Children's Science Observatory

Jantar Mantar

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Koala

The viral wonderland

Zareena, Mookayi and Mari

Mari was smiling. She was reading Zar's email. It was dated 1.5.2040. Zar had enquired about the kolams of Usha Amma and of course all of us. Mooks had also replied to her email with lots of old memories. Trust Zar to dig up from her archives, just as the world was facing yet another viral pandemic, what they had discussed online for a *Jantar Mantar* article on viruses twenty years ago when the *Covid-19* pandemic had been going on. So much had happened to the world since those years when several waves of the pandemic swept the world. How that viral pandemic changed not only the course of human society but also our lives.

Karin Moelling

Zar had gone on to become a virologist exploring the global spread of viruses. Mooks became a maths specialist modelling the interactions of the viral communities within the biosphere. And what about me? Mari thought … I became an artist communicating science to the public. What the *Covid-19* pandemic had showed was a definite need for conveying the science and the importance of public health to the common public and those who governed the countries. She started to read the transcripts of the online meetings that Zar had sent ...

Usha: Good that all three of you are meeting online to discuss about viruses. At the end, I hope you will write-up what you learn as an article for *Jantar Mantar*. The previous issue had an informative article on viruses. But as I told you all we have to think of "*Viruses — more friends than foes*". Hope you all read the book by the same title by **Karin Moelling** published in 2017 by World Scientific Publishing that I sent as a pdf e-book.

Zar: Of course. I was surprised that there are more viruses on Earth than stars in the sky.

Moo: Going by numbers, about 10^{33} viruses, 10^{31} bacteria, "only" 10^{25} stars and soon about 10^{10} humans.

Mari: A decillion viruses! Or a million billion billion billion of them.

Zar: The I*nternational Committee on Taxonomy of Viruses* (see https://talk.ictvonline.org/taxonomy/) gives only 6590 species because only a small fraction of the viruses are identified. For example, the giant viruses came to be known only since 2003.

Moo: An astronomical number of viruses exist in the oceans. But every salad dish is full of viruses — and they cannot be washed off, as they are *inside* the plant cells; yet they are mostly harmless to us because they are so specific to the cells they use to reproduce.

Zar: Moeling makes the point that humans are a superorganism, a complete ecosystem. I was surprised to learn that healthy humans comprise of about 10^{13} cells which are authentically human, our "self", and in addition we host about 10^{14} bacteria and perhaps at least ten to a hundred times more viruses!

Usha: Yes. But this ecosystem is not , as is often described, in a state of constant

"We are the invaders"

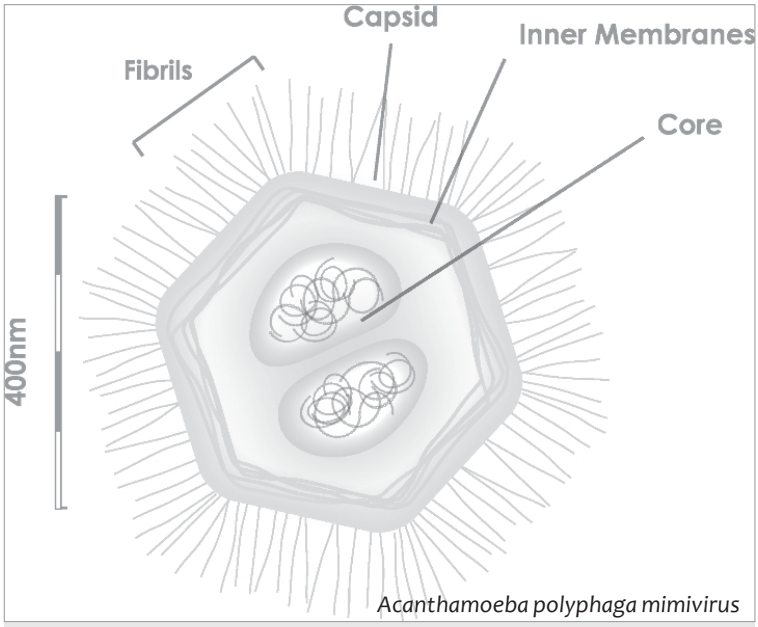
As Karin Moelling says, "We are the invaders in a world of microorganisms, and not the other way round. A gigantic number of micro-organisms, bacteria, archaea, viruses and fungi populate our body and dominate in our environment. Bacteria and viruses are present in kilogram amounts in our intestines — yet without causing diseases. On the contrary, they help us to digest various— even essential — nutrients, which we otherwise would not be able to consume. They also cover our skin, mouth, vagina, toes, nails and birth canal, all with site-specific bacterial and viral compositions."

Front cover: Small Minivet; picture credit https://ebird.org.

war. There is a well balanced co-existence; when we destroy the balance, then things get dangerous and we have pandemics. Viruses are *opportunistic* and take advantage of unusual situations, of weaknesses of their hosts. In most cases humans are the *cause* of the diseases by trying to invade and occupy all biological space.

Mari: Zar, what did you say earlier about **giant viruses**? Surely viruses are small and pass through micron (recall that 1 micron is 10^{-6} metres or one thousandth of a millimetre) sized porcelain filters? I thought this is how they were discovered as being different from bacteria. Remember Tobacco Mosaic Virus (TMV)!

Zar: Yes Mari, but that is science. It keeps coming up with new discoveries and knowledge. In 1992 during a pneumonia



GIANT VIRUSES

Like often with good science – and not pseudo science – once people find something, many others also start discovering similar things. There are two striking features of giant viruses: their genome and particle size are both larger than has been historically considered for viruses. Many more categories of giant viruses have been discovered – **Mamavirus**, **Pandoravirus**, **Pithovirus**. The current size of giant viruses goes upto 1-1.2 micrometers in length! You may know that a translation machinery is present in cells that help to make proteins that we need, starting from DNA or RNA. These giant viruses even have proteins that are part of such translation machinery. These viruses make compartments called viral factories in the cytoplasm of the amoeba to produce more viruses.

The Pithovirus was the most ancient **eukaryote**-infecting (eucaryotes are cells with a nucleus) DNA virus that was isolated from a 30,000 year old layer of ice in Siberia, Russia. After lying in the *tundra* for so many years, it was still viable and able to infect amoeba.

There even is a virus which has been named **Sputnik** which was found to infect the viral factories of the **Mamavirus**. Such viruses which live on giant viruses (like parasites) have been called **virophages**.

outbreak, a micro-organism was found growing in **amoebae** (which are single-cell organisms) from the water of a cooling tower in Bradford, England. But it was visible in a microscope and did not have characteristic bacterial ribosome sequences. So the micro-organism inside the amoebae remained unidentified till 2003 when a group from France showed it was actually a virus. They called it **Mimivirus** in that it mimics bacteria. Mimivirus particles have a size comparable to that of small bacteria.

Moo: Viruses the size of bacteria and living in amoeba ... interesting. Seems rare.

Mari: But are these giant viruses only found in amoeba?

Moo: No, the giant viruses have been reported to infect mice, corals and have been isolated from human blood and are present in the **human virome** (collection of viruses in and on the human body). These giant viruses infect marine algae also. In fact, they are the ones that destroy the *algal blooms* that happen regularly in the ocean. They release the nutrients back into the environment and are an important part of the aquatic cycle.

Moo: The other end of the spectrum in terms of size are the **viroids** – naked RNA not having a coat. They were not considered as viruses. They are predominantly associated with the plant kingdom. In 1971, **Theodor Diener** showed that the *potato tuber spindle disease* where the tuber becomes misshapen is caused by a pathogen 1/80th the size of a typical virus.. In 1976 **Sanger** and co-workers showed it is a single stranded circular *RNA molecule*.

Mari: So these viroids are not in humans?

Zar: Well ... a viroid present in some potato or cucumber or tomato at some point went to the liver of a human being instead of getting excreted out of the gastrointestinal tract. There the viroid found a partner in the **Hepatitis B** virus (HBV) and it became the **Hepatitis Delta virus** (HDV). The RNA of the HDV is packaged *inside* the borrowed coat of the HBV! The two "viruses" replicated in the liver together after they met there. The HBV supplies some of its own protein coat molecules to HDV. This enables HDV to leave the liver cell to infect other cells or even other people, not just move inside plants any more! If people are infected by the two liver viruses, HDV and HBV at the same time, it leads to a severe liver disease and cancer.

Mari: Amazing, how these viral parts adapt and change their host range.

Moo: Even more bizarre is the **poly-DNA virus**, an insect virus. It carries DNA, but does not carry its own genome. How then does it replicate? The DNA of the virus is already a part of the

genome of the female wasp, which hosts the virus. The mother wasp secretes eggs and, with them, the virus, and she injects all into the body cavity of caterpillars. Now the DNA of the viruses helps to release toxins, which kill the caterpillar. This results in predigested food for the young wasps. The virus gives its own genes away to the host and leaves the host without them.

All newborn wasps carry the viral genes in their genomes, inherited from the mother wasp, and will one day repeat the cycle. It is a *vertical reproduction* from generation to generation.

Mari: What about **endogenous viruses**? Are they not important for giving protection against viral infections? I remember reading this somewhere.

Zar: Viruses or parts of their genetic material enter human cells (which are called the hosts) in many ways and infect them. If by chance they infect *germline* cells, which are the cells involved in reproduction, then they can enter into our DNA and become a part of the host genome. Viruses that insert a copy of their own genome into the DNA of a host cell are called **retroviruses**. Once the viral DNA becomes a part of human DNA, they can use the host DNA to replicate. They are called *endogenous* (a part of) rather than *exogenous* (from outside) viruses. Generation after generation these virus genes mutate and eventually in many cases de-activate the virus, such as with Bornaviruses. These are present as endogenous DNA in many species, in humans, monkeys, marmosets, elephants, lemurs, mice, rats and birds — but not in horses. This is how humans may have become resistant, with their *endogenous* Bornavirus sequences, against infections by *exogenous* Bornaviruses. No endogenous Bornaviruses have been detected in horses, and they indeed get sick by exogenous Bornaviruses, coming down with depression. Unfortunately, retroviruses like **Human Immunodeficieny Virus** (HIV) still can harm the host.

Mari: How long does it take for a virus to become endogenous and not cause harm to the host?

Zar: Don't think that is known. It will vary depending on the virus and the host. But in koala bears it has been shown to happen in over 100 years or 20 generations of Koala bears. As Koala bears became endangered due to hunting they were shifted to small islands around Australia and kept in protective custody. But they got infected with the **gibbon ape leukemia retrovirus** and many died. But some survived. Examination of the survivors showed that the gibbon ape virus sequence had become a stable part of the Koala genome. This was not found in the Koala bears in the mainland. So the endogenisation is

likely to have occured after the transfer to the islands. Thus the retrovirus sequences were inherited as endogenous viruses - in the surprisingly short period of 100 years. And the endogenisation provided protection against the exogenous virus infection.

