These are routine when barrels or ship-holds are washed

out at sea. Oil spills at port terminals are a frequent phenomenon too not to mention tanker accidents such as the one involving the *Exxon Valdez* in 1989 or the August 2010 collision between the MSC *Chitra* and the *Khalijia*.at Mumbai.

Worse accidents such as the Deepwater Horizon oil spill in 2010 have wiped the *Exxon Valdez* case from public consciousness. The *Exxon Valdez* accident was environmentally disastrous. It spilled enough oil to fill 125 Olympic-sized swimming pools and led to an oil slick about 6700 km, causing the deaths of many animals including 350,000 sea otters.

Oil slicks are particularly dangerous for migrating birds because oil slicks look like calm waters, but the feathers of any bird landing in a slick, are coated with oil, which impedes its ability to fly. Even slightly oiled birds may die because they ingest toxins when they preen their feathers. Consuming oil-contaminated prey may kill the predators too. Oil vapours can cause damage to the central nervous system, liver, and lungs. Animals are also at risk from ingesting oil, which can reduce their ability to eat or digest food by damaging the intestinal tract. There can be long-term reproductive problems after having been exposed to oil. Oil spills damage kelp beds and sea grass meadows that are resting and breeding sanctuaries for tiny invertebrates and the larvae of many species of fishes.

Chemical dispersants are sprayed to break up oil slick into oil droplets which can then be broken down by marine bacteria. However, this does more harm than good as dispersants can be quite toxic too.

Some naturally occurring species of soil bacteria and fungi can protect the marine environment by breaking down various types of hydrocarbons, the main component of petroleum. For example, bacteria, such as *Pseudomonas*, *Alcaligenes eutropus*, *Rhodococcus sp.* and *Bacillus sp.* can degrade compounds such as benzene and toluene. Environmental remediation of oil-contaminated wastewater is not an easy task. Sometimes the

oily-water is placed in a large pond-like enclosure and treated with oil-eating bacteria. Such enclosures are called bioremediation lagoons. The process is slow, expensive and not very efficient. Scientists point out that to effectively mop up marine oil spills, the microorganisms must be able to thrive in the salty marine environment, often at icy temperatures. They also point out that because petroleum products contain a mixture of several hydrocarbons any one species of bacteria alone may not be able to degrade it.

After the *Exxon Valdez* accident many contaminated beaches were fertilized to promote growth of microscopic bacteria that eat the hydrocarbons. This method was successful on several beaches where the oil was not too thick.

So, scientists have explored successfully, the idea of creating a “Superbug” that would gobble up oil and literally eat its way through an oil spill. On paper, at least the risk of an uncontrollable microbial population boom is not much: once the oil is eaten up, the microbes will starve.

Ananda Mohan Chakrabarty, a scientist of Indian origin, working in USA, genetically engineered *Pseudomonas* - a microbe that has a voracious appetite for oil, and even patented this newly created life-form. However, fears about an inability to recall it, in case of unforeseen developments, prevented its use in the open seas.

Pollutants not only adversely affect the most productive areas of the marine environment such as: mangroves, salt marshes, sea grass meadows, coral reefs, estuaries and near-shore coastal waters but may also take lives...not necessarily when eaten.

Trawl fishing

Earth, it is said, has enough for everybody's needs but not enough for even a single man's greed. Imagine how ravaged the seas are, because human rapacity has perhaps reached its

nadir when it comes to exploiting the seas. Some trawl nets, which can weigh more than two tonnes, and which are big enough to carry six jumbo jets are used to scoop up everything encountered in the path...never mind the mangled mess this leaves behind. The nets are weighted with metal balls or rollers to ensure that they rake up everything in their path.

Some countries have banned trawl fishing within their exclusive economic zones, but seamounts in international waters are harder to protect. Every year, deep sea trawling ventures into newer areas. It has, for the first time, extended from the Atlantic and Pacific oceans to previously unexploited seamounts on the high seas in the Indian Ocean.

Trawl net

This is bad news for biodiversity, because deep-sea coral communities on seamounts are rich in life. A study reported in *Nature* based on a sample of less than 25 seamounts has reported more than 850 species. This is 42 per cent more than all previously discovered species from all studies of seamounts in the past 125 years. Almost one-third of these species are new to science and are likely to be restricted to the seamount environment. The authors of the study – J. Anthony Koslow, Bertrand Richer de Forges and Gary Poore are clear about the implications of their findings. Koslow says, “*Our findings show that seamounts require localised protection and that this protection must cover both areas within the Exclusive Economic Zone of coastal nations and on the high seas.*”

It is commendable that Australia has established a unique protected area for a group of seamounts south of Tasmania.

