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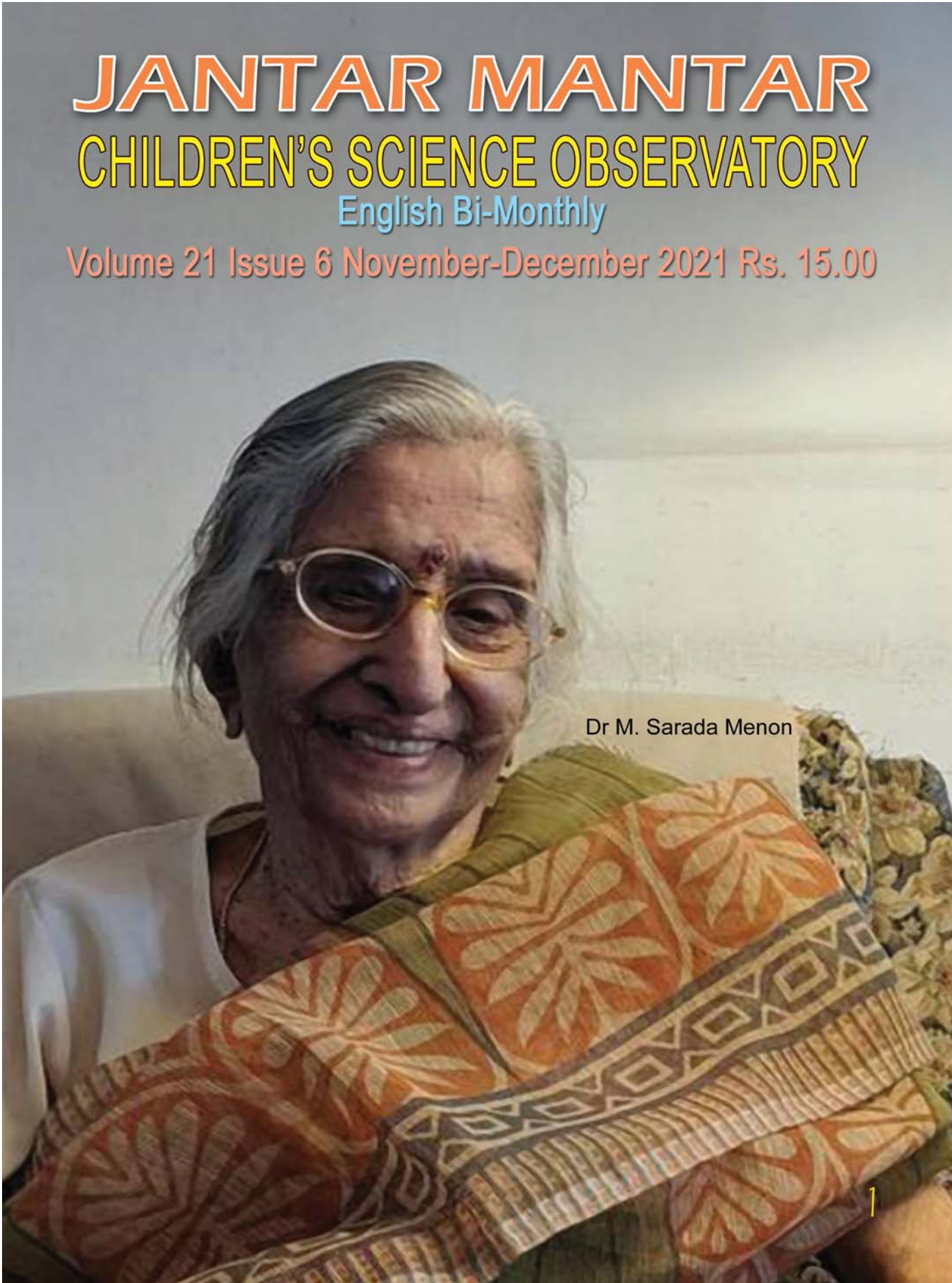


Dr M. Sarada Menon

Dr M Sarada Menon

1923-2021

Sarada Menon was born before India's independence, on 5 April 1923. She was India's first woman psychiatrist, and the founder of the Schizophrenia Research Foundation. She passed away recently on 5 Dec, 2021.