Moo: I think about 50% of the human genome has endogenous retrovirus or retrovirus related genes.

Mari: So what defines us humans then? Not our genome, not the cells in us! At least now, we need to accept that we are an organism made from other organisms including viruses.

Zar: But for the viruses we will not be here today. Retroviral insertion millions of years ago when vertebrates were egg laying gave rise to genes that produce proteins called **syncytins.** These allowed the formation of the fetal membrane and the suppression of immune response which should reject the foetus as it is a foreign body in mammals with a placenta. This insertion event has happened not once but many times in different points during the evolution of mammals. This same insertion type event has been found even in lizards which developed the capability to give birth to *live young* as against *egg laying*.

Moo: Viruses are drivers of evolution. They are the dominant players of evolutionary change across mammals and humans. Many aspects of our adaptive immune system, parts of the brain development that define us, are due to such elements of viral origin.

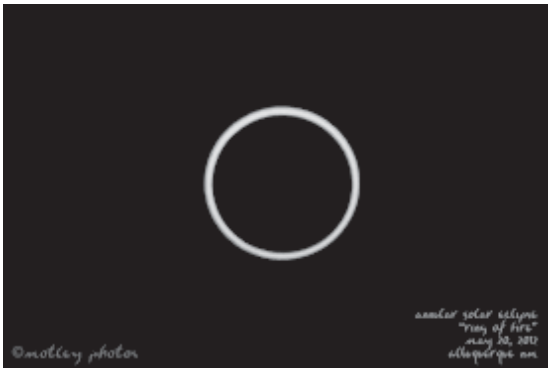
Usha: No viruses, no us. We need to learn this and treat them as friends and not foes. Peaceful co-existence is the only solution. Not a war against viruses.

Mari: Human activity in order to exploit resources has often lead to the introduction of pathogens to new hosts that were earlier not exposed to them. The Mayans were destroyed due to the Spaniards bringing small pox with them. The North American Indians were killed in large numbers due to the diseases introduced by the European invaders. The Australian aborigines are believed to have been wiped out due to infections brought in by the English settlers. So the enemy is within. Not the viruses but those who seek to exploit without regard to the native population of organisms whether humans or others.

Even as she was reading this, Mari felt herself being shaken. She opened her eyes and found her mother telling her "Mari, wake up. Freshen yourself and go to the computer. Zareena and Mookayi are waiting online to discuss with us about viruses. I will make some tea and bring it there."

"But Amma, the dreamer that I am, I already know what is going to happen", said Mari as she gathered her kindle that had fallen out of her hands when she had fallen asleep reading.

Read a more detailed version of this article at https://www.imsc.res.in/~indu/JM/2020/MayJun/Virus/viralwonderland_rev2.doc

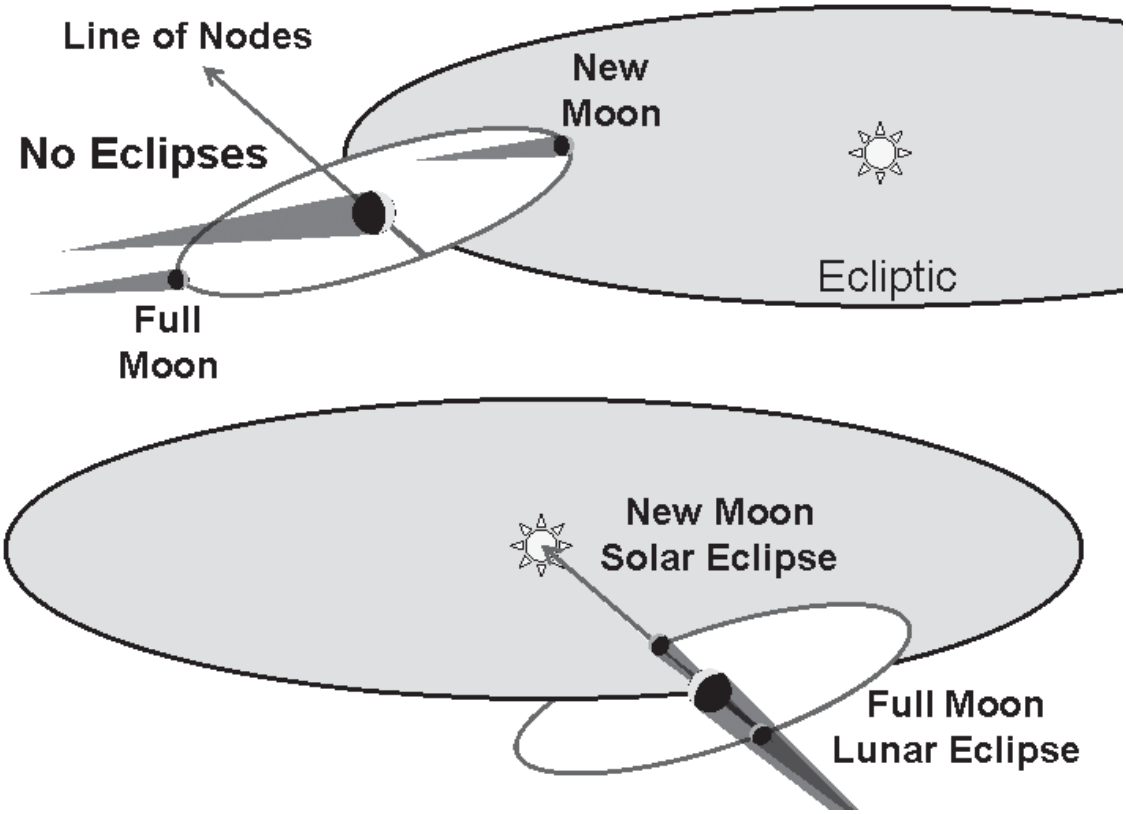


Annular solar eclipse— June 21, 2020

Kamal Lodaya

Eclipses require that the Sun, Moon and Earth be in a straight line (so that the shadow of one can fall on the other). Hence they can only happen on New Moon (*amavasya*) or Full Moon (*poornima*). Since June 21, 2020, is an *amavasya*, the Moon can come between the Sun and the Earth on that day. Its shadow falls on the Earth, giving us a **solar eclipse**.

The plane of the Moon's path around the Earth is tilted at an angle of 5° to that of the Earth's path around the Sun, as shown in the Figure. So on most New and Full Moons, the Sun, Earth and Moon do not fall in a straight line. Because the Moon's path is at an angle, only part of it may fall in the Earth's shadow. This gives rise to a *partial* lunar eclipse. For a **solar** eclipse to be partial, there is an



additional reason. The Moon's shadow on Earth is very small. So a central solar eclipse will be partial when seen from most places, and central only on a narrow path.

Eclipses are classified as:

partial when the Moon only partially obstructs the Sun, and

central when the Moon maximally obstructs the Sun.

Central eclipses are **total** when the Moon completely obstructs the Sun, and **annular** when a thin ring of the Sun's disc is not covered by the Moon.

Because the Earth-Moon distance varies, the Moon need not cover the Sun fully during a central solar eclipse. When the Moon is farther enough from the Earth we get an **annular** eclipse. When the Moon is close enough to the Earth we get a **total** eclipse.

On 21 June 2020, we have an annular eclipse of the Sun. The path of annularity is very narrow. It passes through Suratgarh in Rajasthan, Sirsa and Kurukshetra in Haryana, Yamuna Nagar in Uttar Pradesh, Dehradun and Joshimath in Uttarakhand at around 12:10. About 99.7% of the diameter of the Sun will be covered for 38 seconds at Joshimath.

Most of India will see a partial eclipse starting from around 10 or 11 am for 3 hours or more, ending at 1:30 or 2:30 pm. Bikaner and Delhi will see 95% of the solar surface covered by the Moon, Kolkata and Mumbai about 70%, Chennai just about half and Kanyakumari about one-third.

Viewing an Eclipse

Looking at the Sun, either directly or

through your camera, can burn your eyes and cause blindness. Never look at the Sun without adequate protection. Protecting your eyes adequately means reducing exposure to ultra-violet and infra-red radiation, which can damage your eyes instantaneously without your immediately being aware of it. Also, adequate protection will increase eye comfort by reducing the intensity of sun's visible rays.

The intensity of sunlight for direct safe viewing should be reduced by at least 100,000 times and ultra-violet and infra-red part of the solar radiation should be effectively cut off. Therefore always use a

filter that will absorb equally and sufficiently the ultra-violet, infra-red and visible energy of the Sun. You can wrap a solar viewing filter/ glass in front of the phone camera and view during the partial eclipse phases.

There have been wrong recommendations suggesting the use of materials that absorb the visible energy but do not absorb the dangerous, invisible infra-red rays. These days filters are sold by many commercial platforms. But ensure their safety by reading reviews about the products. Don't always go for cheaper alternatives, safety comes before savings!

Pin-hole images

Monitoring the progress of the eclipse will require seeing the partially eclipsed sun. An interesting phenomenon to observe during partial phase is the "Pin-hole" camera effect created by the leaves of trees as sunlight filters through them (more precisely, through gaps in them). Before the eclipse begins, the ground is covered by overlapping discs which are actually the images of the sun. As the eclipse progresses, these discs take the shape of the eclipsed sun. When the eclipse is quite advanced, one sees a myriad collection of crescents! Spread a white sheet on the ground to enhance the effect.

One can also observe by projecting the image of the Sun. This arrangement should work quite well, it is sometimes mounted on a ball: cover a plane mirror with a piece of paper having a circular hole of diameter 1 to 2 cms. The sunlight reflected is thrown on to a shaded wall indoors. Reduction in the diameter of the hole in the paper will increase the sharpness of the image at the loss of its brightness.

Pin-hole camera

Alternately, one can just build a *pin-hole camera* with two plane cardboard sheets. In one, make a hole that is not too small (smaller the hole, less bright will be the image), nor too big (bigger the hole less sharp will be the image). A separation of 1 metre can produce an image of about half a cm.

Based on the manual by N.D. Hari Dass and Kamal Lodaya

When fish get thirsty do they drink sea water?

Claire Lacey,
University of St Andrews

When fish get thirsty do they drink sea water?

The short answer is yes, some fish do drink seawater – but not all of them. Fish are amazing animals, and have some very cool solutions to living in water. Naturally, different types of fish have evolved different solutions.