It is definitely a trend all nations should follow. Another exemplary development has been the establishment of the Northwest Hawaiian Islands Marine National Monument. It is the largest marine protected area in the world; essential to the preservation of underwater communities and over-fished regions. Only researchers working in the area are permitted to fish, no corals may be removed, and satellite imaging monitors vessels passing through these waters. This is home to an estimated seven thousand species, most of which cannot be found anywhere else in the world. This environmental monument demonstrates the fact that it is possible to create a safe environment for endangered species, as well as maintain some of the world's largest ecosystems in a near- pristine condition.

Deep sea fishing

Over-fishing has depleted many epipelagic and coastal fisheries. So, fish are being sourced from deeper waters than ever before. As much as 40 per cent of the world's fishing grounds are now in waters deeper than 200m. The patagonian toothfish (*Dissostichus eleginoides*) for example, lives at depths below 2,500m in the Southern Ocean. It commands a high enough price to have earned the name of "white gold." Technology, such as echo location, is used to track, and capture, entire schools of fish, resulting in no individuals spared to give rise to the piscine generation next! Are we looking at oceans bereft of fish? The question may have an affirmative answer.

The Aliens are Here

Aliens, in the simplest sense are non-natives. These are also called exotic species, introduced species, nuisance species, non-indigenous species and more graphically, bio invaders. These species that have been either accidentally or intentionally introduced into a new ecosystem often benefit from the absence

of natural enemies or predators in the new environment. As a result, their population grows explosively, often at the expense of native species. Bio invaders often mess up established food webs, introduce new diseases and compete with indigenous organisms for space and food. Hybridization with native species can also bring about changes to the gene pool, reduce genetic diversity and thus, the resilience of an ecosystem to environmental challenges.

Marine plants and animals are introduced to new areas because they often cling to surfaces: boats, ships, even whales end up being unwitting transport! However, an important way in which species jump natural habitats is when they are taken in, along with the ballast water by ships. Port water is home to many different marine organisms. It is estimated that 3,000 alien species are transported every day in ships around the world. Of course, not all exotic species survive to colonize their new home.

Sometimes non –indigenous species, that are being cultured, escape the pens and establish themselves in the new habitats.

Bio-indicator species

A bio-indicator is a living organism whose presence/absence provides a hint about the health of an ecosystem. Some organisms are very sensitive to pollution in their habitat and are wiped out by it. Others change form/physiology even, behaviour. All these serve as an ‘indication’ about the health of the ecosystem. The term ‘bioindicator species’ was coined by German botanists Richard Kolkwitz and Maximilian Marsson. They used it in the context of the impact of organic pollution.

Certain marine species are excellent indicators. The blue mussel (*Mytilus edulis*), Sydney rock oyster (*Saccostrea glomerata*) and the barnacle *Balanus amphitriteis* are bio-indicators for the heavy metal toxins, zinc and cadmium.

The blue mussels, for example, filter food from the water in which they live and so, local contaminants accumulate in their bodies. An analysis of their tissues provides a pointer to the pollutant present and also about its peak concentrations. The US Mussel Watch programme monitors mussels from almost three hundred sites around the US coastline to track trace metals and organic compounds such as polychlorinated biphenyls and dioxins. The programme studies molluscs such as, Smooth-edged jewelbox (*Chama sinuosa*), Pacific oyster (*Crassostrea gigas*), Tropical oyster (*Ostrea sandvicensis*), Eastern oyster (*Crassostrea virginica*), Foolish mussel (*Mytilus trossulus*), Mediterranean mussel (*M. galoprovincialis*), California mussel (*M. californianus*), and Caribbean oyster (*Crassostrea rhizophorae*).

New discoveries, Newer Implications

The more light that is being shed on the inter-relatedness of all life, the more it is becoming clear that we know little about a beautiful tapestry that we are wantonly destroying. The dance of the palolo worms and the whale necropolis are just two examples of the inter-relatedness of life in the oceans. The first case highlights birth and rejuvenation; the second, death and recycling of resources.

