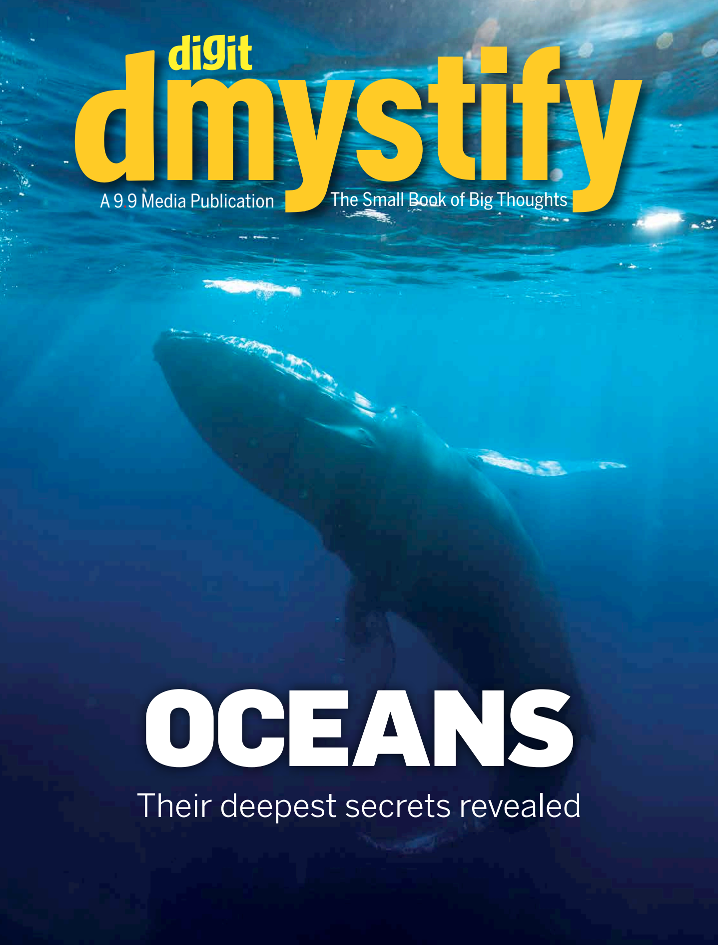

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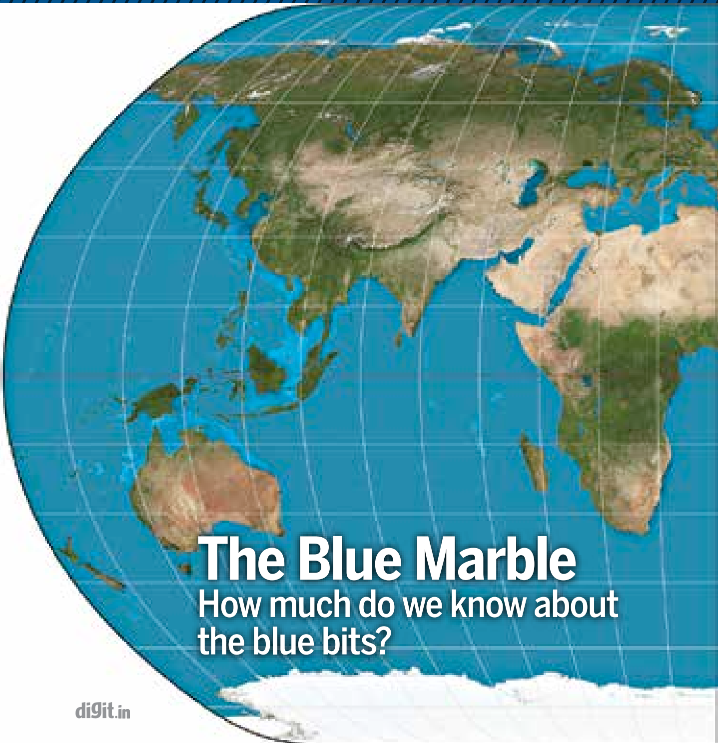
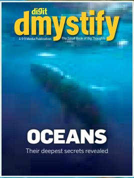


The Blue Marble
How much do we know about the blue bits?

INSIDE



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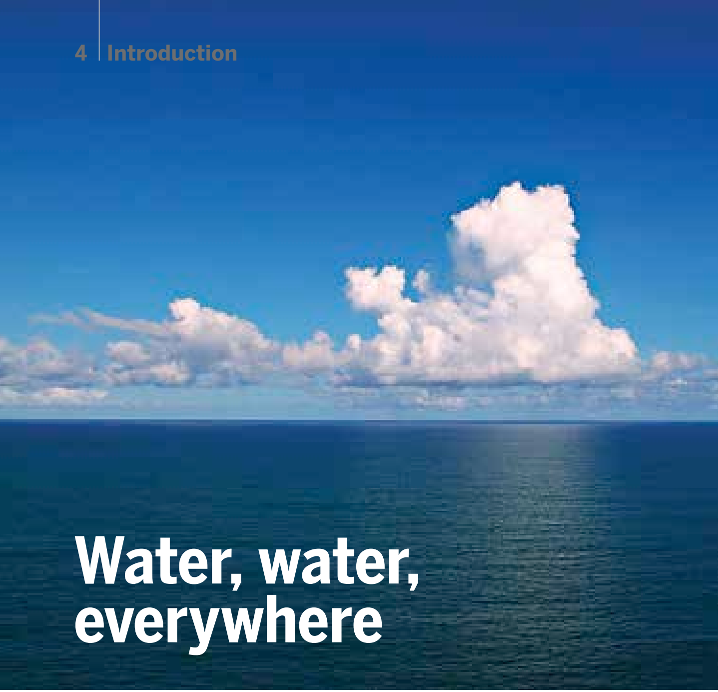


Water, water, everywhere

Well over 70% of our planet is covered by water; we all learn this in school, and it's merely a number to us. Those of us not lucky enough to live near a beach are eventually shocked into understanding when we stand on a beach and look off

into the horizon of blue (or green, depending on where you are and at what time of the year).

Fewer of us still will have the chance to sail the high seas, and reach the realisation of how small and insignificant we humans are, when we look in all directions and see nothing but ocean as far as the eye can see. Humans cannot survive in the largest and most common habitat on this planet!

Apart from a few crazy sailors and surfers, we're all landlubbers (live on land, and can't live on the sea). Some of us know how to swim because we wanted to learn or were forced to. Oceans are considered to be the cradle of life, and where life on this planet began, and yet they are the least explored of all of earth. This is changing, thankfully, and although we only know about 1% of their secrets, that's still enough to fill 10,000 books like this one! ■

History and more

A look at whatever little we know about our oceans

It was Arthur C Clarke, the famous writer, who pointed out the silliness of our planet's name. "Earth" is a terrible name for a planet that's covered by so much water. "Ocean" would have been a far more suitable name for the pale blue dot that is our home amongst all of the cosmos.

Of course, much before we can try and understand the way the oceans are now, we first have to understand where they came from. This little history lesson is going to start at the very start, and that's the beginning of our solar system.

Begin!

Our solar system began about 4.6 billion years ago (best guess), and was first a huge cloud of dust and gas and ice. This was all "star stuff" that had been spewed out by exploding and much older stars that lived fast and died young. Clouds in space don't stay homogeneous for long, and eventually matter starts clumping together because of the miniscule but ever present force of gravity.

Lighter elements were drawn faster into the clumps, and one of the clumps is the one that eventually formed our solar system. The gas cloud that our sun formed from is thought to have been 65 light years in diameter – the closest star to us now is Proxima Centauri, which is a mere 4.25 light years away! Yes, we think the

What the protoplanetary disk that our solar system formed from could look have looked like

Alpha Centauri system was formed from the same gas cloud, as were all of our closest interstellar neighbours.

We, of course, are only interested in our little clumping of gas. As the center of the clumped matter started getting denser, smaller clumps formed. These were the early protoplanets, and there were many more than the current 8 (9?). In fact, it's believed that the early solar system would look more like an asteroid belt than the nice and neat solar system we have now.