The bony kinds of fish that live in the sea – such as cod, herring, tuna and so on – have a few ways of getting water in and out of the body. As well as swallowing and peeing, like humans do, these fish can pass it through their skin and gills

To understand how this works, you first

need to know that bony fish have a different concentration of salt in their bodies to their environment. This means they're more or less salty than the water they swim in.

The bodies of marine fish (which live in the sea) are less salty than the water they swim in, while the bodies of freshwater fish (which live in rivers and lakes) are more salty than the water they swim in.

Both marine and freshwater fish have to control the amount of water and salt in their bodies, to stay healthy and hydrated.

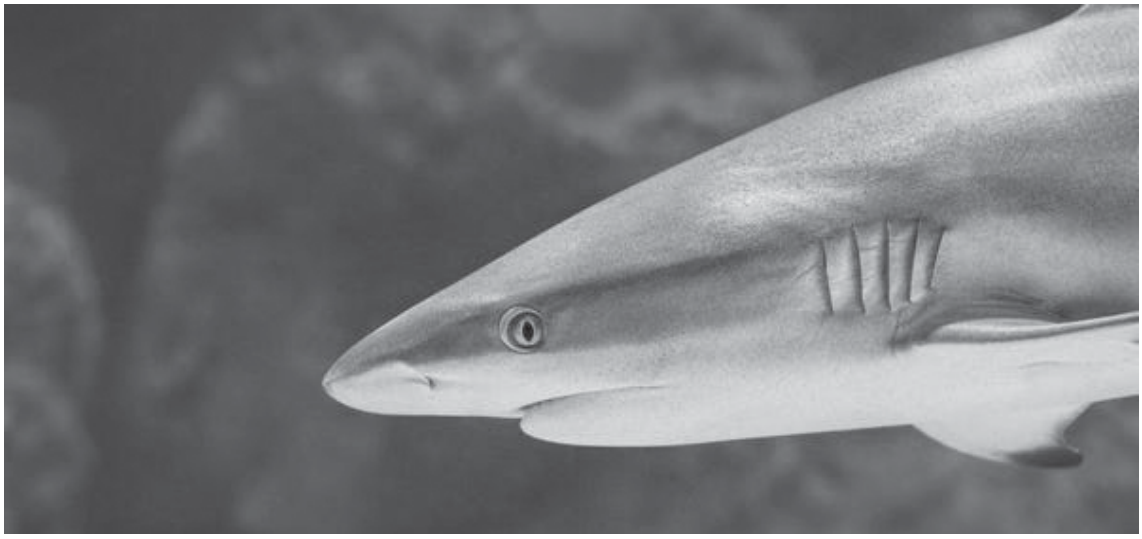
Hard to stay hydrated

Bony marine fish are constantly losing water from their body, through a process called "osmosis"". During osmosis, water moves through a membrane (like skin), from areas of lower concentration to areas of higher concentration.

Remember, the body of a marine fish is less salty than the seawater it swims in – which means it has a lower concentration of salt. So these fish actually lose water through osmosis: it passes from their body, through their skin and gills, out into the sea.

Since they're constantly losing water this way, these fish have to drink a lot of seawater to stay hydrated.

You might be interested to know that the opposite happens in freshwater fish. Water flows into their body through osmosis, instead of out. This means they



don't generally need to drink – but they do have to pee a lot.

We all know that too much salt is bad for us. So of course, an animal that drinks seawater must have a way to get rid of excess salt.

Marine fish have kidneys, which pump excess salt into their pee so they can get it out of their bodies. They also have special cells in their gills that pump excess salt out into the sea. Together, these two systems mean that marine fish can stay hydrated.

Salty sharks

Sharks have evolved a completely different system. Their bodies have a slightly higher concentration of salt than seawater. This means they don't have the problem that bony fish have, of losing water through their skin all the time.

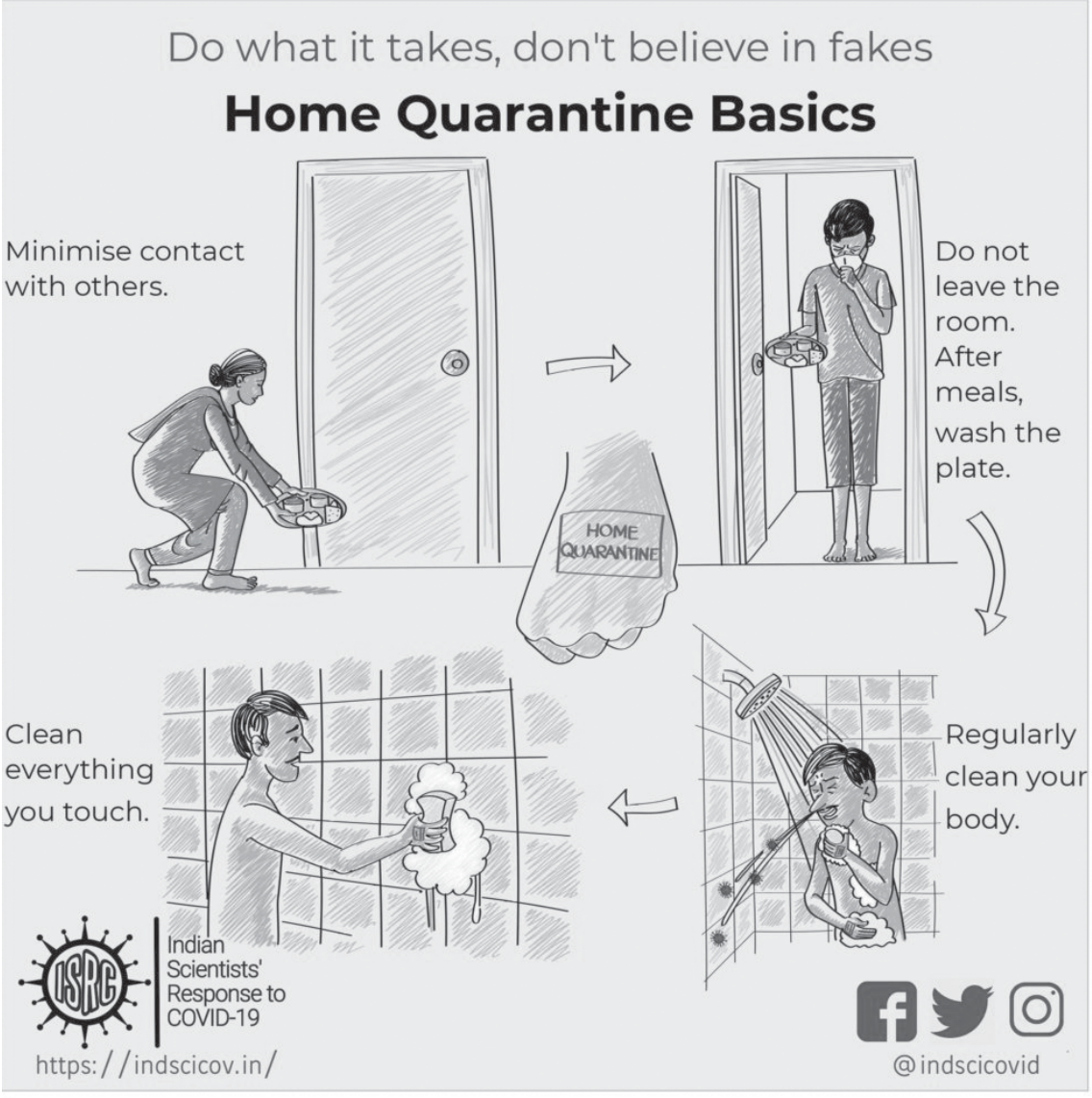
Sharks have high levels of waste chemicals – called urea and trimethylamine N-oxide – in their body, which other animals would usually get rid of. Sharks keep them in their body, which keeps them "salty".

Sharks take in small amounts of water through their gills (by osmosis – because they are slightly saltier than the sea) which means they don't directly have to drink.

Sharks also have a salt gland (in their rectum) to get rid of any excess salt they may have.

The problem of drinking seawater isn't just for fish. Some seabirds – albatrosses, for example – have to drink seawater too. Like sharks, these seabirds have a salt gland to get rid of excess salt. But on an albatross it is found at the top of the bird's beak.

From : https://theconversation.com/curious-kids-when-fish-get-thirsty-do-they-drink-sea-water-122761


Do what it takes, don't believe in fakes
Home Quarantine Basics
Minimise contact with others.
Do not leave the room. After meals, wash the plate.
HOME QUARANTINE
Regularly clean your body.
Clean everything you touch.
ISRC
Indian Scientists' Response to COVID-19
https://indscicov.in/
@indscicovid


Do what it takes, don't believe in fakes
Sensible Shopping Precautions
After the shopping
Wash hands with soap
Clean your legs
Remove your clothes and mask and wash them. Wash your hands again.
ISRC
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Do You Know?

1. I have seen “night vision goggles” in movies. How do they actually work?
2. Can stars become planets ever and go around other stars?
3. How fast can a human being run? Is there a limit and why?
4. Termites seem to work collectively. How do they manage to divide up the work?

Answers to Last Issue’s Do You Know?

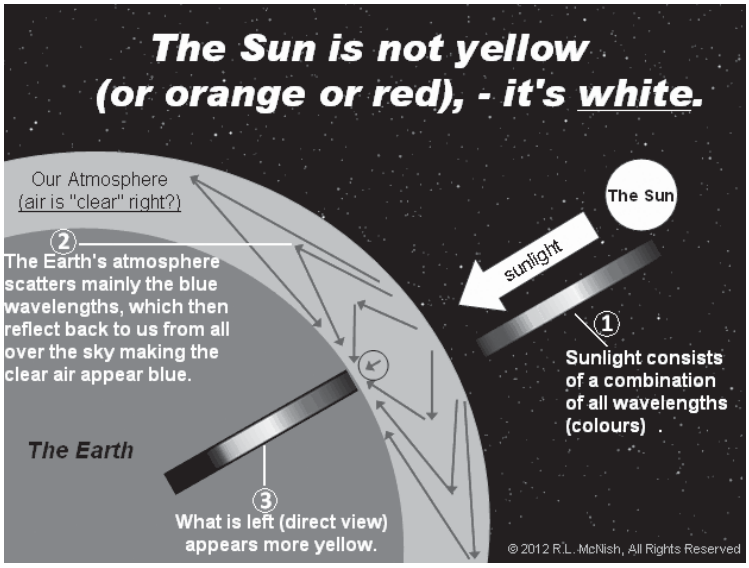
1. According to my science textbook, sunlight is white. Then why does it appear yellow to the eye?