Dance of the Palolo worms

Twice a year, with incredible regularity, the palolo worms (*Eunice viridis* and *E. fucata*) that live in coral reefs in the southern Pacific Ocean assemble for what can only be described as a 'reproductive frenzy.' The lower halves of their bodies change drastically becoming laden with the reproductive organs at the expense of the muscles and other internal organs that degenerate. This part then breaks free and armed with a rudimentary 'eye' swims to the surface of the ocean. Here it disintegrates setting free the eggs and sperm. What is incredible is not that the mature worm remains safely inside a tube while releasing a part of its body to carry out the process of

reproduction, but that all the worms do this in a synchronized manner. Swarming and spawning takes place at dawn., the day before or the day after the moon is in its last quarter, at neap tides of October and November. The sea is filled with seething mass of wriggling bits of palolo worm and milky with eggs and sperms. The locals forecast the spawning of the palolo worms three days beforehand...by observing the day land crabs go down to the sea to spawn.

Palolo worm mating frenzy

We still do not know how the crabs decide on a date to spawn and how, the palolo worms follow them so precisely. However, this inability does not deter the locals from relishing the reproductive bits of the Palolo worms; either raw or cooked. And yes, it is quite a tourist attraction too.

Whale necropolis

Another recently discovered sequence of events, albeit on a larger scale is what happens after whales die.

It is estimated that there are about 690,000 skeletons of the nine largest whale species on the sea bed at any given time. Whales are great travellers and swim huge distances, so their

final resting sites are random. Much of the ocean floor is an energy-poor, cold and otherwise hostile environment to most lifeforms. Yet within a short time of the whale carcass hitting the sea floor, animals (some unknown to science) home in on the carcass. They then establish a succession of unique ecosystems, which may survive for decades. The choreography of events that follow a whale fall has only recently begun to be studied; thanks largely to the efforts of scientists such as Craig Smith and T. S. Crispin.

The first discovery was serendipitous when the *Alvin* stumbled over a 20 m long whale skeleton in 1987. Interestingly, at first glance the observers did not realize it was a whale skeleton. They thought it was a dinosaur. Craig Smith and his team revisited the whale-fall next year and discovered several new species and some unusual ones. It triggered a new area of study—that of whale-falls.

Irrespective of the species that died and the place where it settled on the ocean floor, three partially overlapping ecological stages take place.

Mobile Scavenger Stage

Just like vultures eat the carcasses on land, aquatic scavengers such as hagfish, lithodid crabs (a new species of crab found at whale-falls), rat-tails, sleeper sharks, and crustaceans called amphipods converge on the carcass to feast on the flesh. More than 90 percent of the soft tissue is stripped from the carcass within four months. This stage lasts for about nine months but if the whale is a large one, the party can go on for two years.

Enrichment-Opportunistic Stage

This stage is characterized by the establishment of “*high-density, low-diversity communities of animals*.” These animals settle down in the sediments around the carcass and the bones to

chomp on the left-over soft tissues. The whale skeletons may be surrounded for several meters by dense aggregations of hooded shrimps and other crustaceans and polychaete worms. One such “beautiful and bizarre” worm species covers the whale carcass so densely that it looks as if a shag carpet shroud has covered the dead whale. At least two new species have been discovered from these communities and scientists think that these could be “whale-fall specialist” species.

Sulpho-philic Stage

This is the longest-lasting phase and may go on for ten years or more. It begins when the soft-tissue has been eaten away and specialized bacteria that can break down the fats and lipids, even in the absence of free oxygen, enter the picture. The bacteria use dissolved sulphates as their source of oxygen and release hydrogen sulphide as waste. Now, animals cannot directly use hydrogen sulphide as a source of energy; so they strike up a mutually beneficial association with those microbes that can. This is an example of chemo-autotrophism, which means that the organisms derive energy from chemical reactions. Dense bacterial mats, mussels, clams and tube worms dominate this stage. Today more than 400 species associated with whale carcasses have been listed and at least 30 of these have not been found anywhere else.

This makes the ecosystems extremely important from the point of biodiversity conservation. Besides, the genetic resources of these newly-discovered organisms that thrive in such hostile environments could have potential for economic exploitation and commercial applications. For example, an American biotechnology company is exploring the potential of using an enzyme found in bacteria growing on whale bones to develop a cold-water detergent.