Eventually, over millions of years, the lumps would form planetoids and then these would collide with one another, and then those would form a new planetoid. Clumping would occur around the smaller planetoids as well, and these would become moons. Of course, some of our solar system's moons were not formed in orbit around their parent planet, but are thought to have formed independently and then "caught" by the planet that had much more gravitational effect as the moon passed close to it.

The third way in which moons can form is via a giant collision of two bodies that are closer in mass. For example, a planet called Theia is thought to have collided with earth very early in it's history, and this is why the moon formed – from the matter that was ejected into space from the impact of Theia colliding with proto-earth.

Now there are two main theories about how the Earth got all it's water. One is the theory that many of you will know about or have

A collision like the one drawn here could have resulted in the moon

read about already, which is that in the late heavy bombardment period, a lot of comets hit the earth, and brought a lot of water in from space. Eventually the earth would cool and the water in the atmosphere would fall as acid rain.

Not everyone is convinced about this theory though. A more widely accepted theory is that all of the water was merely inside the stuff (as ice) that formed the Earth. All of the dust and gas and ice came together to form the earth, and the water got pushed towards the center, under layers of dust and rocks, and eventually, when the pressure was high enough, it all erupted like water volcanoes and sent steam up into the atmosphere. Then, once the earth was cool enough, the acid rains began, and all of the lower lying areas of the planet were submerged.

The reason the rain is always acid rain is because there was a carbon dioxide rich atmosphere, and that when dissolved in water causes acid rain (carbonic acid). This theory is very hard to prove, but there are some indications of it, given that only zircons seem to survive from a time about 4.4 billion years ago.

Of course, the more balanced theory is that all of the water on earth was built up over millions of years, using both of the methods described before, and also a newer method that's recently been discovered. Apparently life itself could create water. About 2.3 billion years ago, the Great Oxygenation event happened (also called the Oxygen Holocaust), which basically flipped the biosphere of the entire planet on its head. We've found bacteria that produce water as a byproduct of photosynthesis and also use up carbon dioxide and hydrogen sulphide. This is basically the exact makeup of the early earth leading up to the Oxygen Holocaust. Cyanobacteria were busy gassing out oxygen, which would then be trapped in organic matter

Our corner of the blue planet

or react with the iron that was dissolved in the water. Eventually, however, when the cyanobacteria were thriving, and had probably taken over the entire oceans of earth, there was just too much oxygen, and no sinks to capture it, and thus the atmospheric content of oxygen started to rise. It was during this time (between 2.5 and 2.3 billion years ago) that sulfide-dependent chemoautotrophic bacteria could have extracted hydrogen sulfide and carbon dioxide from the earth's atmosphere and water and created even more water as a byproduct. ($CO_2 + 2H_2S \rightarrow CH_2O + H_2O + 2S$). This of course would have accounted for a very small fraction of the earth's water, but it's not thought to be a negligible amount. These three and perhaps other processes we don't know of yet (or might never know) are thought to be the three major ways in which the earth got its oceans.

Ignorance!

The oceans cover about 72 percent of the earth's surface (that's about 360 million square kilometres), and make up about 97 percent of all the water on earth. All of the freshwater lakes, rivers, polar ice caps, groundwater, etc, all make up about 3 measly percent of the water on earth! It's obvious that the oceans are by far the biggest, most awesome thing we see on the planet. With a volume of about 1.38×10^{18} m^3 (about 1.38 billion cubic kilometers), the oceans are much more than large, they're humongous, and yet they're still tiny compared to the size of our planet.

While it's obvious that we're land creatures, and have thus explored land masses much more thoroughly than we have the oceans, it's the scale of our ignorance that is truly staggering. Of all

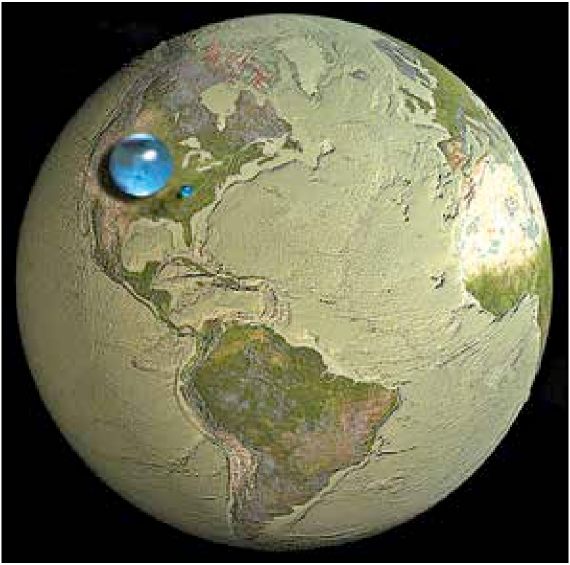


Image Credit: Howard Perlman, US Geological Survey

The earth is pictured here without water; the large blue sphere is all of the water on earth (inside animals, inside plants, in the atmosphere, oceans, lakes, groundwater, etc), the second little blue marble shows all of the groundwater, and the tiny dot is all of the freshwater on the surface in lakes and rivers and the like.

of the oceans, we've probably explored about 10 per cent of them. If we modify the word "explored" to mean how much have we mapped (including ocean floors and depths) and know a great deal about, then that number will probably come down to one or two percent at best. The fact is, we don't know anything about our oceans still, and we're always discovering new life forms and new species, and constantly being reminded of our ignorance.

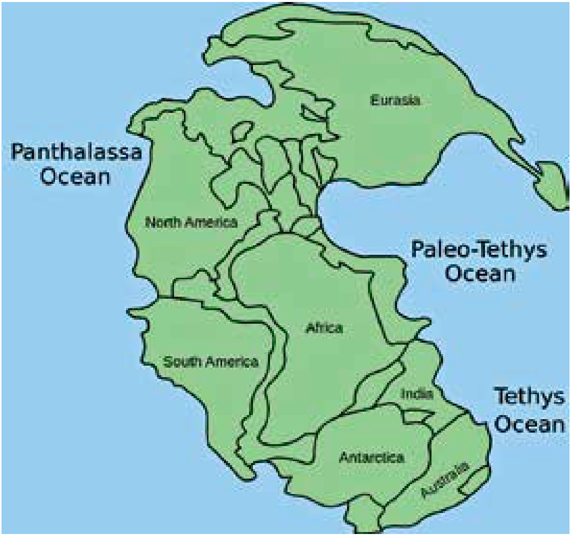
The best way to illustrate how little we know about our oceans, and how useless we are at exploring them (despite all of our modern technology), is to recount the tragedy of MH-370. In case you've lived under a rock and don't know this, MH-370 was a Malaysian Airlines flight from Kuala Lumpur, Malaysia to Beijing, China that suspiciously went missing on March 8, 2014. As of publishing this book, it still has not been found, and although the 239 people aboard it are considered dead, there has been no closure for the family members of those on board. Despite all of the technology at hand, and hundreds of million of dollars spent in the search, the only evidence of the crash has been a few parts that have washed up on Reunion Island (near Mauritius and Madagascar) and on some beaches in east Africa. Basically, the only evidence we have of the crash is what the Indian Ocean returned to us, and not something that we found on our own, because we truly know nothing about our planet's oceans, and our ignorance is humbling.

Ancient oceans

Although our planet looks like it is unchanging, it is. In its 4.4 billion year history, our planet has changed dramatically, and what we recognise as maps of earth have only existed for a few hundred million years. Before that, we might not recognise our own planet if we saw it from space. Most of you would have heard about continental drift, and even read about the history of our continents. Sadly, there's no such thing for oceans, or ocean floors, because of the way plate tectonics happen on earth. Because the continental plates are in constant motion, and are always moving on top of one another, the ocean floors have not remained the same. While quite a lot of land mass has stayed above water from the earliest stages of earth, the ocean floor is different.

Memory is often clearer the more recent the events are, and the history of earth is no different. Scientists are a lot more sure about their theories of the earth 20 million years ago than they are about what happened 200 million years ago. However, they're much more sure about their theory of 400 million years ago than they are about what happened 4 billion years ago... etc. Basically, the further back in time we go, the less sure we are about the accuracy of our predictions – even if those predictions are based on evidence and fact, there are limits to the fidelity of our instruments, which affects how accurate our extrapolations are.