Answer: Let us first start with a fact: white light is a combination of all colours produced equally by a glowing object. If that glowing object produces more blue light than it produces red, orange, yellow or green light, then it appears blue. Why does it produce blue or orange light at all? That depends on its temperature.

Now we can proceed to answer the question. The two reasons why the sun appears yellow are:

(a) The surface temperature of the Sun is 5,500 degrees C. This produces a range of visible light (red to blue) in which yellow is the largest, but not much more than the other colours it produces. If the Sun were cooler, say 2,500 degrees C, it would look red, like the stars **Antares** and **Betelgeuse**. Or if the Sun were hotter, say 15,000 degrees C, it would look blue, like the star **Rigel**.

(b) The Earth’s atmosphere acts as a kind of light filter, and some colours are filtered more than others. The Sun is a yellow star, but if you were to observe it from space where it would appear more white than



yellow. See NASA's photo on the cover page. It is the Earth's atmosphere makes the Sun look more yellow.

Actually you do not need to go into space to see the difference. If you are in the Himalayas at 4000 metres elevation, the Sun would look less yellow and more white than at sea level. This is because there are fewer air molecules at this elevation to filter the Sun's other colours. Imagine how the Sun would look from an airplane at 10,000 metres altitude: fully white.

There is another aspect to consider. For us it is easier to look at the Sun in the morning or the afternoon, even if only for a few seconds, than at noon. The Sun appears more yellow at those times than at noon when it looks at its brightest and whitest. The reason is that because of the Sun's high position at noon, the sunlight has less air to travel through. Less air means less filtering of other colours. (Please do NOT look at the Sun directly, it is dangerous.)

It is also relevant to recall why the sky appears blue: the short wavelengths (blue) of light from the Sun are scattered by the atmosphere.

2. How is a hissing sound produced when water falls on a hot surface?

Answer: Ask yourself first how you hear any sound at all. Sound propagates by a pressure wave: this happens by the to and fro motion of particles of the medium. When an object vibrates, the particles around the medium vibrate. The particle in contact with the vibrating object is first displaced from its static position. Each particle disturbs the other particle in contact. This sets up the pressure wave.

When water (or in general, when a liquid) heats up, its vapour pressure increases. It is the pressure exerted by the particles in a liquid by their kinetic energy (got from heating) in opposition to atmospheric pressure. When the vapour pressure increases to a value greater than the atmospheric pressure, boiling occurs. At what is called normal pressure (one atmosphere of pressure), this occurs at 100 degrees centigrade.

When water is poured on a surface that is sufficiently hot to heat water to its boiling temperature very quickly, it appears instantaneous to us. Then we can imagine that there would be a very hot local environment around the surface. The temperature then falls

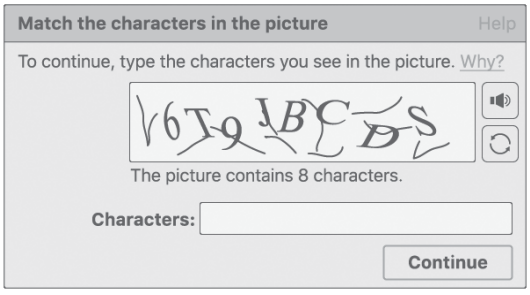
off so fast as you move away from the surface, that you can even say that the temperature and pressure are not affected by the surface at all. But at the same time the heat is enough to further heat, and increase the pressure of the water vapour boiling off of the surface. This rapid increase in pressure relative to the atmospheric pressure creates a pressure gradient which propagates as a sound wave, which is why you hear sound from the boiling water.

You do not hear the same sound from a pot of boiling water because we do not have the same rapid heating of water vapour creating the large pressure difference between vapour and the atmosphere.

3. Many websites have a "Captcha" to check that a human being is using it. How does this work?

Answer: The Internet has made a big difference in modern life. Especially during the times of national lockdowns to stop virus spreading, online transactions have become important. Students have online classes. Many of these services intended for human beings need a way to ensure that only human beings are using them. That is where these "Captcha" tests come in.

A natural question to ask: if it is not human beings using the services, who can it be?

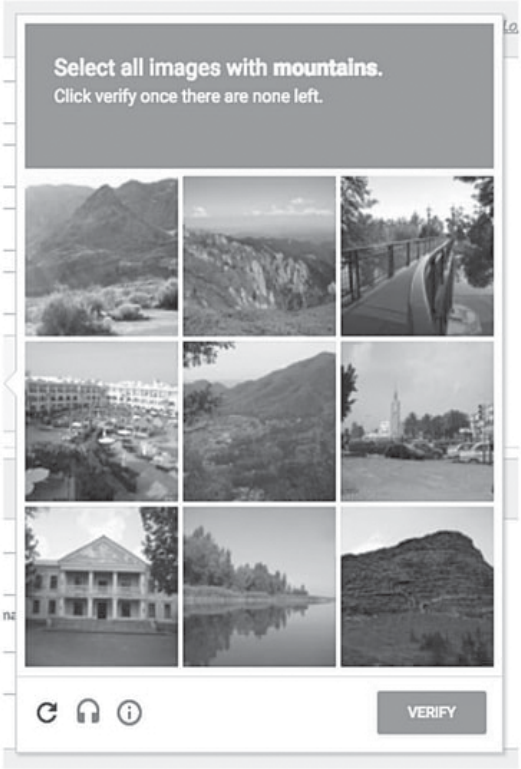


How can something inhuman use a "service"? The answer is simple: other computer programs. We need to understand that anything that we use on a computer (or mobile phone) is actually a program. It takes "input" from the user and responds. That input could come from another program Y, and the program X cannot tell.

This is what makes computers extremely flexible, connect to anywhere, disconnect at will. By programs connecting to other programs, we have built the Internet. That a program does not distinguish a device, a human being and another program is actually a great source of strength, an important principle in computer science. Unfortunately this comes at a cost: some services are meant only for human beings, where we wish to disallow devices and programs. To cheat these services, some programmers have created "bots" (short for Internet robots) that pretend to be human users and access secrets, commit frauds.

Bots can be trained to do many bad things. Bots can create multiple accounts on social networking platforms and email providers (like Gmail), thus inflating the number of users and creating havoc elsewhere on the internet with these email accounts. They can fill in forms with unwanted content and spread nonsense. They can post nasty comments on websites. Worse, they can collect people's passwords.

Hence the need to distinguish humans and bots is serious. **Alan Turing**, the British mathematician on whom the Hollywood film "The Imitation Game" was based, asked this question in 1950. He suggested that an



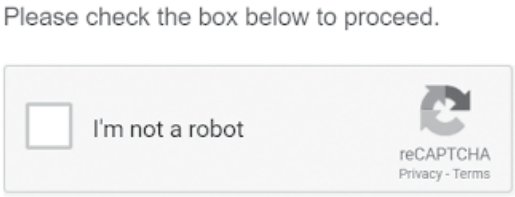
intelligent program is one that passes the **imitation test:** a human observer who submits questions should not be able to tell whether the answer is coming from another human being or from the program. This initiated the field of Artificial Intelligence and many researchers have been studying this problem.

Among these studies one led to CAPTCHA, short for "Completely Automated Public Turing test to tell Computers and Humans Apart", developed by American scientists in 2000. It was a way to filter out unwanted bots from websites by using distorted images, puzzles, audio transcription, etc. This method has been used to monitor credit card fraud by the program *PayPal*.

The idea is that programs find it hard to decipher distorted visuals, whereas humans can easily decode them. At one point in time, this CAPTCHA method was being used by 200 million users every day! In 2014, Google released a scientific paper stating that it had developed image recognition systems that are capable of solving the hardest CAPTCHAs with 99.8% accuracy, which made the current system unreliable.

In December 2014, Google announced that it had developed a new version of reCAPTCHA (a variant of CAPTCHA): the one that is common today, the "I am not a robot" click box. This version figures out with just one click if you are a human or bot. The method analyzes what the user was doing before, during and after clicking the box, including how you move the cursor. The CAPTCHA has not completely been replaced. Instead there are images of, say a cat, or traffic lights, or cars, that the user must identify among other options. This method is also a boon for people with visual impairments, as it reduces the time it takes to transcribe and replaces it with just a few clicks.

It is safe to say that this is an ongoing battle, between bot makers and bot breakers. At the moment the reCAPTCHAs and click boxes are doing better, but before long we can expect superior bots that can get around



them, leading to another escalation.

4. In many competitions, we often "root for the underdog", that is, support someone who would ordinarily be expected to lose. Why do we do this?

Answer: One simple reason for this is that it makes the competition more exciting. There is clearly no fun in any one-sided, predictable game. We want evenly matched players, and if one of them is clearly expected to lose, we would rather have that person be resilient and do better, just so that we have a matched game.

There is another reason why we support underdogs: in many ways, we feel that we are very much like them. Everyone likes to win in life, confront all our challenges, and emerge victorious. But we are not always that fortunate, and understand that one has to struggle. Deep inside us, we know how it feels to have everything going against us, while others may seem to be getting things easily. We can relate to the underdog, identify with their struggle, their passion and their resolve to push forward, despite being in a disadvantaged position. Another reason: watching the underdog persist through difficult times and succeed gives us the hope that we can perhaps succeed too.

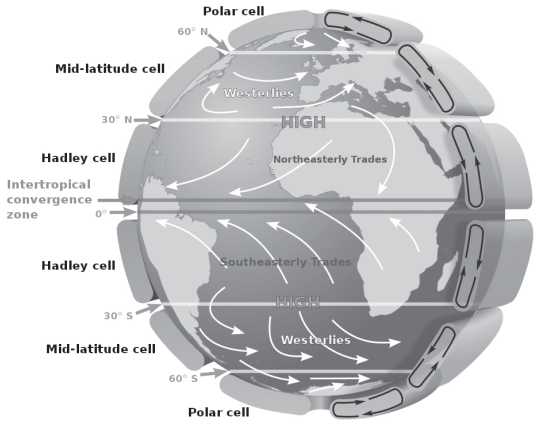
There is a deeper reason that social psychologists talk of: we all have a deep concern for justice and fairness within us. When we see the history of two teams, we might notice that the "top dog" has had far more victories than the underdog. Therefore, without even realising it, we introduce a parameter of fairness into our judgment, and conclude that things must have been unfair for the underdog. This is especially true if we see the underdog putting in very strong effort.

All these are plausible explanations, in the sense they can all be right, in different contexts, for different persons. It is not some thing we can always answer in general.