She was a final-year medical student in Madras in the 1950s, when she visited a mental hospital. In those days, there was very little understanding of mental illness. The patients were filthy and uncared for, and no-one knew how to help them when they became aggressive or violent.

Dr Menon was perturbed by the indignity of their lives, and felt that she "must do something". That moment of empathy was the first step in her life-long effort to transform the lives of mentally ill people.

Today, mental illness does not carry (or should not carry) the stigma that it did more than 50 years ago. Today's psychologists and psychiatrists enable many mentally ill people to lead useful and productive lives. Importantly, they also enable them to try and lead independent lives.

The eighth and last daughter of Malayali parents, she was born in Mangalore but studied later in Chennai when her father moved there. She studied medicine in Madras Medical College, one of the very few women to study medicine in those days. After realising the plight of the patients she met in the mental hospital, she went on to specialise in psychiatry at Bangalore's India Institute of Mental Health (now called **NIMHANS**).

In those days it was common for mentally ill patients to be sedated or subjected to electric shocks to calm them down when they became violent. They were locked in rooms for long periods and not allowed to go out and exercise in fresh air. Often they were abandoned by their families so that they did not even have any social interaction.

Slowly these attitudes changed. Dr Menon was one of the early practitioners who helped change the mind-set of people towards mental health. Drugs were often very effective in helping mentally ill people to lead an active and independent life. Importantly, such people needed sympathetic employers so that they could also become financially independent and not a burden on their family. Also, the hospital wards and premises needed to be a calm place where the patients could get better and feel secure.

Dr Menon made all this possible at the **Government Kilpauk Mental Hospital** in Madras, when she was the superintendent. Patients were treated humanely and the place became a rehabilitation centre with a great degree of success. An out-patient department was set up, and a day care centre where families could leave patients for the day. Social workers were brought in to act as a bridge between

patients and doctors; and the mentally ill were coaxed back into a life of self-independence and work. Because of Dr Menon's efforts, the Tamil Nadu Government opened psychiatry centres in all district hospitals. She is remembered not only as an institution builder but as a teacher and practitioner who inspired future generations of psychiatrists.

Even today there is a lot of ignorance about mentally ill people and how to treat them kindly and compassionately. There is also a social stigma around mental health issues; many people do not want to admit that their close family member has mental health issues. However, things are slowly changing and people are being more sensitised to the fact that mental health problems are treatable through a combination of medicines and therapy. Dr Menon was one of the scientists responsible for this visible change.

Dr Menon was also keenly aware of the fact that families of mentally ill people have a very difficult life, with very little soial support. She was responsible for starting **AASHA**, a community-based organization to help such families in Chennai. In fact, she converted one of the rooms in her own house into a shelter for such needy people. Later, in 1984, along with a few like-minded people, she founded **Schizophrenia Research Foundation** (SCARF), a non-profit non governmental organization, for the rehabilitation of people afflicted with schizophrenia and other mental diseases. She also recognised the stress on prisoners living in cramped and unhealthy prisons and was a member of a committee that proposed various prison reforms, especially with a view to improve the mental and physical health of prisoners.

Dr Menon has won many awards, including the Padma Bhushan by the Indian government in 1992. This simple and compassionate psychiatrist and social worker died at the age of 98 on Dec 5, 2021, leaving behind a great legacy and many grateful patients and their families.

Sources: Newspaper sources and Wikipedia

Her own words on mental health patients:

"These people can be made whole. Mental illness is like any other illness. Response to treatment should not be sidelined from the mainstream of medicine. If treatment is not given properly, relapses occur. About 20 per cent recover well fully, 60 per cent need rehabilitation to come back to original state, 20 per cent do not recover. Even with this 20 per cent one can work on their residual ability and tap their resources to a constructive goal. When we can tolerate a drunkard, why not a schizophrenic? Give affection. Be considerate."

SCARF

Over the years, SCARF has developed into a full-fledged research base and is one of the few Indian institutions recognized by the World Health Organization (WHO) as a Collaborating Center for Mental Health Research and Training. The organization provides temporary shelters and telepsychiatric therapy, runs vocational training centers aimed at the rehabilitation of patients and manages a mobile clinic. They also facilitate employment and conduct awareness campaigns and research projects regularly.