We are pretty sure that there have been cycles of formation and then breaking apart of supercontinents on earth. What this means, of course, is that there were also some pretty major superoceans formed which surrounded ancient supercontinents. In fact, there's



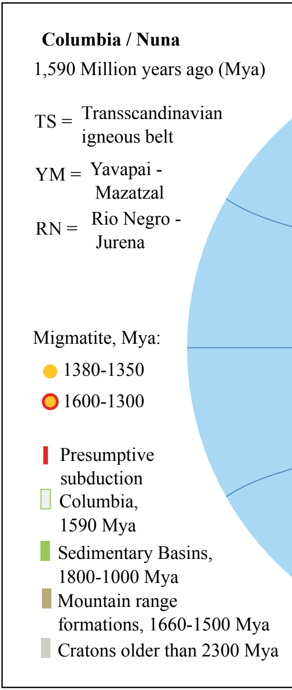
Panthalassa was the major ocean that surrounded Pangea

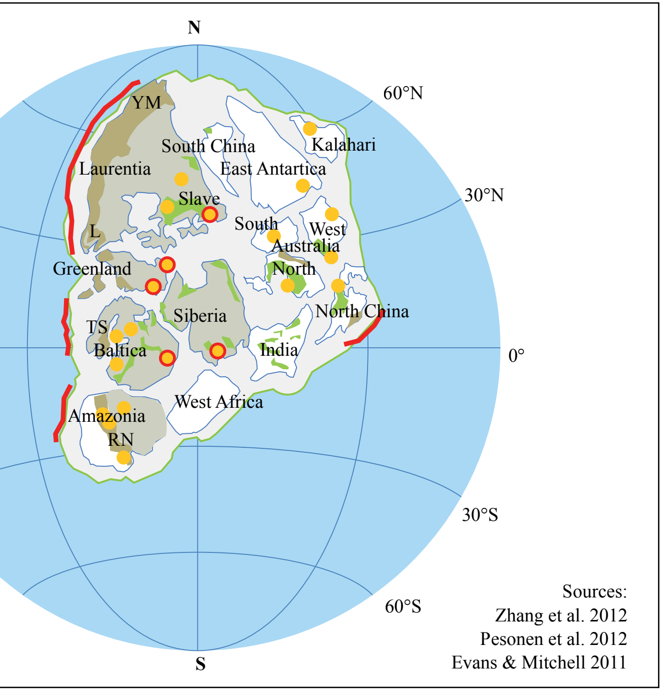
no doubt that having very large bodies of water unbroken by large land masses would have resulted in a very different climate system in our ancient past. Exactly how different is still being debated, because there are a million factors to address and millions of tiny changes that

Rodinia existed until about 700 million years ago

can all add up to significant weather differences... suffice to say, weather would be more extreme in some places for sure.

Our first step back takes us to about 250 million years ago (Triassic period), where the supercontinent Pangea dominates as the huge land mass that straddles the equator. Both the poles are submerged underwater at this time. The superocean is called Panthalassa, and it covered most of the surface of the earth. There are also smaller oceans called the Paleo-Tethys and Tethys ocean which are considered by many geologists to be responsible for the eventual breaking up of the supercontinent. One theory is that pressure of the Tethys ocean exerted on the inside of the C-shaped landmass of Pangea, was pushing it outwards, while the pressure exerted by the Panthalassa ocean on the outside of the C-shaped Pangea was also exerting pressure that might have guided the super continent





The supercontinent Columbia

to break up in the way that it did. Once the gaps between the land masses appeared and were filled by the oceans, the process was only sped up.

Before the Pangea supercontinent, there existed a supercontinent called Rodinia, which formed about 1.13 billion years ago, and broke up about 750 to 600 million years ago. It's thought to have followed a previous supercontinent called Columbia which formed about 2 billion years ago... and so on.

The supercontinent that will form about 250 million years from now has a few different names. Some call it Pangea Proxima, some call it Pangea Ultima, or Neopangea. We're pretty sure the name won't matter 250 million years from now anyway, so that's not the important bit anyway. What's important is that the earth will change, as it always does, and humans most probably won't exist to witness it. We'll either evolve into something else, or die out like all of the other species from 250 million years ago that don't exist anymore today. ■

The Oceans

And now we're getting to the point...

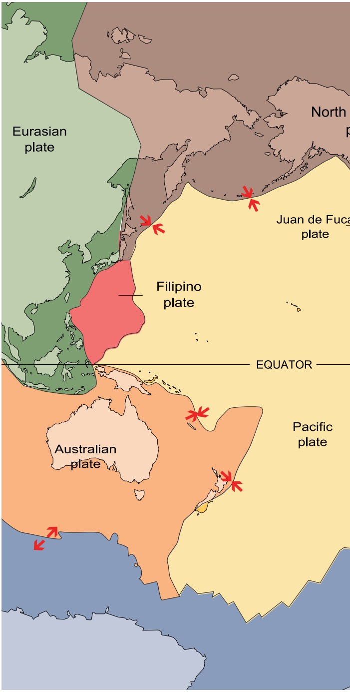
Although humans are but a blip in the history of the planet, and also as a result the history of the oceans, we're a narcissistic bunch who love talking about ourselves. With that in mind, let's look at all that we've learnt about our oceans.

Five oceans

We all know this, we're taught it in school at a very young age. In order of size, the Pacific, Atlantic, Indian, Southern and Arctic oceans make up the one large interconnected water body that is our global ocean. It's important to note that these divisions are man-made and that in essence the Earth really has one large ocean that covers 71 percent of its surface area.

Pacific

The largest ocean by far, the pacific ocean accounts for about 47 percent of the global ocean area, and about half of the total volume of seawater on earth! Covering an area of just over 165 million square kilometers, it's just under one third of earth's total surface area of 510 million sq. km. The Pacific is even larger than all of earth's land masses (all the continents, islands, and every little bit of land that can be walked upon), which have a combined surface area of 148 million sq. km. The Pacific is also the deepest ocean on average of the five, and is also where the deepest place on earth is situated – the Marianas Trench. Located east of the Philippines, the trench is 2,550 km long, and about 69 km wide on average. The deepest known parts of the trench are about 11 km deep. Because the earth is an oblate spheroid (flatter at the top), the



A look at the major tectonic plates

Marianas trench is not actually the part of the seabed that's closest to the centre of the earth. In fact, that is somewhere in the Arctic ocean, which funnily enough is also the shallowest ocean of them all. The Mariana trench is caused by the pacific plate being subducted under the Mariana plate. Here "plate" is the tectonic plates that make up the earth's lithosphere.

The Pacific lies in between the Arctic ocean in the north and the southern ocean in the south, and in the east-west direction separates Asia and Australia from north and south America. North of the equator is known as the north Pacific and south of the equator is known as the South Pacific. The Pacific is shrinking because of plate tectonics, as the americas move towards Asia and away from the European plate. This will go on for another 100 million years, and it's unclear whether the Atlantic (which is growing larger as a result) will become the largest ocean at that time. However, the Atlantic is doomed, as in the next 150 million years after that (250 million years from now) the Americas will again move towards Africa and forever close off the Atlantic for good.

Atlantic

Dividing North and South America from Africa and Europe, the Atlantic is the second largest ocean. It covers a surface area of about 106 million sq. km. It's an S-shaped ocean that runs from

Greenland in the north to Antarctica in the south. It's also divided into the north and south Atlantic ocean by the equator. The name comes from the Greek "Sea of Atlantis", which was considered to be the sea inside the great "Oceanus" – the large ocean that was supposed to boundary all known land. Obviously, it was named before Europeans discovered the "new world" (the Americas). Often the Atlantic ocean is described as the ocean that divides the new world from the old world (Europe).