5. I always see wind coming from somewhere. Where does wind come from?

Answer: As I write this in Chennai on a June afternoon, I have strong breeze blowing — so much so that I have to shut the windows for fear of papers flying. The stiff breeze is invigorating, but we rarely to pause to wonder where it is coming from, and why. Wind is a localized phenomenon, but in reality, it is a byproduct from huge global cycles of pressure, temperature and moisture. At the most basic level, wind is born because of differences in Earth's temperature, which are caused by the uneven heating of our planet by the sun. Another crucial factor behind wind is the air itself, the atmosphere around us, which is composed of nitrogen, oxygen and water vapour. Wind is caused by the motion of air from areas of high pressure to areas of low pressure. Air pressure is defined as the amount of force that the air exerts on a specific area.

When a large mass of air is warmed by the heat of the sun, it begins to expand, become lighter, rises and disperses, thus exerting less pressure on the area. If the air that rises happens to be full of water vapour, then its movement can also create clouds, storms and adverse weather conditions. Conversely, there are also high-pressure



areas surrounding these warmer bubbles; when these low-pressure conditions are created and the air rises, the high-pressure air (cooler and drier) will rush in to fill the empty space above the ground. This movement of air is the atmosphere's attempt to balance itself and find stability, but in the process, wind is created.

Those who live on the coast have experienced this: the land temperatures rise throughout the course of the day, causing that air to rise, and the relatively cooler, high-pressure air over the water rushes inland to fill that empty space. At night, when the land temperature rises, the air over the water body is higher, so the wind direction is shifted as cooler air from the land flows back out over the water.

On a much larger scale, a similar thing occurs in the tropics, where hot air is continually being pushed upwards, where it spreads to the north and south, while high-pressure air from the north and south are summarily pulled into these tropical areas, where it will start to warm up.

The explanation above may suggest that wind tends to move in straight lines, from high-pressure areas to low-pressure areas in an easily predictable cycle. But it is more complex. The Earth is constantly rotating, and this affects how wind moves across the surface of the planet. The **coriolis effect** is the result of this rotational force exerted on anything moving relative to Earth.

The spin of the Earth changes the direction of the wind, so wind blows towards the Equator from the northeast in the northern hemisphere, and blows from the southeast in the southern hemisphere. Directionally, they blow to the right in the northern hemisphere and to the left in the southern hemisphere. This coriolis effect bends the direction of wind across the planet, resulting in easterlies (wind blowing in from the east), westerlies (wind blowing in from the west), and adverse weather systems like thunderstorms, hurricanes, monsoons and tornadoes.

How does the same movement of air that creates a gentle afternoon breeze also creates a cyclone capable of blowing houses down? When air moves across a pressure gradient (from high to low), it generates a certain amount of force. If there is a high-pressure area and a low-pressure area very close to one another, the pressure gradient will be high, the air will shift locations more forcefully, and wind speed will increase rapidly.

The wind is a fascinating natural system responsible for weather patterns and atmospheric balancing across the globe. It is basically how the atmosphere moves heat around the planet.

-Compiled from several sources

Science News

Headlines

- This cow's antibodies could be the newest weapon against COVID-19
- Scientists obtain 'lucky' image of Jupiter
- Pain Researcher David Julius Wins 2020 Kavli Prize in Neuroscience
- How Line-Dried Laundry Gets That Fresh SmellLaundry smell

Read more details below.

- **This cow's antibodies could be the newest weapon against COVID-19**

The latest recruits in the fight against COVID-19 are munching hay in a South Dakota barn in the USA. A biotech company has coaxed genetically modified cows to pump out human antibodies that subdue SARS-CoV-2, the pathogen causing the deadly disease, and it plans to start clinical trials of them this summer.

"This is promising," says Amesh Adalja, an infectious disease physician at the Johns Hopkins University Center for Health Security. "We want to have as many countermeasures as we can."

To manufacture antibodies for treating or preventing diseases, companies typically turn to sources such as cultured cells or tobacco plants. But almost 20 years ago, researchers began to develop the approach now pursued by SAb Biotherapeutics of Sioux Falls, South Dakota, to produce antibodies on the hoof. The company genetically alters dairy cows so that certain immune cells carry the DNA that allows people to make antibodies. That upgrade enables the animals to manufacture large quantities of human antibodies against a

pathogen protein injected into them, such as the "spike" surface protein of the new coronavirus. "Essentially, the cows are used as a giant bioreactor," says viral immunologist William Klimstra of the University of Pittsburgh, who has been analyzing the bovinemade antibodies' potency against SARS-CoV-2.

Cows make good antibody factories, and not just because they have more blood than smaller animals engineered to synthesize human versions of the proteins. Their blood can also contain twice as many antibodies per milliliter as human blood, says Eddie Sullivan, SAb Biotherapeutics's president and CEO.

The animals may provide another advantage. Most companies trying to produce antibodies to combat COVID-19 have pinned their hopes on mass-producing identical copies of a single version, a so-called monoclonal antibody that homes in on and attaches tightly to a particular section of a virus. Instead of making just one antibody variety, the cows fashion polyclonal antibodies, a range of the molecules that recognize several parts of the virus. "That's the natural way that our bodies fight disease," Sullivan says. This diversity may make the cow's proteins more powerful than monoclonal antibodies, he says, and they may remain effective even if a virus mutates.

When the COVID-19 pandemic erupted, SAb Biotherapeutics had already completed a clinical trial with cow-generated antibodies against Middle East respiratory syndrome, which is caused by a coronavirus related to SARS-CoV-2. Developing that treatment "gave us the initial knowledge to focus on the right target," Sullivan says. Within 7 weeks the cows were generating antibodies against SARS-CoV-2's spike.

Before the animals start to release these antibodies into their blood, the cows need a starter immunization—a DNA vaccine based on a portion of the virus' genome that preps their immune system. Then comes the injection that contains a piece of SARS-CoV-2's spike protein, which serves as the virus' passkey to cells. Each month, one cow can yield enough antibodies to treat several hundred patients, Sullivan says.

In test tube studies, Klimstra and colleagues recently pitted the antibodies against so-called convalescent plasma from the blood of COVID-19 survivors. Rich in polyclonal antibodies, the plasma is being tested in clinical trials as a treatment for the virus. The cow antibodies were four times better than convalescent plasma, preventing the virus from entering cells, the company announced last week.

The biotech hopes to begin a clinical trial within the next couple of months, Sullivan says, and wants to test whether infusions of antibodies sifted from the cows' blood prevent healthy people from getting infected by SARS-CoV-2 and prove beneficial for patients who are already sick.

Not everyone thinks the cows are the best choice for making antibodies, however. Infectious disease physician Manish Sagar of Boston University Medical Center says he will remain skeptical "until I see further proof that production of antibodies in cows is a lot more feasible and economically viable" than other

methods. So far, no antibodies generated by the animals have been approved for treating any disease.

But infectious disease specialist Jeffrey Henderson of Washington University School of Medicine in St. Louis describes the cow-produced antibodies as “the logical next step” to the convalescent plasma he has been studying. “The whole approach,” he says, “is based on sound science and on past experience going back more than a century.”

- **Scientists obtain ‘lucky’ image of Jupiter**

Astronomers have produced a remarkable new image of Jupiter, tracing the glowing regions of warmth that lurk beneath the gas giant’s cloud tops.

The picture was captured in infared by the Gemini North Telescope in Hawaii, and is one of the sharpest observations of the planet ever made from the ground.

To achieve the resolution, scientists used a technique called “lucky imaging” which scrubs out the blurring effect of looking through Earth’s turbulent atmosphere.

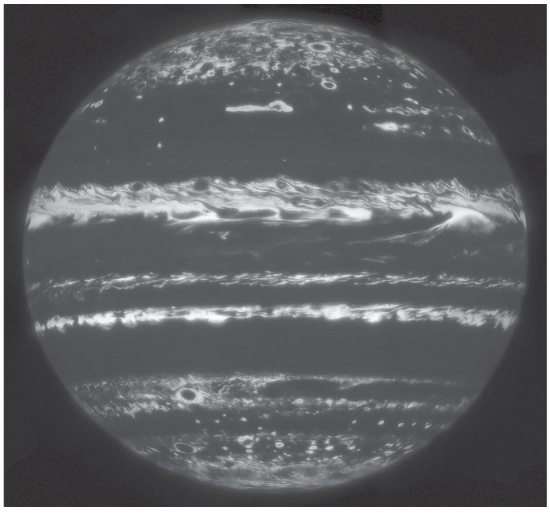
This method involves acquiring multiple exposures of the target and only keeping those segments of an image where that turbulence is at a minimum.

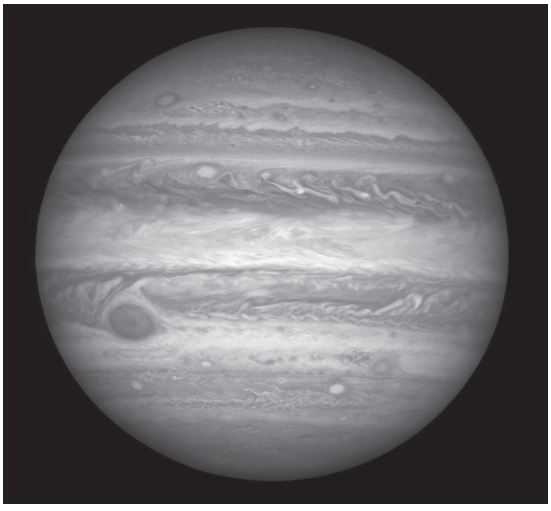
When all the “lucky shots” are put together in a mosaic, a clarity emerges that’s beyond just the single exposure.

Infrared is a longer wavelength than the more familiar visible light detected by the likes of the Hubble telescope. It is used to see past the haze and thin clouds at the top of Jupiter’s atmosphere, to give scientists the opportunity to probe deeper into the planet’s internal workings.

Researchers want to understand better what makes and sustains the gas giant’s weather systems, and in particular the great storms that can rage for decades and even centuries.