According to Julie Z. Russo writing for the National Oceanic and Atmospheric Administration (USA), “*The diversity of species found in these dense populations far outnumber local species richness*

in other extreme deep-sea environments including hydrothermal vents, cold seeps, and manganese nodules. In fact, the population at the whale falls rivals the species-rich rocky intertidal habitat.”

There is no doubt that more light needs to be shed on these unique ecosystems that are no less an important because they are rare. We still do not fully know how the whale-fall specialists—some of which may be so specialized that they rely on dead whales to complete their lifecycle—find their way to the party or even about the dynamics of their thriving populations. However, it is clear that when whales are threatened, so are the specialized ecosystems that depend on their carcasses. Since in nature’s tapestry all threads are woven together, in the long run it may even affect us! Not for nothing is it said, “...ask not for whom the bell tolls, it tolls for thee.

Global Initiatives

It is fortuitous therefore that in 1995, as many as 108 governments and the European Commission declared their commitment to protect and preserve the marine environment from the adverse environmental impacts of land-based activities by adopting the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities and the Washington Declaration.

Today, the United Nations Convention on the Law of the Sea (UNCLOS) obliges governments to, “... take measures to prevent, reduce and control pollution of the marine environment from land-based sources.” Since then the Montreal Declaration 2001 and the Beijing Declaration in 2006 have been signed.

World Oceans Day

Since 2009 June 8 has been officially declared as World Oceans Day by the United Nations. The World Oceans Day provides us with one dedicated day to raise awareness and to build involvement at the personal and community level. Community

participation is encouraged and the message of awareness is disseminated. Beach cleanups, educational programmes, art contests, film festivals, sustainable seafood events etc., are organised across the world. On World Oceans Day we honour the oceans of the world. We celebrate the gifts that the seas provide so bountifully and give thanks for them. The spirit of gratitude encompasses not just tasty seafood but all marine life, including those that we keep as pets in aquaria or train in circuses!

On the first World Oceans Day the Secretary-General of the United Nations gave the following message:

“The first observance of World Oceans Day allows us to highlight the many ways in which oceans contribute to society. It is also an opportunity to recognize the considerable challenges we face in maintaining their capacity to regulate the global climate, supply essential ecosystem services and provide sustainable livelihoods and safe recreation.

Indeed, human activities are taking a terrible toll on the world’s oceans and seas. Vulnerable marine ecosystems, such as corals, and important fisheries are being damaged by over-exploitation, illegal, unreported and unregulated fishing, destructive fishing practices, invasive alien species and marine pollution, especially from land-based sources. Increased sea temperatures, sea-level rise and ocean acidification caused by climate change pose a further threat to marine life, coastal and island communities and national economies.”

However, one cannot but help thinking how much better it would have been if we dedicated 365 days to caring for the oceans worldwide. We better get our act together, because time is running out for the oceans...and us. It is time to pay heed to John L. Culliney’s words *“The Oceans are the planet’s last great living wilderness, man’s only remaining frontier on Earth, and perhaps his last chance to prove himself a rational species.”*

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5. <http://www.mii.org/Minerals/photobromine.html#bckgrnd>
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7. <http://www.allthesea.com/Sea-Exploration.html>
8. <http://www.enchantedlearning.com/subjects/ocean/>

9. <http://www.oceansatlas.org/index.jsp>
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12. http://www.our-energy.com/ocean_energy.html
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14. http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography_currents_1.html
15. <http://www.waterencyclopedia.com/Mi-Oc/Ocean-Currents.html>
16. <http://www.gpa.unep.org/>
17. <http://www.biotecharticles.com/>
18. <http://www.mdpi.com/1660-3397/2/1/39/>

The websites of the following institutions were also repositories of enormous amounts of information used in the book.

1. National Aeronautics and Space Administration, USA (NASA): <http://www.nasa.gov/>
2. Pelamis Wave Power: <http://www.pelamiswave.com/>
3. National Oceanic and Atmospheric Administration: <http://www.noaa.gov/>
4. The Woods Hole Oceanographic Institution: <http://www.whoi.edu/>
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7. Food and Agriculture Organization (FAO): www.fao.org/
8. National Institute of Oceanography(NIO): www.nio.org/
9. Science Daily: <http://www.sciencedaily.com/>