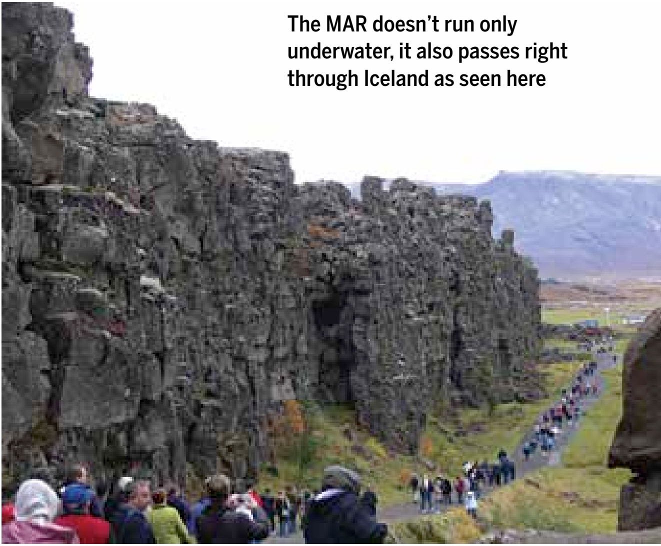
One of the major features of the Atlantic ocean is the mid Atlantic ridge (MAR) which divides it almost perfectly into two equal halves. Considered to be the longest mountain range in the world (above or below water), the MAR is thought to be over 40,000 km long!

Although the second largest ocean it is not the second deepest on average, but is in fact the third deepest. The average depth of the Atlantic ocean is about 3.6 km, whereas the average for the Pacific is closer to 4 km, and the average depth of the Indian Ocean is over 3.7 km.

The Atlantic is the saltiest ocean of them all – surface salinity of the oceans depends on the rainfall vs. evaporation ratio, and obviously, when there's more evaporation than rain, an ocean gets slightly more saline. Because all of the oceans are interconnected this never goes out of whack by a large amount, but nonetheless, some oceans are more salty than the others on average.

Indian

The only ocean named after a country, and that country is ours! Covering an area of about 70 million sq. km, the Indian ocean is considerably smaller than the first two, but still makes up about 20 percent of the global ocean by area. It runs all the way from East

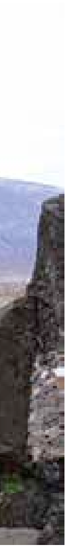


The MAR doesn't run only underwater, it also passes right through Iceland as seen here

Africa to Western Australia, and from the Indian subcontinent in the north to Antarctica in the south.

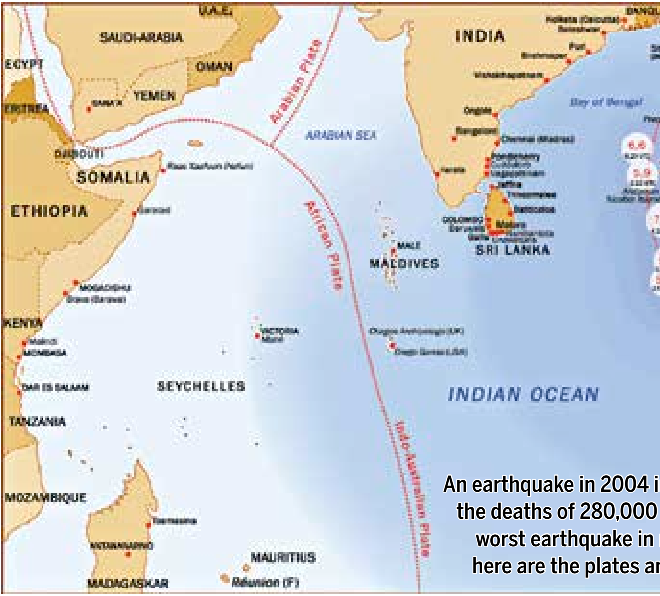
The deepest point in the Indian ocean is the Diamantina Deep, which is located about 1,100 km south, south-west of Perth, Western Australia, and is over 8 km deep. On average though the Indian ocean is about 3.7 km deep, and is the second deepest ocean after the Pacific.

Unsurprisingly to us Indians, the Indian Ocean is the warmest of all the oceans, but sadly, it is also warming up faster than the others. Temperatures have risen 1.2 degrees in the past 100 or so years, which may not seem like a lot, but will play havoc with oceanic life and also the global climate. Our oceans are our heatsinks (think of them like a good liquid cooled PC, where the oceans are the reservoir) and a hotter ocean means a hotter planet. Besides, imagine the amount of energy needed to heat 264 billion, billion litres of water by even one degree centigrade, and you will know how much hotter our little neck of the woods is getting!



Southern

Also called the Antarctic ocean, this ocean is basically the southernmost waters of the global ocean. It's usually considered to be the bodies of water south of the 60 degrees south latitude. This latitude was probably chosen because no land lies on it, and only



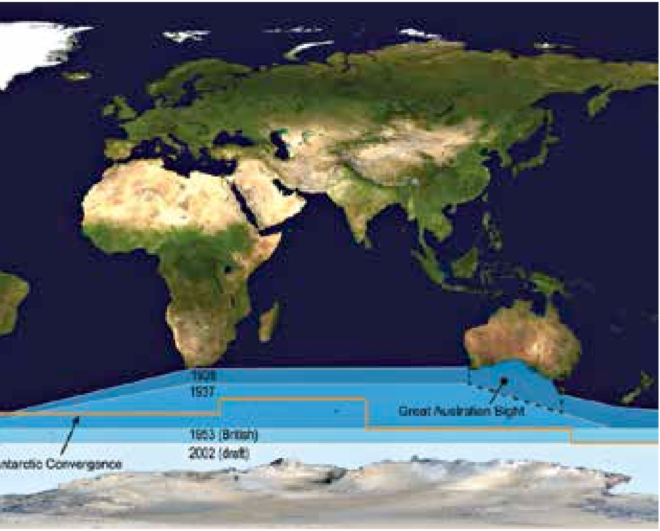
Antarctica lies south of it. Of course this is not widely accepted, and in fact, many believe that we're fine with having four oceans instead of five. Many still consider the Pacific, Atlantic and Indian oceans to

n the Indian Ocean caused people and was the third recorded history! Seen nd the earthquake sites

touch Antarctica, which obviously leaves no space for any Southern Ocean to exist. It's so chaotic that every country seems to have their own definition (if at all). While some still consider only four oceans, Australia, for example, considers the Southern Ocean as the waters that touch the south of Australia and New Zealand, while the rest of the world believes that the Indian Ocean touches the south of Australia on the west of Tasmania, and the Pacific to the east of Tasmania. The UK consider the Southern Ocean to be all of the water south of the 55 degrees south latitude.

Even in the International Hydrographic Organization there is no consensus. The IHO consists of 87 countries and is considered by the UN to be the authority on surveying and charting the world's water bodies. While most voting representatives from countries in the IHO agreed that there should be a Southern Ocean (they also agreed that it should be called the Southern Ocean and not the Antarctic Ocean), that's pretty much all that they agree upon. Some members want the Southern Ocean to begin from as north as 35 degrees south, some wanted 50 degrees south, but about half voted for 60 degrees south as the start of the Southern Ocean. Because of bureaucratic nonsense, and many other disagreements in naming of various other water bodies and a lack of consensus on the Southern Ocean limits, the proposal hasn't been adopted officially yet. The US, however, has accepted 60 degrees south as the limit, and updated all its charts and also mentions it in the CIA World Fact Book. Given the clout they have, we're just also accepting it and giving you the definition.

How the Sout



thern Ocean has been redrawn over the years

The Southern Ocean covers an area of just under 22 million sq. km, which is a mere 6 per cent of the global ocean. It contains about 72 million cubic km volume of water (5.5 percent of the total sea water on earth), and has an average depth of 3.2 km. It's the youngest ocean, and is thought to be a mere 30 million years old. The deepest part of the Southern Ocean lies in the South Sandwich Trench, off the eastern coast of the tip of South America. At it's deepest, the trench is about 8 km deep at a point called Meteor Deep.