The year 2021 in Science

The year 2021 (and mostly 2020) was dominated by Covid-19 and climate change. Here is a compilation of some of the highlights in science of 2021.

January 2021

● Chinese scientists have established the world's first *integrated quantum communication network*. It connects two ground-to-satellite links to 4,600 kilometers of optical fibres.

● Global ice loss is found to be accelerating at a record rate in a scientific review, matching the worst-case scenarios of the IPCC.

February 2021

● COVID-19 pandemic: Russia's **Sputnik V vaccine** is shown to be 92% effective against COVID-19.

● The Chinese **Tianwen-1 spacecraft** successfully enters orbit around Mars. Its lander *Zhurong* landed on Mars in May.

March 2021

● The **Event Horizon Telescope** presents the first polarized-based image of a massive black hole, at the center of **Messier 87**, revealing the forces giving rise to quasars.

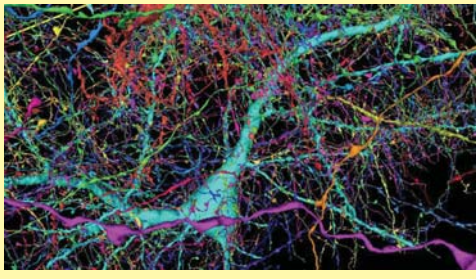
April 2021

● NASA's Mars 2020 mission (containing the Perseverance rover and Ingenuity helicopter) lands on Mars at Jezero Crater in March. **Ingenuity** performs the first powered aircraft flight on another planet in history.

● A *malaria vaccine* with 77% efficacy after 1 year – and first to meet the WHO's goal of 75% efficacy – is reported by the University of Oxford.

May 2021

● Google demonstrates a research project called **LaMDA**, an automatic language generation system designed to sustain a conversation with a person on any topic.



● Google and Harvard University made an amazing 3D colour-coded 1 mm^3 sized map of nearly 4,000 incoming *axons* connecting to a single *neuron* in the human brain.

June 2021

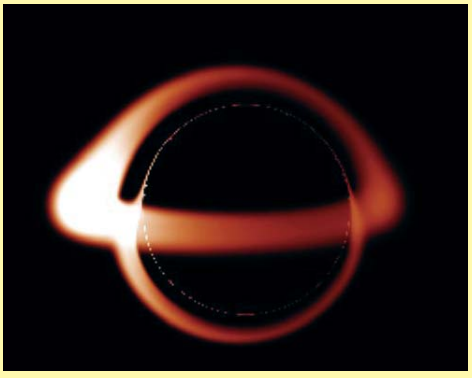
● **Toshiba** achieves quantum communications over optical fibres exceeding 600 km in length, a new world record distance.

● Researchers report the development of a plant proteins-based biodegradable packaging material. It can be an alternative to plastic but it can be as strong as high-strength spider silk.

July 2021

● The SARS-CoV-2 **Delta** variant, first discovered in India in late 2020, triggers several waves of the pandemic across the world, including in India.

● The first direct observation



of light from **behind a black hole** is reported, further confirming Einstein's theory of general relativity.

August 2021

● The *Intergovernmental Panel on Climate Change* (IPCC) reports (in its Sixth Assessment Report) that effects of human-caused climate change are now "widespread, rapid, and intensifying".

● *Probiotics* can help coral reefs mitigate heat stress. It could help them overcome **coral bleaching** due to climate change.

● Nationwide data of Israel's vaccination programme finds that immunity from the Pfizer-BioNTech COVID-19 vaccine decrease significantly after 6 months. So the protection from vaccines is not long-lasting.

September 2021

● In Japan the first CRISPR-edited (genetically edited) food has gone on public sale. **Tomatoes** were genetically modified so they contain about five times the normal amount of possibly GABA, a neurotransmitter that calms you down.

October 2021

● 98% of DNA does not code for proteins and is considered "junk". Scientists show experimentally that differences between humans and chimpanzees are also substantially caused by this so-called "junk" DNA.

● A study shows for the first time how immunity is **inherited**, via *epigenetic* (via behaviour and environment) changes, in mammals

November 2021

● A study reports the second case of a person whose immune system apparently cleared HIV (virus that causes AIDS) on its own without treatment.