The study that produced this infrared image was led from the University of California at Berkeley. It was part of a joint





programme of observations that involved Hubble and the Juno spacecraft that's currently orbiting the fifth planet from the Sun. Also shown here is Jupiter as seen in visible wavelengths of light by Hubble Telescope. (Jupiter Image copyright NASA/ESA/ A.Simon)

Fast facts about Jupiter

* Jupiter is 11 times wider than Earth and 300 times more massive

* It takes 12 Earth years to orbit the Sun; a 'day' is 10 hours long

* In composition it resembles a star; it's mostly hydrogen and helium

* Under pressure, the hydrogen assumes a state similar to a metal

* This 'metallic hydrogen' could be the source of the magnetic field

* Most of the visible cloudtops contain ammonia and hydrogen sulphide

* Jupiter's low-latitude 'bands' play host to very strong east-west winds

* The Great Red Spot is a giant storm vortex wider than Planet Earth

- **Pain Researcher David Julius Wins 2020 Kavli Prize in Neuroscience**

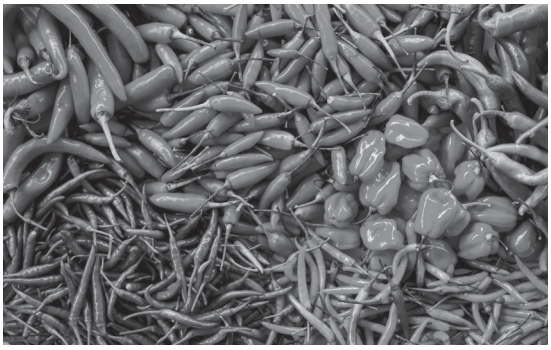
UC San Francisco biochemist David Julius has been awarded the 2020 Kavli Prize in Neuroscience for his foundational work describing the molecular machines that allow us to feel heat, cold, inflammation and related physical sensations. His research has opened up new avenues for the development of safe, targeted painkillers that researchers hope will avoid the addictive

properties and other side effects of opioids.

Julius, professor and chair of the Department of Physiology at UCSF, shares the prize, a cash award of one million dollars, with Ardem Patapoutian, PhD, a professor at Scripps Research and a Howard Hughes Medical Institute investigator.

In three decades of research at UCSF, Julius has focused on a class of ion channel proteins called TRP (pronounced "trip") receptors, and his work has stimulated intense interest in TRP channels as potential targets for new painkillers.

He has tried to understand how neurotransmitters, drugs, and natural products regulate the nervous system. The work that led to the Kavli Prize began by asking how the chemical compound responsible for the spicy "heat" of chili peppers – called capsaicin – causes a burning sensation when eaten or touched. This research laid the foundation for the detailed characterization of the specific protein responsible, named



TRPV1 – a specialized ion channel located at sensory nerve endings, which transmit electrical signals to the brain, where the sensation of heat or pain is ultimately generated.

Julius has shown that "hot" chili peppers are aptly named, since TRPV1 is triggered not only by capsaicin, but also by actual heat greater than 43 degrees C. This ion channel also contributes to the hypersensitivity to heat felt in injured tissue, such as sunburned skin, in which the brain perceives mild stimuli as burning hot.

Julius has also applied these approaches to identify the molecular source of the icy sensation triggered by menthol from mint. Just as heat acts on TRPV1 similarly to capsaicin, Julius's lab found that a related channel called TRPM8 can be activated either by menthol or by cold temperatures. A third TRP channel, TRPA1, responds to the pungent compounds that give the Japanese horseradish called wasabi its punch, and is also involved in inflammatory pain. Julius and Cheng have used cryo-EM to determine the structure of this "wasabi receptor," Julius and colleagues continue to use a variety of other natural compounds, including spider and scorpion toxins, to better understand the family of pain receptors these chemicals target, and have embarked on studies of more exotic sensory systems, such as the electrical sensation systems of sharks and skates.

- **How Line-Dried Laundry Gets That Fresh Smell**

People have written poems about it. It has been imitated by candles and air fresheners. At least one person has even fought in court for the right to produce it naturally. It's the smell of line-dried laundry.

Some atmospheric chemists like that scent, too. In a paper published this year in Environmental Chemistry, ilvia Pugliese and her colleagues pinpoint the source of their specific fragrance.

In between their more official thesis work, Ms. Pugliese and two labmates, with their adviser Matthew Stanley Johnson, commandeered two little-used areas of the university's chemistry building — a dark, empty office and a small, fifth-floor balcony — and obtained materials, including ultrapurified water and a set of cotton towels from Ikea.

Each towel got washed three times in the water, and then hung out: inside the office, on the balcony under a plastic shade or on the balcony in the sun.

When they came across the drying racks, "a lot of colleagues laughed," Ms. Pugliese said. "But we had a lot of support."

When a towel finished drying, the researchers sealed it in a bag for 15 hours. As the towel sat in the bag, they sampled the chemical compounds it released into the air

around it. The researchers performed similar sampling on an empty bag, an unwashed towel and the air around the drying sites.

By comparing the experimental towels' chemical profiles to those controls and to each other, the researchers were able to tease out which compounds popped up only when they hung wet towels in the sun.

Line-drying uniquely produced a number

of aldehydes and ketones: organic molecules our noses might recognize from plants and perfumes. For example, after sunbathing, the towels emitted pentanal, found in cardamom, octanal which produces citrus-y aromas, and nonanal which smells roselike.

Why is that? It may have to do with exposure to ozone, an atmospheric chemical that can transform some common chemicals into those aldehydes and ketones.

A more fundamental contribution, she thinks, may come from the sun itself. When exposed to ultraviolet light, certain molecules "get excited" and form highly reactive compounds called radicals. Those radicals then recombine with other nearby molecules, processes that often lead to the creation of aldehydes as well as ketones.

It's possible that the water on a wet towel gathers a lot of these excitable molecules together, and then works "like a magnifying glass, concentrating the sunlight and speeding up these reactions.

Similar processes are likely occurring on any number of natural outdoor surfaces, including bare soil and individual blades of grass — perhaps part of the reason that sun after a rainstorm makes the world smell fresh. Although the scent seems to last longer on clothes, potentially because aldehydes bond with cotton.

Ricardo López, a chemist at the University of Zaragoza in Spain who was not involved in the research, thinks the aldehydes and ketones may not tell the whole story. "When testing for key flavor compounds, sometimes compounds in low concentrations are as important as those in high concentrations," he said. Additional forms of testing might be helpful to get the full bouquet.

Ms. Pugliese has, for now, moved onto headier things — her doctoral research involves artificial photosynthesis but she hopes to dig into similar topics in the future. "I thought it was a really nice way to do science," she said.

"Adapted from various sources, including Science, BBC News, University of California, San Francisco, and New York Times"

Nightskywatching

Kamal Lodaya

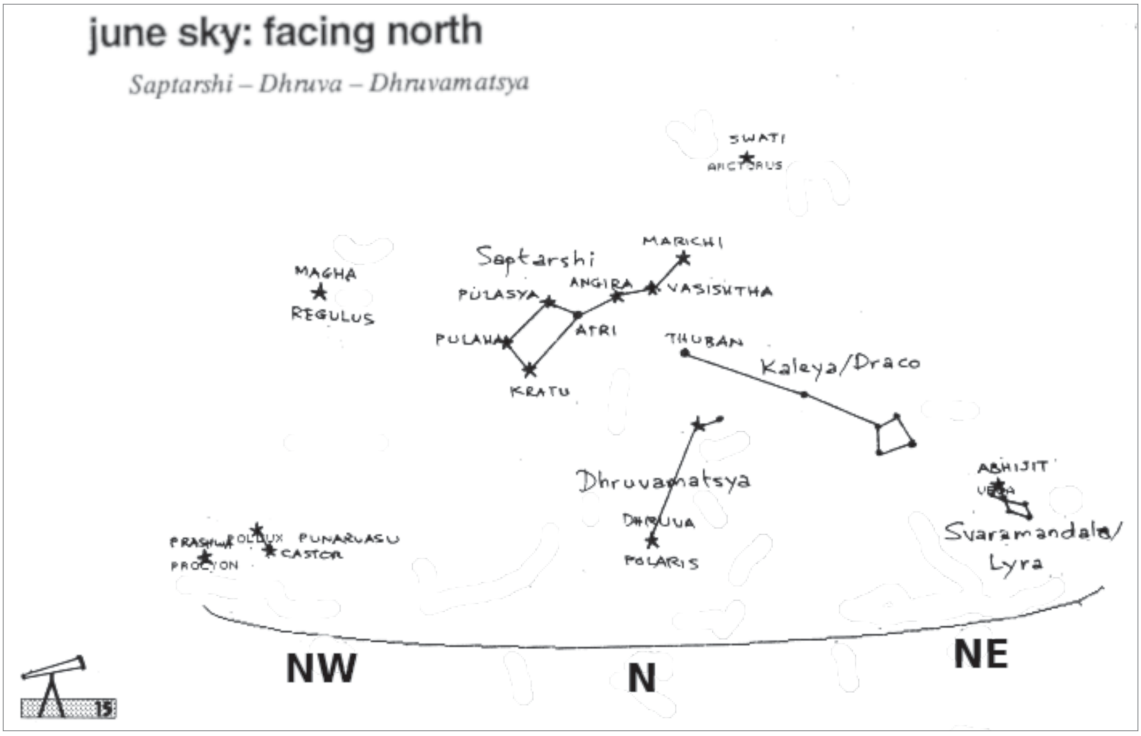
Every issue, ***JM*** has a map of some stars seen during the month, with a small explanation. Take this map to a place where the sky when you face North is dark and there are no lights in that direction. East is where the Sun rises in the morning.

The map shows stars seen at 9 pm on June 1st, or at 8 pm on June 15th, or at 7 pm on June 30th. Take a few minutes to let your eyes get adjusted to the darkness. Then you will start seeing stars. Use a small torch (maybe from your phone) covered with red paper to give a soft red light to the map. Red light interferes least with your ability to see things in the dark.

Facing North, you will find the large constellation of **Saptarshi** with four stars forming a quadrilateral, and then a curving arc of three stars pointing upwards. Following that curve overhead you will find the bright yellowish star (*vinmeen*) **Swati**, called *Arcturus* in English. Follow the curve some more and you come to **Chitra**, a bright white star in the constellation **Kanya** or *Virgo*, the Young Girl. Follow the curve a bit more and you reach the little constellation of **Hasta**, known as *Corvus the Crow* in English.

Those seven stars have names: in order, *Kratu*, *Pulaha*, *Pulasya*, *Atri*, *Angira*, *Vasishtha* and *Marichi*, the seven rishis, in English it is called the *Great Bear*. (Do bears have tails?) It is one of the best known constellations, you might even find someone who knows it and can show it to you.

If the sky is clear, very close to *Vasishtha* you will find a faint star, named after his wife *Arundhati*. This pair of stars is mentioned in the Mahabharata, which was written from about 800



BCE to 400 CE, so around 2000 years ago. Now they could be just in the same line of sight as seen from Earth, but they are reasonably near each other, about half a light year from each other. (A light year is the distance light travels in one year. Our Sun is 8 light minutes away from us. The two stars are around 80 light years away.) It is not known if they are a real couple, that is, whether they are bound to each other by gravity.