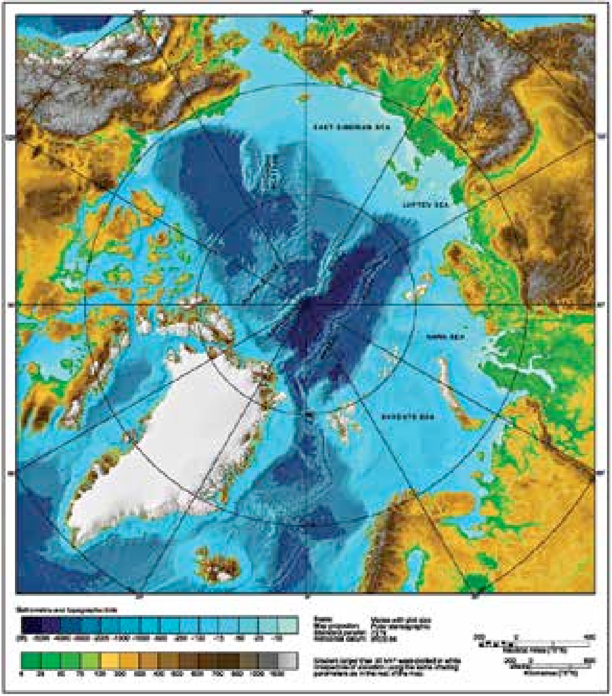
Arctic

The smallest ocean of them all, the Arctic Ocean is also called the Arctic Sea because it is so small. It is the smallest and also the most shallowest of all the world's oceans. At 15.5 million sq. km it's just 4.3 percent of the global ocean in surface area, but because it is only about 1.2 km deep on average, it accounts for a mere 1.4 percent of the global ocean volume (18.7 million cubic km). Almost all of the Arctic Ocean turns to ice during the winter in the northern hemisphere. The deepest point in the Arctic Ocean is Litke Deep, which is a trench off the north east coast of Greenland, and goes down to a depth of 5.45 km at its deepest.

Because of the cold, and the angle at which the Arctic Ocean is hit by the sun's rays, it has the lowest evaporation rate of all the oceans. However, because of the large amounts of land masses, the long coastline and because of the topography of the area, the Arctic Ocean has a lot of fresh water flowing into it. This means that the Arctic has the lowest salinity of all the oceans. With global warming, however, the salinity of the oceans is decreasing, and this is also the case in the Arctic. This change can only spell disaster for the sea life of the arctic. Studies have shown that the average annual sea ice in the arctic is steadily decreasing, and this is directly attributed to global warming, of which, human caused global warming is the biggest factor. Many believe the most famous inhabitant of the Arctic, the polar bear, is already doomed to natural extinction because of climate change. They're going to need human intervention to be able to survive.

Why Salt?

As we mentioned before, because of the outgassing and water being brought in by comets 4.4 billion years ago, there was a lot of water in the atmosphere of the hot earth. Eventually, when the earth cooled, rains started. Because of the high concentration of carbon dioxide, the rains were slightly acidic, which meant that even more minerals were dissolved as the torrential water flowed and eroded the newly formed rocks. Eventually, undersea geysers and volcanoes were also adding water and minerals to the mix, and when the water system stabilised, the evaporation of the oceans caused inland rain, which then flowed across the land dissolving minerals as it went, and eventually brought it all to the oceans again. Since Sodium and Chloride ions are the most commonly found ions in most minerals, and they are both salty, the seawater they're dissolved in are naturally salty.



The topography of the land surrounding the Arctic Ocean

There are about 35 parts per thousand (3.5 %) of dissolved minerals to water molecule ratios in seawater. This also works out to 3.5% of the weight of seawater being made up of salt. While it may not seem like much, that's a LOT of salt. If all of the oceans on earth were to boil away for some reason, they would leave enough salt to cover the entire earth's surface with a layer of salt 40 metres thick!

A cubic km of seawater would weigh about a billion tonnes – one cubic metre of sea water weighs about 1024 kilos, so 1000 x 1000 x 1000 x 1024 = 1,024,000,000,000 kg or 1.024 billion tonnes (1,024 million tonnes). If 3.5% of that weight is salt, then the amount of salt in a cube of seawater 1 km on each side is 3.5% of 1,024 million tonnes = 35.84 million tonnes of salt! That's also works out to 35.84 kilos of salt in one cubic metre of sea water!

In the saltiest lakes, for example the Dead Sea in Jordan, where the salinity is as high as 40%, one cubic metre of water contains as much as 410 kg of salt!

Tides

Seen from the land, the sea appears to rise and fall at different points of the day. This is because the level of the seas or oceans change because of the effects of various things. For example, the moon exerts a gravitational force on the oceans, which causes the water to literally be pulled towards the moon. This causes a high tide on the

The high salt content (40%) makes it easy to float effortlessly on the Dead Sea side of the earth that is facing the moon, and also on the opposite side of the earth. Another mammoth object in the sky is the sun, and that also causes a gravitational effect on the water. Then there's the spinning of the earth, which causes tides as well. All of these come together to form a complex system of high and low and mixed tides.

Add in the complexity of the shape of the shore, which direction it's facing in, the speed of the wind, and so many other factors and you get a very complex system of global tides indeed.

Gravitational forces are the most responsible for tides, and there are a few different tides, given that we have the sun and the moon influencing the earth. A spring tide is when the sun and moon are on the same side of the earth, or when the sun and moon are on directly opposite sides of the earth. In both cases you get really high and really low tides. Neap tides are when the sun and moon are at 90 degree angles (or 90 and 270 if you want to be geometrically accurate), and are lower tides than spring tides. Note that "spring" here does not mean the season, but is the variant used in the sense of springing up, or springing into action, etc.

Since the moon doesn't orbit the earth in a perfect circle, and neither does the earth orbit the sun in a perfect circle, there are times in a year when the earth is closer to the sun, and also times in the lunar cycle when the moon is closer to the earth. All of this affects the heights of tides.

Whilst one would think that the sun, being a much more massive object, would have more of an effect on the tides than the moon, the fact is the sun's effect is less than half the gravitational effect of the moon. This is because the gravitational force exerted on a body on the earth's surface is the difference between the force that it feels at the surface and that it would feel at the gravitational centre of the earth. Because gravitational effects involve an inverse square component to the distance calculation, it's obvious why the sun exerts less of an effect despite being much more massive, because it is much further away. Something that is 10 times closer affects another body 100 times (10 x 10), and as a result, something 10 times further away, would affect the body one hundredth the amount. Assuming that the radius of the earth is 6,000 km (it's actually 6,371 km), the force of gravity felt by the moon is the difference between the moon's gravity on something 384,400 km and 390,400 km away. While for the sun, it's the difference between gravity exerted on something 149,600,000 km and 149,606,000 km away. Without getting into the complex equations, we assume you can see why the inverse square law is the great equaliser for gravity effects of the nearer moon and the far more massive but much farther sun.

If you're interested in a simplistic equation, imagine the force on 1 kg of water on the surface of the earth, vs. at its center, 6371 km further. We will ignore the effect of earth's own gravity. Please

Boats made to look oddly grounded because the tide went out

don't assume this is an actual equation to be used, this is merely to illustrate the difference between the gravity of the moon vs the sun and show the inverse square law of distance in action.

We will use the equation $F = GMm/R^2$

Here **F** = force felt in newtons, **M** is the mass of the large object, **m** in our case is 1 kg of water, to make the calculation easier, and **R** is the distance from **M** to **m**. **G**, of course is the gravitational constant $= 6.674 \times 10^{-11}$

The Mass of the moon is **7.35×10^{22} kg**, and the average distance of the moon is about 384,400,000 metres away from the surface of the earth (390,771,000 metres from the centre of the earth.)

Difference in gravitational effect =

$G * \{[1/(384{,}400{,}000)^2 - 1/(390{,}771{,}000)^2] * 7.35 \times 10^{22}\}$

$= G * (497{,}417 - 481{,}330)$

$= 6.674 \times 10^{-11} * 16{,}087$

$= 1.073 \times 10^{-6}$ N of force

For the sun the equation would be:

$G * \{[1/(149{,}600{,}000{,}000)^2 - 1/(149{,}606{,}371{,}000)^2] * 1.989 \times 10^{30}\}$

$= G * \{88{,}873{,}359 - 88{,}865{,}790\}$

$= 6.674 \times 10^{-11} * 7{,}569$

$= 0.505 \times 10^{-6}$ N of force

Sun's effect in percentage of Moon's = **0.505 / 1.073 * 100 = 47%**

The ocean floor

For centuries humans have tried to make proper maps of the sea floor. In ancient times, the floor of the sea wasn't as important to most seafarers as much as the depths of the water. This is because many a ship was wrecked on some of the more treacherous waters because of invisible rocks lying just under the surface of the water. Often waters that were navigable during high tide were death traps at low tide, especially closer to land masses. However, given that there are ridges and large mountains hidden under the oceans, there's no telling where disaster could strike ancient seamen.