● The World Health Organisation (WHO) announces the classification of the *Omicron variant* as a SARS-CoV-2 variant of concern.

December 2021

● Scientists studying the huge **Thwaites Glacier** in West Antarctica report evidence that it could "shatter like a car windscreen" within five to ten years. This would add about 65 cm to global sea levels.

Source: Wikipedia

Nobel Prize in Physics: Climate and its Understanding

D. Indumathi,
The Institute of Mathematical Sciences, Chennai

The Nobel Prize in Physics in 2021 was awarded "for groundbreaking contributions to our understanding of complex systems". Let us try and understand what this means. The rather complicated statement of the Nobel Committee is:

"This year's Nobel Prize in Physics is awarded with one half jointly to **Syukuro Manabe**, **Klaus Hasselmann** and the other half to **Giorgio Parisi**. They have laid the foundation of our knowledge of the Earth's climate and how humanity influences it, as well as revolutionized the theory of disordered materials and random processes."

The phrases we need to understand are, "complex systems", "climate change" and how humanity influences it, "disordered materials" and "random processes". Let us look at them one by one.

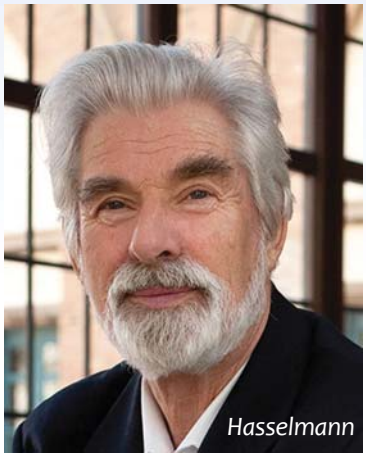
Complex systems

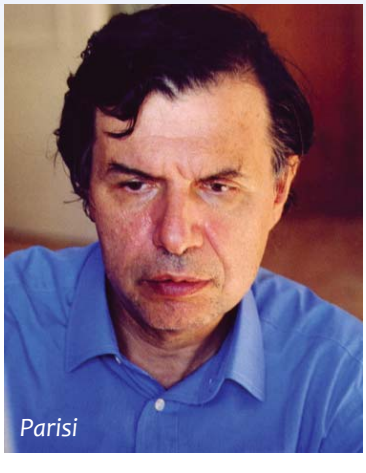
As the name suggests, all complex systems consist of many different interacting parts. They have been studied by physicists for a couple of centuries, and can be difficult to describe mathematically. For instance, Earth's climate is an example of a complex system.

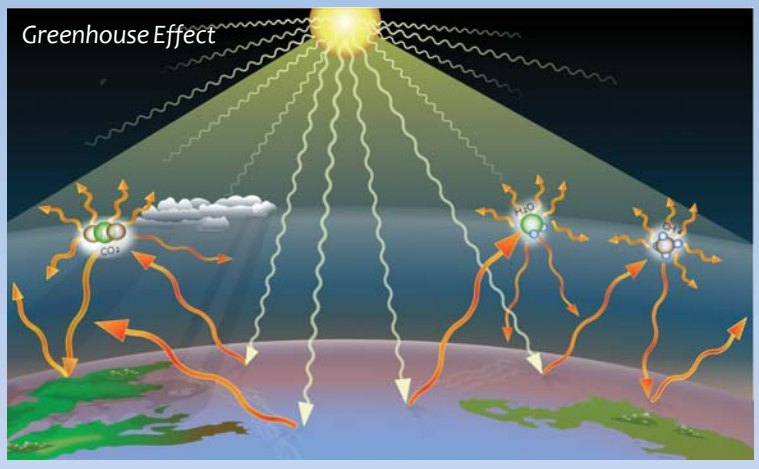
One of the key properties of such systems is called **chaos**. The English dictionary meaning of "chaos" is "complete disorder and confusion". However, scientists still try and make sense of such disorder. For instance, many of you must have been following the recent heavy rainfall patterns and their predictions. You could see that it is very difficult to accurately predict the weather, although we have so many instruments and measurements to help us.

In physics, the word "chaos" has a very specific meaning.