More recently it was pointed out to **Galileo Galilei** in 1617 (which he checked with his telescope) that the star *Vasishtha* (*Mizar* in Arabic and English) is itself a pair, in this case the two stars of the pair appear equally bright. Separated by about 4 light days, they actually revolve around each other over thousands of years.

Each of these stars, *Mizar A* and *Mizar B*, are themselves double stars revolving around each other, *Mizar A* has identical twins, both yellow and 35 times as bright as the Sun, revolving around each other in about a day. The *Mizar B* pair revolve arond each other in about six months. All this we cannot see. It was *inferred* from the Doppler shift seen in its spectrum by astronomer **Antonia Maury** in 1890. She was the first to find such a spectroscopic pair. If you lived on a planet there you would have four suns in the sky. What fun!

5th June is Full Moon (*Jyeshtha Poornima*) and 21st June is New Moon. The month of *Jyeshtha* ends with the amavasya and the month of *Ashadha* begins. Why are they called Jyeshtha? Check out the July night sky.

Questions: Please send questions and experiences about your night sky watching to JM.

Nightskywatching: July Sky

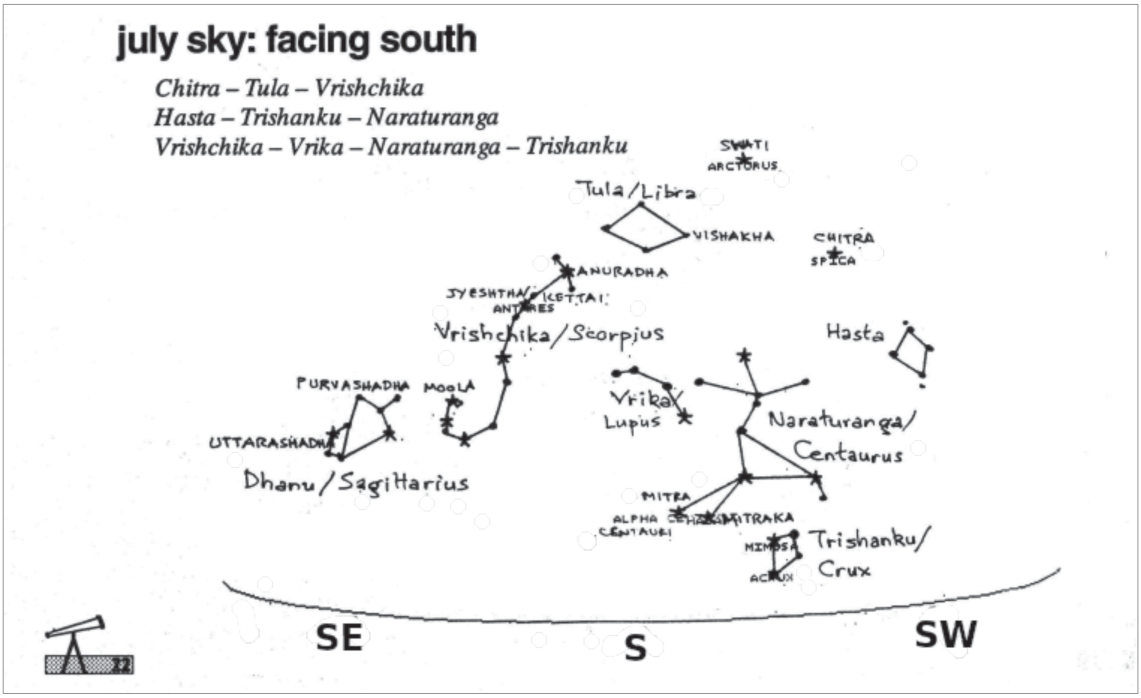
The map shows stars seen at 9 pm on July 1st, or at 8 pm on July 15th, or at 7 pm on July 31st. Take a few minutes to let your eyes get adjusted to the darkness. Then you will start seeing stars. Use a small torch (maybe from your phone) covered with red paper to give a soft red light to the map. Red light interferes least with your ability to see things in the dark.

Facing South, you will find the large constellation of **Vrischika** or *Scorpius*. It is also a “rashi”. The scorpion’s head (three stars) is called the **Anuradha** *nakshatra*. The bright reddish star *Antares* in its middle is called *Jyeshtha* or *Kettai* or *Parijat*. The tail of the scorpion, with two stars very close to each other forming the “sting”, is called the **Moola** *nakshatra*.

Gandhiji learnt to recognize the constellations and stars in the night sky when he was in Yerwada jail in Pune with **Kaka Kalelkar**. In a letter he wrote to children in *Sabarmati ashram*, he regretted that he never got to see *Parijat*. The map should help you find it.

Here is another way. If you know how to find the constellation of **Saptarshi** in the North, and follow the curve of its tail to *Swati* and *Chitra* and the little *Hasta*, you will find they are in the southwest. Taking a right angle left **coming up** from *Chitra* to *Swati* until you reach the south, you should find the reddish looking *Jyeshtha*.

Going the other way from *Chitra* to *Hasta* and taking a right angle **down**, you will find two bright stars (below right from *Scorpius*).



The one on the left is **Alpha Centauri**, just 4 light years away, the nearest star after our Sun. Here is your chance to see it.

Just imagine, seen from **Alpha Centauri,** our Sun looks like a similar yellow star!

Planets

The **Moola** *nakshatra* is the "sting" of the scorpion. If you follow the direction they point to towards the southeast horizon, you will find the bright planet *Jupiter* (**Guru** or **Brihaspati**) and the less bright planet *Saturn* (**Shani**). They are better seen later at night when they rise higher. July 5 is Full Moon (*Ashadha poornima* or *Guru poornima*) and July 20 is New Moon. The month of *Ashadha* ends with the amavasya and the month of *Shravana* begins.

Last month we had the *Jyeshtha poornima*, can you guess why it is so named?

On 3rd June, the Moon will be near Jupiter and Saturn. Hmm, the sky is so big. Why do the Moon and Jupiter and Saturn find only one place to gather together in? This kind of coincidence is a great boon to astrologers, they will forecast all kinds of things from such "conjunctions". If you have been following this series of articles in ***JM*** you will have realized that the Moon and planets (and the Sun if you could see the stars behind it) follow the *same circular arc* along the sky, and what we call the **nakshatras** (not all *vinmeen* are nakshatras), such as *Anuradha*, *Jyeshtha* and *Moola*, and the rashis such as *Vrischika*, are so named because they mark their path in the sky. Since the Moon goes around this path over one month, on one day of the month it has to come in front of Jupiter and Saturn. The Moon is about 4 lakh km away, Jupiter behind it is 75 crore km, Saturn behind it is 140 crore km away. ●

Microbial Life Deep Under the Seafloor—A Story of Not Giving Up

Man-Yin Tsang,
Fumio Inagaki

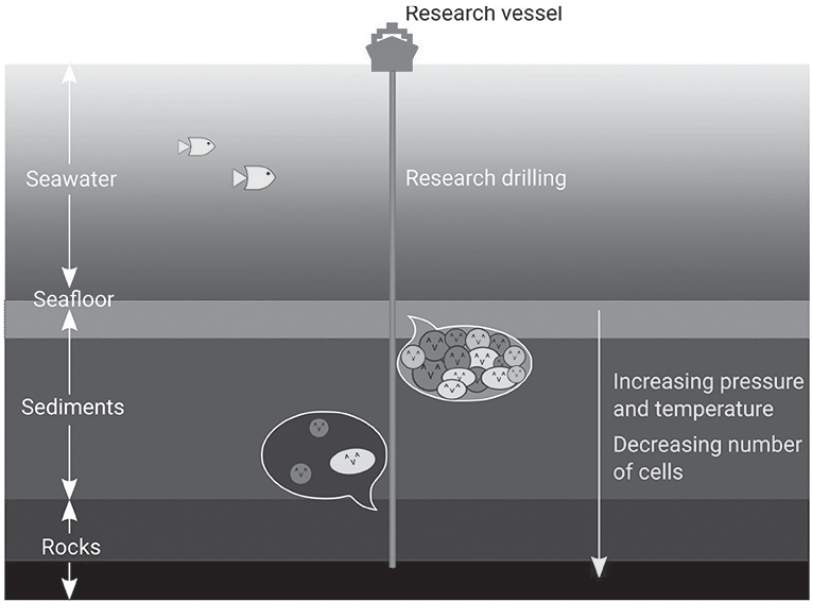
Below the seafloor are trillions of single-celled microbial life. Marine sediments bury these micro-organisms deeper and deeper. Meanwhile, the micro-organisms face increasing pressures and temperatures and reduced amounts of food and water. Although they are living in difficult conditions, these micro-organisms stay alive and maintain their communities. To date, we know that these microbial communities can survive for millions of years, at 2.5 km below the seafloor, and at temperatures over 100°C. Scientists use multiple approaches to study these fascinating micro-organisms.

Under the Seafloor: a Harsh Place to Live

You jump into the sea and sink slowly in the salty water. It gets darker and darker, as light cannot reach the deep sea. You lie on the seafloor with some fish, squids, and worms. At a rate <1 cm every 1,000 years, dust from above buries you. You become part of the sediment and can hardly move. How can one survive under the seafloor? While humans are not fit to live there, micro-organisms are (shown as coloured circles in the figure). You can find them in the sediment of all the seafloors on Earth. These micro-organisms are so tiny that each of them is made of only one cell. Scientists estimate that there are more one-celled organisms under the seafloor than there are stars in the universe!

Is it difficult for the micro-organisms to live under the seafloor? Yes, it is. These organisms face high pressures, lack of water and food, and high temperatures.

Seafloor micro-organisms need to cope with higher pressures the deeper they are buried. In deep-sea sediments, these micro-organisms withstand pressures hundreds of times higher than what we experience at the surface of the Earth. Therefore, scientists study these micro-organisms to understand the limits of life and the strategies these micro-organisms use for survival. These micro-organisms inspire us to invent new materials and medicines for coping



with extreme environments. They also play a part in regulating carbon and oxygen, and the Earth's climate over its long history. Some of the micro-organisms produce interesting chemicals, such as methane, which we may use to generate energy.

The figure shows the changes in physical conditions under the seafloor, measured in the Nankai Trough, east of Japan. At the seafloor (4.8 km underwater), the pressure is already high—imagine 305 elephants standing on your chest! When we go down another kilometer under the seafloor, the pressure greatly increases, to an equivalence of about 365 elephants standing on your chest-60 elephants more!

Micro-organisms live in the space with water between sand and clay grains. At the seafloor, 60% of the sediment is space. At 1 km under the seafloor, half of the space that can hold water is gone. The temperature increases from 2°C at the seafloor to about 100°C at 1 km below the seafloor. That is the difference between swimming in Arctic water and in boiling water. The deep sediment at the Nankai Trough is particularly hot. Ordinary sediments at 1 km depth are about 20°C.