What started off as captains wanting to know where it was safe to travel soon became an obsession for oceanographers. With the invention of sonar, and related technologies, and also with the invention of submarines, there was more capability in measuring the depths of the oceans. Or so we thought. It quickly became apparent to scientists looking to find the seafloor away from the shores of land that the underwater world was far more impressive and diverse than the topography of land masses. Scientists came up with bathymetric maps, which show contours and shapes and valleys and mountains under the sea level, or basically the exact opposite of topographic maps.

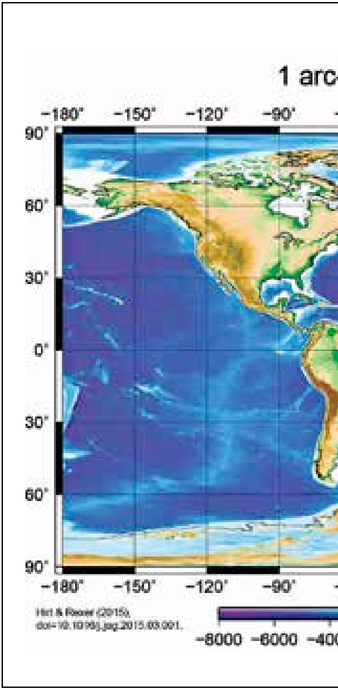
When they discovered mountain ranges that put anything we knew above sea to shame, and trenches that could swallow six grand canyons and still have room to spare, scientists knew that they were exploring the last frontier of our planet.

It's not all jagged rocks, because there are great plains under water which spread out far and wide, and are the equivalent of underwater deserts. Of course, as we have mentioned before, mapping is tedious and expensive work, and the more fidelity or clarity of maps you want the more tedious and expensive it gets. We know the deepest parts of the ocean, because that was exciting and it was obvious that we would look for that frontier.

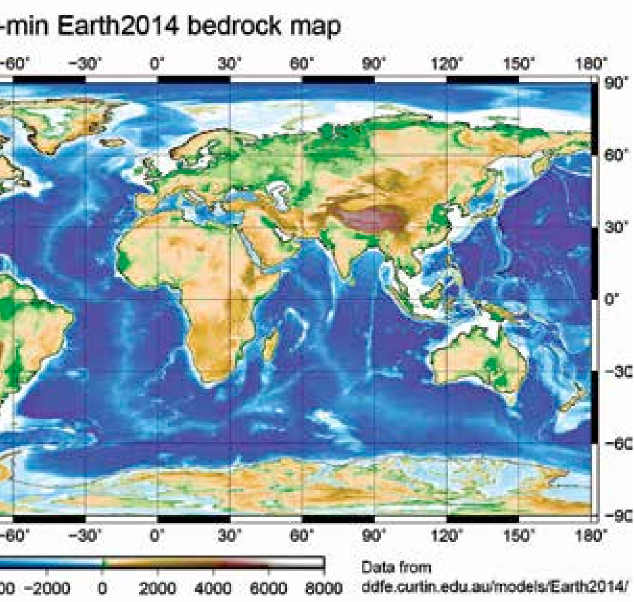
At first, the way the measurements were made were very primitive. A weight was lowered into the sea, and when the line went limp they knew it hit the bottom, they'd mark the point and pull it back up and measure the length of the line that was underwater. They would sometimes paint the bottom of the lead weight with lard, and try to catch some of the sediment from the seabed.

These devices were called sounding devices, and they got more complex and able to measure deeper and deeper. Early versions were put together using bicycle parts and mechanisms, and were able to measure up to 1,000 feet deep.

Next came more complex sounding devices, with more focus



A modern bathym



etry cum topography map called a global relief model

A sounding device from 1886

on bringing up the stuff on the seabed, instead of just measuring the depth.

Once sonar came along, and the speed of sound in water was understood and calculated, ships were able to create pings under them and listen for echoes. The time difference between the ping that was sent out and the echo that came back, multiplied by the speed of sound in water, and divided by two (the sound was travelling double the depth) and it was easy to find the depth of the seabed directly under the ship.

Of course, this did nothing for understanding the shape of the seabed, and merely gave an approximation for how deep, on average, that spot was. This is when advances in science brought about advances in bathymetry.

For one, it was discovered that just by modulating the frequency of the ping, we could penetrate the upper sand layer. Lower frequencies penetrated the silt layer considerably, and thus were actually measuring under the seabed. Higher frequencies, of course, just gave the depth of the seabed. By playing with this it was now possible to get data on the rock formations vs the seabed itself. Thus, it was now possible to find a rock valley that had been filled in with sand, and thus would appear to be a plain, but wasn't.

Modern bathymetric systems include interferometry sensors. What this means is that the sensors are sensitive enough to not just pick up the echoes of sonar with much greater fidelity, but are also able to check for interference patterns, which is what happens when a ping hits an uneven surface. Thus, jagged rocks would reflect the ping in an asymmetric manner, which would cause interference in the signal that's received. Modern systems are able to work backwards from distorted echoes, analyse the interference patterns and plot a detailed bathymetric map of the sea floor. This is leading to much higher fidelity imaging of the ocean floor, and is critical to us understanding our oceans better.

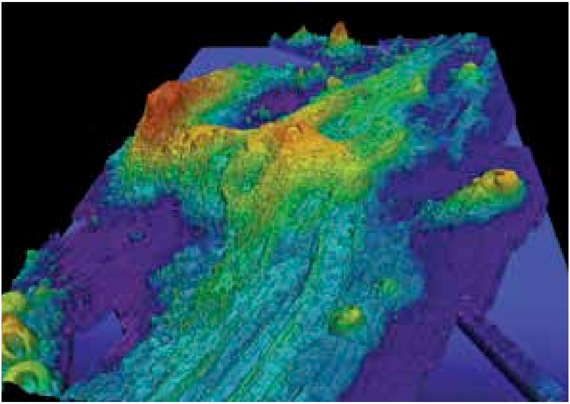
Important expeditions

There were always firsts when it came to ocean explorers, but we're not going to tell you about land discoveries, but instead focus on the pioneers who wanted to understand the oceans themselves, and not just cross them to get to more land.

In older history, although the Gulf Stream (an Atlantic Ocean current) was discovered in 1512 by Juan Ponce de Leon whilst trying to sail against it (and failing). Ships started using the gulf stream to return to Europe from the new world (the Americas), because it could as much as double a ship's speed (and halve the travel time!), and even back then time was money. However, although everyone knew about the Gulf Stream all through the sixteenth and seventeenth centuries, it was only towards the end of the eighteenth century that Benjamin Franklin was able to explain why the Gulf Stream existed (in 1769) as a result of climate and wind patterns. He did so by meticulously measuring the temperature of the stream over several journeys across the Atlantic – a process that took years!

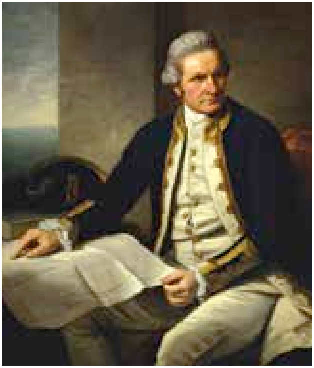
James Rennell, an English historian, was a pioneer in oceanography, and was among the first to detail the major currents of the Atlantic and Indian oceans (apart from the Gulf Stream obviously) in 1777.

Before Rennell, James Cook, aboard the HMS Endeavour set sail in 1768. He would also sail on two more voyages until 1780 aboard the HMS Resolution and HMS Discovery. He charted the Pacific and Antarctic oceans, made invaluable maps of New Zealand, and even sailed as far as as 71 degrees south latitude. He was stopped in his



Exaggerated example of modern bathymetry mapping

path by icebergs and frozen seas, but he never found Antarctica. He turned out to be an excellent scientist in his own right, and was known to meticulously take careful measurements of water temperatures, note down currents, keep track of tides, and even keep track of biological life forms that were encountered. He was killed in 1779 while attempting to kidnap the chief of Hawaii, in an effort to get back a longboat that had been stolen from his crew by the natives. In what may seem a horrific fate, his body was dis-



James Cook was known as a superb scientist

emboweled, baked, his flesh removed and his bones removed and cleaned. However, this was a traditional state funeral for Hawaiian chiefs, and was considered a mark of highest respect.