Manabe


Hasselmann


Parisi



Very often, the reason for this disorder is the lack of accuracy with which we know the initial conditions. For instance, we roughly know the position and velocity (and other parameters such as pressure, etc) of a moving cyclone. But we still cannot accurately tell where exactly it will hit and how severe its impact will be. The theory of chaos states that in fact, in truly "chaotic systems", it will be impossible to know some factors to the accuracy required. Hence even if there is a very very small change in some property of the system (like its pressure or velocity), it may end up behaving very differently from expectation. How, then, can we reliably predict the behaviour of such systems?

Chaos theory tells us that there are still patterns and repetitions in the behaviour of such systems so that there is still predictive value. After all, we can see patterns such as the onset of the South West or North East monsoons, although we may not be able to predict exactly how much rain there will be over Chennai today. All the scientists who have been awarded this year's Nobel Prize in Physics have contributed to our understanding of such complex systems.

The greenhouse effect

Two hundred years ago, French physicist **Joseph Fourier** studied the energy balance between the Sun's radiation towards the ground and the radiation from the ground. He found that the Earth's atmosphere played an important role in this balance. Sunlight consists mostly of visible light, although it has invisible ultraviolet (UV) and infrared (IR) components as well.

A part (about a quarter) of the incoming sunlight is reflected back to space by the atmosphere and clouds, while another part is absorbed by the gases and clouds in our atmosphere. About half the remaining energy is absorbed by Earth's surface.

We know that hot bodies radiate (you must have felt the heat coming off from your hot glass of milk). The Earth's surface when heated then radiates back this absorbed energy, but in the form of heat (thermal energy). This heat is absorbed by Earth's atmosphere and hence the layer of atmosphere/air just above the surface gets warm. This heat slowly disperses through the entire atmosphere which

The greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without this atmosphere.

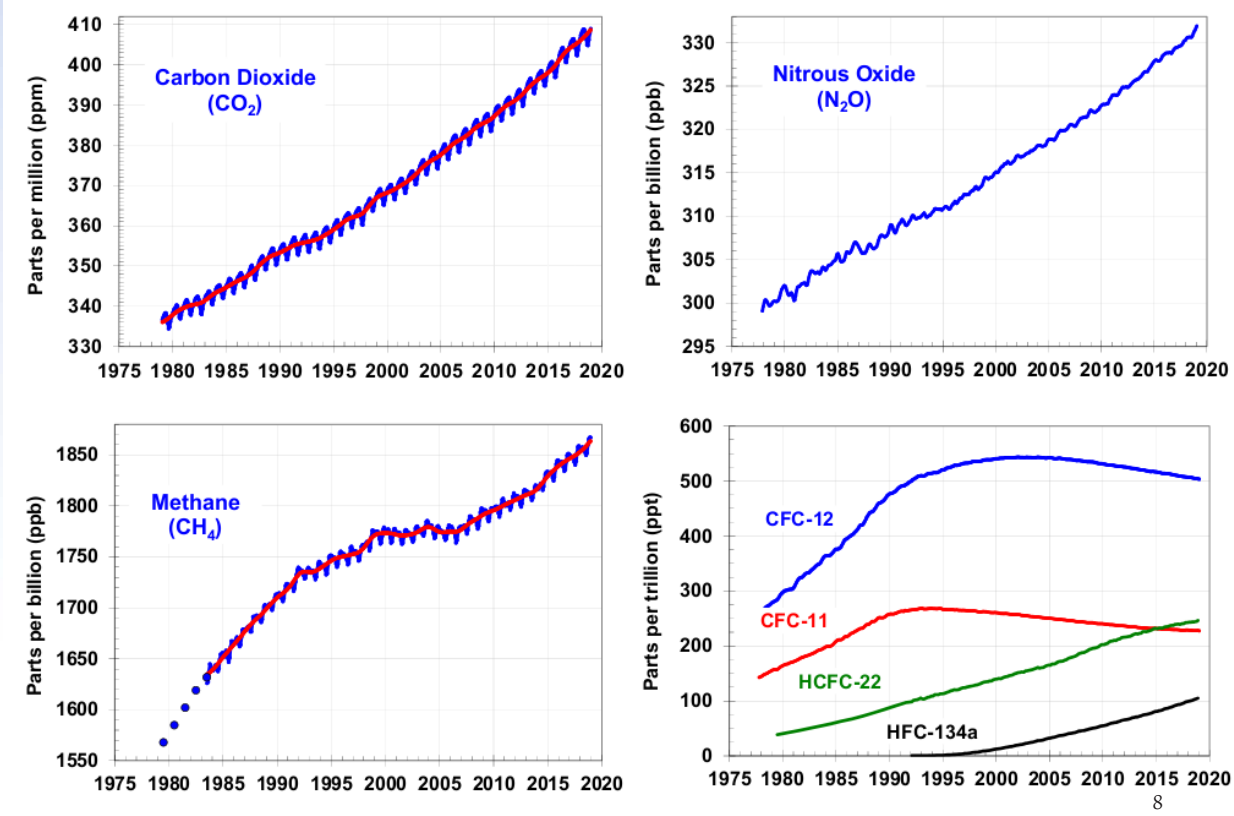
becomes hot and therefore also begins to radiate! Now, the atmosphere radiates in all directions (like all hot things do). The part of the heat that is radiated downwards is re-absorbed by the Earth which therefore becomes warmer.