Trivia

- World Oceans Day is on 8th June. It has been formally celebrated worldwide from 2009 onwards.
- Temperature, salinity and depth are the chief barriers to free movement of marine species; not geographical barriers.
- Ninety percent of all volcanic activity occurs in the oceans.
- In 1993, scientists located the largest known concentration of active volcanoes on the sea floor in the South Pacific. This area has 1,133 volcanic cones and sea mounts.
- The highest tides in the world are at the Bay of Fundy, which separates New Brunswick from Nova Scotia. At some times of the year the difference between high and low tide is the equivalent of a three-storey building.
- Earth's longest mountain range is the Mid-Ocean Ridge, which winds from the Arctic Ocean to the Atlantic, skirting Africa, Asia and Australia, and crossing the Pacific to the west coast of North America. It is four times longer than the Andes, Rockies, and the Himalayas combined.
- Although Mount Everest, at 8848m, is often called the tallest mountain on Earth, Mauna Kea, an inactive volcano on the island of Hawaii, is actually taller. Only 4205m of Mauna Kea stands above sea level, yet it is 10,200m tall if measured from the ocean floor to its summit.
- If the ocean's total salt content were dried, it would cover the continents to a depth of 1.5m.
- According to World Register of Marine Species (WoRMS) there are currently 199,146 named marine species.

- The largest coral reef is the Great Barrier reef of Australia that stretches for 2027 km.
- The largest fish is the Whaleshark (*Rhincodon typus*) which grows to 15m; the Basking Shark (*Cetorhinus maximus*) comes second.
- Cuvier's beaked whales (*Ziphius cavirostris*) can dive to depths of nearly 1,900 meters and stay down for 85 minutes. Blainville's beaked whales (*Mesoplodon densirostris*) can dive 1,250 meters for up to 57 minutes.
- Sperm whales (*Physeter macrocephalus*) can dive for more than an hour to depths greater than 1,200 meters, but typically dive for 45 minutes to depths of 600–1,000 meters.
- The sea slug *Atagema osseosa* has the same colour and texture as the sandy sponge on which it lives and feeds. There are also a series of darker markings which look like the waterholes in the sponge. This is called mimicry.
- *Doridella* sp. is a shell-less mollusc that lives on lace corals, or bryozoans. Their white lace-like colour pattern exactly matches the white outline of the bryozoan skeleton.
- The blue whale, *Balaenoptera musculus* is the largest known animal.
- Jewel squids (*Histioteuthis* sp.) have mismatched eyes, one of which is larger than the other to scope for prey in the dark depths.
- Since the chemistry of coral resembles that of human bone, it has been used to replace bone grafts in helping bones to heal nicely.
- Oils from the Orange Roughy (*Hoplostethus atlanticus*) a deep-sea fish are used in making milky lotion, creams, lipsticks, foundations and shampoo. Ambergris from the whale is used in perfumes.

- The luminous crustacean *Cypridina* sp. was conscripted in large numbers during World War II. They were dried and when illumination was needed in a situation where light would have given away position, all the Commanding officer needed to do was to moisten his palm with water and rub a little dried *Cypridina* on his hands. A pale light was given out. Dried *Cypridina* powder retains its luminescent property for up to 30 years...wonder why no one has thought of cloning and mass-marketing these bioluminescent lanterns for our electricity starved metros.
- With no sunlight, there are no plants; all vent life belongs to the animal kingdom.
- Meiofauna are small benthic invertebrates. The term Meiofauna loosely defines a group of organisms by their size. These animals—all less than a millimeter long—live between sand grains. Meiofauna samples in a single bucket of sand, may yield up to 22 phyla. The world's rain forests have 15 to 16 phyla of all kinds of organisms at most.

The seas are mysterious, unpredictable and unforgiving. Yet, the waves speak a language that is hard to resist. Beneath the waters lies a world characterized by paradoxes... a world of incredible colour as well as inky darkness; of incredible swiftness of motion and immense stillness. It is a place where magnificent deposits of minerals await discovery; a place where fire meets ice-cold water as underwater volcanoes erupt and where most inhabitants remain unknown and unnamed.

The author Dr. Sukanya Datta, a scientist by profession through this book takes the readers on a journey deep under the waves and also through time. Along the journey many mysteries are uncovered and many discoveries made. *Marine World traces* the entire saga from how the first oceans were formed and explores realms of the watery world in all its dimensions: geographical, physical, chemical, and biological unfolding, in detail, the secrets of the seas.

The lure of the seas is no doubt irresistible.

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