The HMS Beagle was the next voyage that we should mention, and if you're into reading about natural selection or evolution, you already know that this was the famous voyage that Charles Darwin took, which eventually led to his theory of evolution by natural selection. On a mission to map the South American coastline, Darwin did more than just stare at rocks on that voyage. While we all know about his study of finches, what many don't know is that Darwin also studied reefs and atolls in great detail, and detailed how coral reefs form around volcanic islands.

By far the star of the show... the expedition of the most importance to oceanography was the famous voyage of the HMS Challenger.

The voyage started off in December 1872, and the ship sailed from Portsmouth, England. This is an important voyage because it was the official birth of the field of oceanography. Charles Wyville Thomson, a Scottish zoologist convinced the British government to allow him to refit a Royal Navy ship for scientific research. Wyville Thomson had already made a name for himself previously by dredging the deep sea floor, and pulling up some amazing looking creatures, the likes of which had never been seen before. It was this that prompted the British to bankroll an expensive trip around the globe.

As it came to be, Challenger sailed 130,000 km and went all over the world and advanced our understanding of the oceans like never before. The crew took deep sea soundings, dredged the bottom of the sea beds all across the planet, took hundreds of temperature readings and discovered over 4,000 species of marine animals that had never been seen before by humans. Although the Challenger also sailed close to Antarctica, it never spotted it.

Challenger was also the ship to discover the Marianas Trench, and took a sounding recording at the south end of the trench that measured over 8 km deep. It wasn't until much later expeditions and more modern equipment that the real depth of the deepest part of the Marianas Trench was found to be closer to 11 km. Named after the ship that discovered the spot, the Challenger Deep is still the deepest spot on the seabed that we know of.

On January 23, 1960, a deep sea submersible called Trieste carried two men (Jacques Piccard and Don Walsh) to the bottom of the Challenger Deep. The official recorded depth they went to was 10,916 metres, and it took them about 5 hours to dive to that depth. They were only able to spend 20 minutes at the bottom of the ocean because a crack formed in the outer window, and then they had to spend three hours and fifteen minutes ascending to the surface again.

It wasn't until 26 March 2012 that famed movie director James Cameron made a solo dive in a Deep Sea Vehicle called Deepsea Challenger, and reached the bottom of the Challenger Deep in the Marianas Trench after just over two and a half hours of descent. He spent about two and a half hours at the bottom collecting samples, and the official recorded depth at touchdown was 10,898 metres. He was forced to return to the surface earlier than planned because the extreme pressure caused a leakage in the hydraulic fluid of his robotic arm, and also caused some thrusters to malfunction. He rose to the surface quite fast and the submersible broke the surface after a mere 90 minute ascent. ■

Oceanic Life

Vastly different from the land creatures, here's a look at life in the oceans

As early as 4.1 billion years ago, very soon after the formation of the earth and moon, and a literal blink of an eye after the cooling of the earth, we know that the building blocks of life already existed. We also know that life began in water – because of the special properties of water being a super solvent, it is just the perfect place for complex chemistry to occur. It would be dishonest to claim that we know how life got started, because we don't know for sure yet, however, it certainly did start in the early oceans of earth. And there life stayed for a whopping 3 billion years. Then again, the first 3.5 billion years of our planet's history was marred by huge extinction level events, which wiped out almost all life... several times! Life was persistent though, and the fact that we're here now is proof of that.

Origins of life

The first 500 million years of the earth's life is called the Hadean period, named after the greek god of hell, Hades. Although many believe that it would have been impossible for life to have been kickstarted in these first 500 million years, that's exactly what we think happened. Although direct fossil evidence of life dates to about 3.5 billion years ago, there are ancient zircon crystals that date back to between 4.1 and 4.2 billion years ago that were found in Western Australia that contain chemo-fossils – these are the chemical traces left by microbial life. Of course, there could be a natural explanation for the weird combination of carbon isotopes, but the only reason why this happens that we know of for sure is decay of living cells. It's not the same as a nice fossil of a cyanobacterial colony that can be dated to 3.5 billion years ago (also found in Western Australia), but if the assumption is correct, life starting off so quickly suggests something interesting. Firstly, life may be inevitable on any planet that has liquid water and a mix of minerals orbiting a main sequence star like our sun, and secondly, it might very well be abundant in the universe (at least bacterial life).

DNA has already been created in a test tube from dead chemicals by the J Craig Venter institute as far back as 2010, and they then repeated the feat in 2016 with additional markers on the genome sequence of the artificial life they created called Syn 3.0 – it was the first synthetic bacteria to be made on a computer, and have it's own website's code written to its DNA!

Stromatolites (bacterial colonies) are found even today in Western Australia

How life went from naturally forming amino acids to RNA and then DNA in nature is still a mystery to us, and to be honest we may never know how it happened. We do know the path it took once it got started though.

We could go on for a million words more, detailing the journey life took in the oceans, but this is more about oceans today, and the life it contains, so we're going to fast forward 3 or 4 billion years to present day.

Living diversity

Biologists classify life into six major categories or kingdoms; these are animals, plants, fungi, bacteria, archaea and protists. Because all life began in the oceans, even today, the oceans have all six of these kingdoms represented. Heck, we're discovering new species all the time, because of how little we know about our oceans, and if we ever discover a seventh kingdom, it's bound to be found in the oceans.

Given that the most abundant source of energy on our planet is sunlight, it makes sense that the ocean also lives off it. Just as we all live off plants (directly or indirectly) on land, the ocean survives on plankton which produces food from the sun and minerals dissolved in seawater. The largest animal to have ever lived on this planet, in all its 4.4 billion year history is the blue whale. It's much larger than any of the monsters that lived in the ancient ocean deeps, and much larger than the largest dinosaurs that ever walked the earth, and yet it feeds off tiny krill, which in turn feed off plankton. Directly or indirectly, almost every living thing on earth feeds off the sun.

Just to give you one example each of the various kingdom, phylum, class, order, family, genus and species that are found in the sea would take up more words than we can write, so we're going to focus on some interesting ones like the blue whale we already mentioned.

Did you know that there are archaea found under the sea that actually eat rocks? These microscopic cells live deep underwater (a kilometre or more) and survive by gradually extracting the minerals from rocks. Eating rocks aren't the only things underwater microbes do... true extremophiles, microbes have been found to live in the most inhospitable conditions imaginable.

Life has been found in the superheated water that's ejected by underwater geysers, and is in abundance around methane or sulphide vents or volcanic vents. Bacteria are the garbage men of the sea, and they're responsible for disposing of all of the dead and dying stuff that's in the ocean. Thanks to bacteria the ocean is replenished with the minerals of dead creatures.

The protists are basically organisms that straddle the definition of the kingdoms of animal and plants. In the ocean, there are uncountable, and often very weird. Some protists act like plankton and produce food using sunlight, and don't really locomote, while others are killers that feed off other creatures and very motile. Protists in the sea are amazingly useful to the planet, and some estimates suggest that as much as half of the oxygen produced on the planet is by these creatures. Algae are also usually lumped in with protists.

Plants and fungi are both plentiful in the ocean, but chances are you wouldn't recognise them as such because of the land-based bias we all have. Plants would include kelp, seaweed and the likes, which are very primitive plants, actually. There are some seagrasses and

Life in the ocean is diverse!

mangrove trees, but they're not truly ocean life, as they cling close to the shores in order to survive. Fungi on the other hand were long thought to be plants, but thanks to modern biology we know they're more closely related to animals than plants. They're also part of the clean up team of the ocean, and help decompose the dead.

Finally, animals are the oceanic life that you will be most familiar with. Everything from jellyfish to fish, the very intelligent dolphins, whales, sea anemone, sea cucumbers, shrimp, crabs, lobsters, squid, octopus, oysters, starfish, killer whales, shark and more are all part of the kingdom animal.