In summary, because of the action of Earth's atmosphere in trapping heat, the Earth's surface is warmer than it would have been if it *did not* have an atmosphere. For instance, instead of the average 15 degrees that it currently is, it would have been cold, at -18 degrees, much below freezing, and not convenient for living things.

Fourier understood that the atmosphere therefore plays a role in protecting the temperature of the Earth. The effect is due to the gases and aerosols (see Box) in the atmosphere which play an important role in this so-called "greenhouse effect".

Human activity and climate change

Industrialisation that happened around 250 years ago has caused increased human activity (electricity, cars, and other utilities that use petrol, coal, etc) that has increased the amount of greenhouse gases in the atmosphere. The main emissions are carbon dioxide (from burning fuel) and methane (from agriculture). For instance, the amount of carbon dioxide in the air has increased by almost 50% compared to the pre-industrial era. This has upset the balance and caused climate change. Hence the Nobel laureates have worked

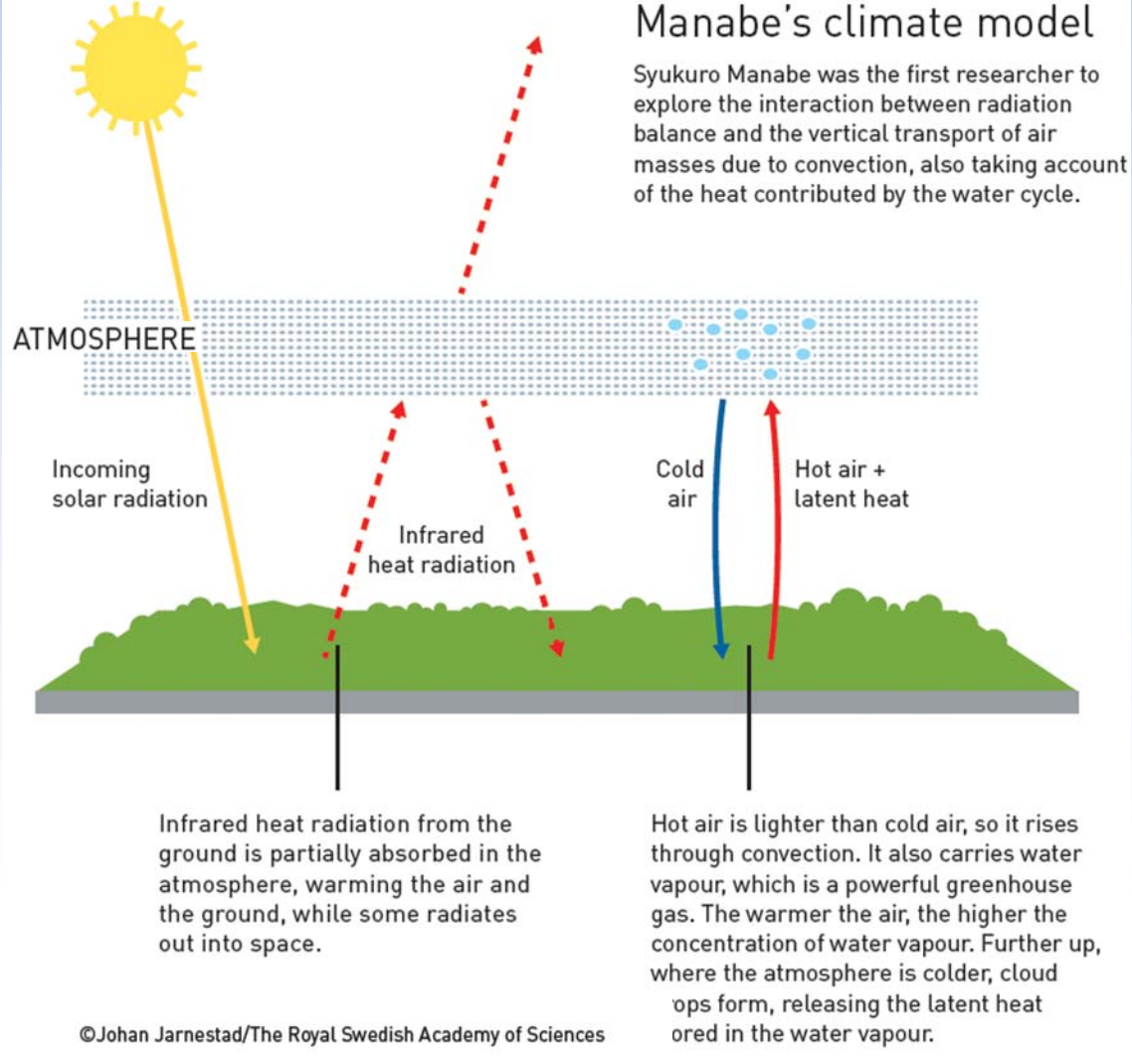


in an area that will help to understand climate change. The question is, *how is carbon dioxide emission related to global warming and climate change?*

Carbon dioxide and its role in the atmospheric temperature

The Swedish scientist, **Svante Arrhenius**, first understood the physics of the greenhouse effect more than 100 years ago. It had just been discovered that the Earth had gone through a series of **ice ages**, and Arrhenius was trying to find out the cause. He realised that if the amount of carbon dioxide in the atmosphere halved, this would cause a new ice age. And if the carbon dioxide doubled, the temperature of the atmosphere would increase by 5–6°C. This is because of the protective nature of this greenhouse gas that traps heat in the atmosphere.

Over the years, these theo-



ries have been improved but the understanding is basically the same: *human activity causes emission of greenhouse gases, which drive global warming and climate change*.