As the micro-organisms are buried, the tremendous amount of seawater and sediments above squeeze their living environment. The deeper the micro-organisms are buried, the less water is in their immediate environment. Thus, while the seafloor is right under seawater, the micro-organisms under the seafloor can face a lack of water.

Another challenge to these deep micro-organisms is a lack of food. Less than 10% of the organic food from the sea surface eventually reaches the seafloor. If you have a banana, which part of the banana will you eat, the sweet flesh inside or the tough peel? Most of us will choose the sweet flesh. It is a similar situation in the deep sea. As food sinks from the sea surface, organisms above the seafloor take whatever is easy to digest and yields the most energy. The last bits of food that reach the seafloor are the less favorable options, the "banana peel" left on the plate. Since they have food with very few nutrients, micro-organisms deep below the seafloor need to conserve their energy, so they are not very active. They can only afford to expend energy that is essential for survival, for example, to repair body damage and support the basic functions of life.

Since these deep micro-organisms are inactive, you may be picturing them "chilling" under the seafloor! But, "chilling" is not exactly the right word, because their homes can be very hot! The deeper the micro-organisms, the higher the surrounding temperature. Why? Well, there is heat coming from inside the Earth. Sediments above the micro-organisms are like blankets that trap heat, so the temperature increases. The thicker the blanket, the hotter the environment becomes. The temperature commonly increases by 2°C every 100 m (however, in some areas, such as the Nankai Trough east of Japan, the temperature can increase by 10°C every 100 m). By volume, half of the marine sediments on Earth have temperatures higher than 40°C; a quarter are higher than 80°C.

After learning about all of these challenges, we can conclude that life is difficult under the seafloor. We might think that any organisms would struggle to survive under these conditions, but, to our amazement, we have

found living micro-organisms with more than 2.5 km of sediments piled up on top of them! Laboratory experiments have found that some micro-organisms can grow even at 122°C. Although they are only performing the basic functions needed for survival, these microbial communities can survive below the seafloor for tens of millions of years. Scientists drill into the seafloor to sample these old microbial communities. Often, when we take these micro-organisms back to the laboratory and feed them nutritious food, they thrive again! It is amazing to think about how these tiny organisms have lived in hardship, persisting for millions of years. If, one day, they have a chance to rebound, they make the most of that opportunity.

How Do Scientists Study Micro-organisms Below the Seafloor?

To study these deeply buried micro-organisms, we first need to take samples of the sediment or rock under the seafloor. When studying micro-organisms in coastal areas, we can sail a small boat to take samples. In the deep sea, with kilometers of water depth, we need specialized vessels that can drill into the seafloor.

The figure shows **The Chikyu**, a drilling research vessel. The polygonal platform at the bow is a helicopter deck and the tall tower behind is a drill rig. Next to the photo a part of a sediment drill core can be seen. The circle indicates a greenish-yellow, roughly 5 cm-long, pyrite mineral formed from the waste products of micro-organisms. The enlarged image of the pyrite (1,400 times) from a scanning electron microscope is shown on the right side of the figure. Pyrite under the seafloor is often framboidal (raspberry)-shaped when enlarged.

Once we get the samples, we remove the outer layer of the samples to get rid of contaminants from seawater during drilling. Then we further process the samples to preserve them for later studies. For example, some biological and chemical studies require the samples to remain fresh, so we store them in freezers below 0°C or even at -80°C. When studying micro-organisms that do not like oxygen from the air, we need to process the samples in nitrogen-filled boxes in the laboratory. We clean and sanitize equipment and always wear gloves to prevent contamination of the samples with micro-organisms from our own bodies. Some laboratories are even designed to prevent dust in the air from contaminating the samples.

To count the number of micro-organisms in each sample, we can look at the samples with high-power microscopes. To learn about who the micro-organisms are, we can analyze their genetic materials DNA and RNA. Genetic materials control how the cell develops and behaves. Different types of micro-organisms

Front Cover: Flowering rain tree, Albizia Saman, Photo credit Wikipedia

Back Cover top: Bioluminescence in jellyfish, Photo credit: Wikipedia

Back Cover bottom: Sunset over the Pacific Ocean, as taken from space. Compare the light reflected off of the Earth's oceans -- which passes through the atmosphere twice -- with the light directly from the Sun: The direct sunlight? Nearly perfectly white! But the light that passes through the Earth's atmosphere, reflects off the ocean, and heads back through the atmosphere to you? Yellow! Photo Courtesy NASA.

have different genetic materials (DNA or RNA) present in the samples. To study how active the micro-organisms are, we feed them some artificially prepared food with chemical tags. Later, we measure the number of chemical tags in the waste products of the micro-organisms, to calculate how much food the micro-organisms take.

We can also study the activities of the micro-organisms by looking at the environmental changes they create in the sediments. For example, a large group of micro-organisms under the seafloor breathe in dissolved sulfate instead of oxygen. Where this group of micro-organisms is active, we can observe a decreased sulfate content in the water of our samples. This group of micro-organisms also produces hydrogen sulfide gas, H_2S, as waste. H_2S reacts with iron in the seafloor and forms the mineral pyrite—a greenish-yellow mineral with the nickname "fool's gold". By studying the pyrite that arises from microbial processes, we can learn about the micro-organisms themselves. The advantage of studying minerals is that minerals can be stable in sediments and rocks for millions of years. Thus, using minerals, we can study the activity of micro-organisms that lived in the distant past.

Conclusion

Over the past decades, we learned a lot about deep microbial life below the seafloor, but so many questions remain unanswered. These questions include: what is the maximum depth and age at which these micro-organisms

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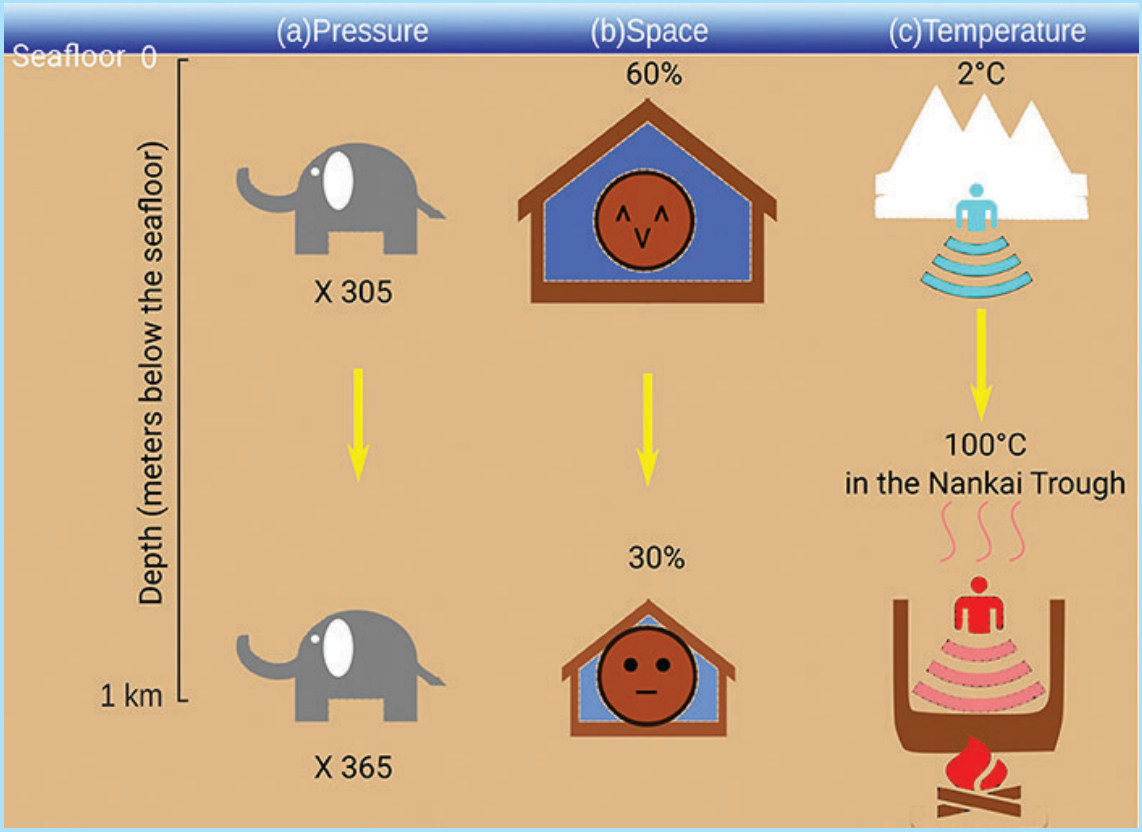
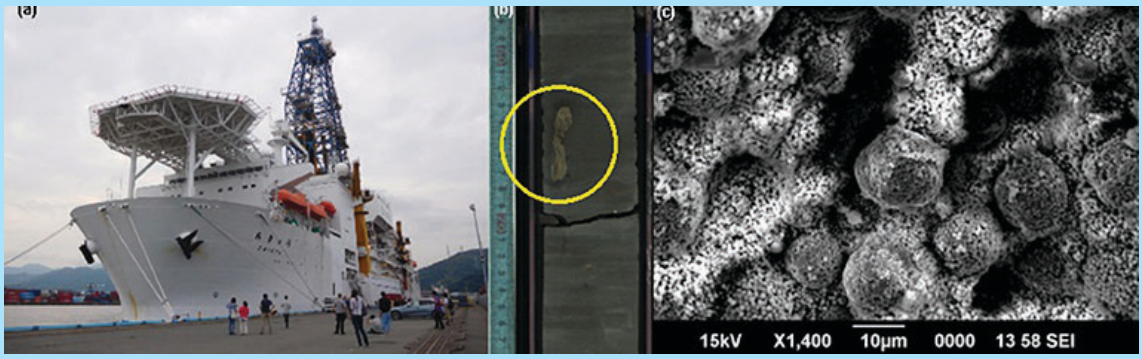


can live? What is the maximum temperature and pressure they can bear? Do different types of micro-organisms help each other to survive in deep sediments? Are there unknown chemical pathways that the micro-organisms use to generate energy? Underneath marine sediments are basement rocks, such as basalt. Are the micro-organisms in these rocky environments the same as those in the sediments above? Scientists are eagerly trying to answer these questions. Deep micro-organisms have surprised us with their persistence and ability to adapt. These tiny organisms deep under the seafloor teach us big lessons and will continue to surprise us in the future. ●



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