We know most about the last kingdom we mentioned, but by no means does that suggest that most of the sea life belongs to that kingdom. We still have a very large land bias, unfortunately. Of all of the species we know (about 1.5 million or so) only 25% are from the oceans. Most of the 1.5 million are land-based plants and insects and bacteria, but this is only because we are truly still ignorant of the secrets of the deep.

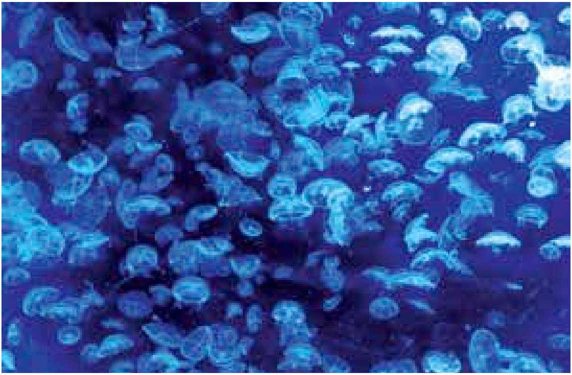
Protection

The oceans are filled with life, and rich in food and minerals, but the problem is that everything is something else's food, and in the ocean, there's not too much space to hide from predators. Then again, there's the environment itself that's harsh, with extreme cold and pressure that animals need to deal with as well. So how do they all manage?

One of the problems of being a salt water animal is needing to ensure that you achieve homeostasis with the surroundings. This means being able to prevent the water from your body being absorbed by the salty surroundings. Water moves through cell membranes in a process called osmosis, which basically is the movement of water from a dilute solution to a more concentrated solution. If the animal's cells are more concentrated with salt, they will absorb water, and if they're more dilute, they will lose it to the seawater. Taking a freshwater fish and putting it in seawater will cause it to die from dehydration! Many ocean animals have developed a method of osmoregulation. Many fish, for example, drink a lot of seawater and absorb the salts to balance the concentrations. Excess salts are expelled through their gills.

Pressure is another killer for us humans. For every 10 metres you dive further down, the atmospheric pressure increases by one atmosphere. At the bottom of the Challenger Deep, you would experience 1100 times the atmospheric pressure on the surface. The reason we humans (and other land dwellers) are so fragile to pressures at different depths is because we have a lot of gas inside us. Even within our blood we have dissolved gases, and it's that which keeps us alive – oxygen is transported to the body and carbon dioxide is transported away from the body and to the lungs. As pressure increases, liquids don't compress as much, but gases compress a lot. It's all the gas we have inside us that compresses and causes us to be crushed. Deep sea animals have very little gas in their bodies, and are filled with liquid, which allows them to handle the pressure.

Most marine animals are cold blooded, which means that they rely on the surroundings to regulate their body temperature. Mammals are warm blooded creatures, and rely on their own bodies to



Jellyfish are pretty... pretty dangerous that is...

regulate the heat to stay alive. It's why fish can survive perfectly at near freezing temperatures, but we'd just die of hypothermia in minutes. Whales and other mammals use layers of fat to insulate themselves from the cold surroundings. Seals are the mammals that live in the most extreme cold environment. They live in permanently frozen seas, and have to keep holes in the ice open to be able to surface to breathe, between hunting for food.

Jellyfish and the octopus have developed defense mechanisms to safeguard themselves against attack. While jellyfish have stingers that make it an unpleasant experience for anything that touches them, an octopus has mastered the art of deception by being able to blend into its surroundings and also some species are able to squirt ink in a predator's face to distract them while they make a quick getaway.

Crabs and shellfish have developed shells to help protect them against predators. Other body appendages include thorny like protrusions such as those on porcupine fish, and others like the puffer fish are able to blow themselves up to appear much larger than they are to scare away medium sized predators. Poison and venom are also used as defenses, and eels can give you a good old jolt of electricity.

Locomotion

Moving in water is like nothing we experience on land. If you've been swimming you know that water offers much higher resistance than air, as it is a far denser medium. Most marine life forms that have adapted to speed in order to survive or hunt have developed shapes that are streamlines and offer the least amount of drag. This is natural selection at work, because obviously their shape was the best for their survival.

Not all movement is streamlined or even built with speed in mind. Jellyfish move by taking in water on top and squeezing it out the bottom, and do so slowly. They're not built for speed, and they don't care because they have a powerful defense mechanism.

Turtles use flippers to swim and also to move slowly across land

Plankton, on the other hand, just float, and let the tide take them. Of course some zooplankton have been known to travel considerable distances. They descend to the deep waters in the day, and come up to feed in the darkness of night.

Some fish are built for speed, and are constantly flitting about the ocean, while others are built for short bursts of rapid acceleration, and have fins that are naturally selected to allow them to make very sharp turns underwater. This helps in attacking prey and also getting away from hunters.

Seahorses are weird. They vibrate their tiny dorsal fin up to 70 times a second, which causes a very minor wave like movement that allows them to move at ridiculously slow speeds. Seahorses can take over 5 minutes to travel just 1 metre!

Then of course there are the shelled creatures who have legs that move them across the sea floor

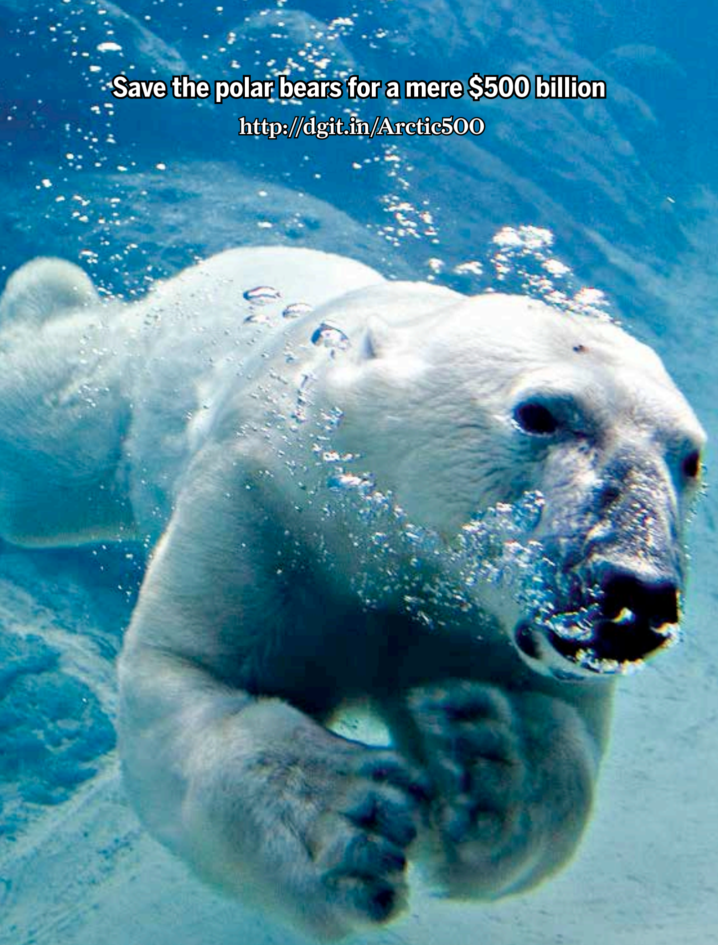
Senses

The sense of smell and hearing is generally heightened in many animals. This isn't only for communication reasons, but also to help

Did you cut your finger?

protect the organism, or even to help in hunting. Sharks can smell blood from kilometres away, and whales can communicate across great distances. The medium itself is the advantage because sound travels twice as fast in water and up to four times as far, which is why so many marine animals (especially mammals like whales and dolphins) use high frequency sounds to communicate. Dolphins also use sound as a sort of sonar to map their surroundings.

Honestly, we've barely scratched the surface of the oceans and the life within them, but we're running well past our wordcount barrier. What we do hope is that you have developed a renewed interest for all things watery, and will give your local aquarium a visit as a way of supporting it. Remember to write in and tell us how we did, and to give us suggestions for more topics – *dmystify@digit.in* is the address you need... ■


Save the polar bears for a mere $500 billion
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