Now that we have understood the role of carbon dioxide in climate change, let us see what each of the Nobel laureates has found.

Carbon dioxide and temperature

Syukuro Manabe showed in the 1960s that if there is more carbon dioxide in the atmosphere, then the surface of the Earth gets warmer. He wrote down one of the first models of the Earth's climate by considering the atmosphere as a one dimensional column and considering the flow of air across it. He and his colleague **R.T. Wetherald** calculated that there is 2.3°C warming per doubling of atmospheric CO_2.

The model confirmed that this heating really was due to the increase in carbon dioxide, because it predicted that the temperatures would rise closer to the ground while the upper atmosphere got colder. If the increase in temperature was instead due to changes in the amount of sunlight, the entire atmosphere should have been heating at the same time. Today's more complicated climate models are based on this work.

Climate versus weather

It may or may not rain tomorrow. That is a *weather* prediction. It is valid over a short time. *Climate*, on the other hand, is a long-term pattern. It is in a sense, the **average** over the daily weather at any place. In order to determine whether humans are causing climate change, it is important to factor out variable weather (short-term) conditions and look at long term effects. How is this possible?

This question was answered about ten years later, by **Klaus Hasselmann**. He created a model that links together weather and climate, thus answering the question of why climate models can be reliable despite weather being changeable and chaotic. It was a very technical approach, which took into account the complexity of climate.

This complexity is expressed often as the possibility of whether a butterfly flapping its wings in Brazil could cause a tornado in Texas, and is called the **butterfly effect**. This is because the equations governing the evolution of the system are **non-linear**: small changes in the initial values cause the system to change very differently, and this is called **chaotic behaviour**.

Making sense of noisy data

How can we produce reliable climate models that are valid for hundreds of years although we cannot predict the weather 10 days ahead?! In 1980, Klaus Hasselmann showed that chaotically changing weather is like rapidly changing noise on your radio: the song (or long-term climate) that is actually playing can still be heard and understood. More importantly, it can be extracted and processed by removing the noise. Hasselmann created a **stochastic climate model**, which is difficult to explain. But this model showed that the rapid changes in the atmosphere can actually cause slow variations in the ocean's temperature (causing oceans to warm or sea ice to melt).

Determining human impact

Hasselmann also developed methods for identifying specific signals, which he called *fingerprints*. These are activities that leave imprints in the climate and can be both natural and due to human activities.

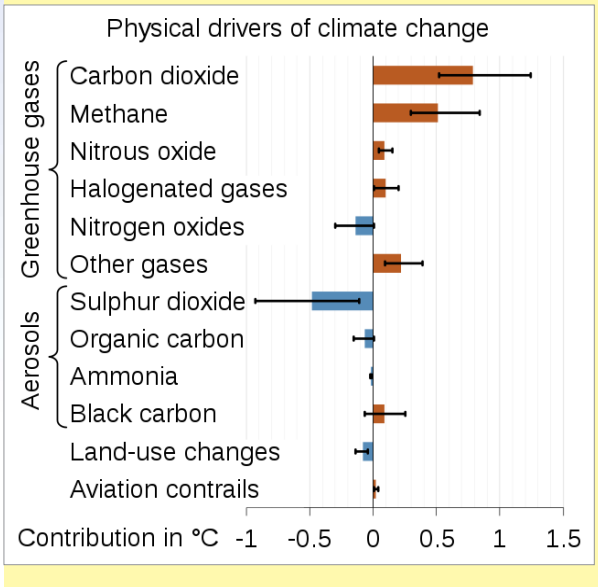
It soon became clear that Hasselmann had discovered a way to detect the signal of global warming due to human activity like burning fossil fuels. Satellite-borne microwave sounders began to monitor atmospheric temperature. Data was slowly collected that would be used by the Hasselmann model to provide global patterns for change.

Modern climate models show that the amount of carbon dioxide in the atmosphere has increased by 40 per cent. Earth's atmosphere has not contained this much carbon dioxide for hundreds of thousands of years. Accord-

Greenhouse gases and aerosols

There are four major greenhouse gases. *Water vapour* is the largest contributor, at 36–70%, while *carbon dioxide* (9–26%), *methane* (4–9%) and *ozone* (3–7%) account for the rest. Note that the gases which are prevalent in large amounts in the atmosphere such as nitrogen (78%), oxygen (21%), and argon (0.9%), are **not** greenhouse gases.

Water vapour is not much affected by human activity. In fact, the average time of a water molecule in the atmosphere is only about nine days, compared to years or centuries for other greenhouse gases such as methane or carbon dioxide. Hence, when talking about climate change, carbon dioxide is most often mentioned. However, warm air can hold more water vapour than cold air and so the presence of this extra water in warm air, makes the air even hotter since water vapour is a greenhouse gas.



Recently the role of **aerosols** has also been studied. They are tiny particles suspended in the air, both natural and man-made, such as sea-salt, mineral dust, ash, soot, sulphates, nitrates, and black carbon. They remain in the air for around 10 days, and act as a nucleus for water droplets to form around them. This increases clouds, which shield us from sunlight, thus cooling the Earth. So there is a delicate balance between greenhouse gases and aerosols in the air: greenhouse gases *warm* the surface; aerosols *cool* the surface.

Humans and climate change

Syukuro Manabe and Klaus Hasselmann have contributed to the greatest benefit for humankind, in the spirit of Alfred Nobel, by providing a solid physical foundation for our knowledge of Earth's climate. We can no longer say that we did not know – the climate models are very clear.

Is Earth heating up? Yes.

Is the cause the increased amounts of greenhouse gases in the atmosphere? Yes.

Can this be explained solely by natural factors? No.

Are humanity's emissions the reason for the increasing temperature? Yes.

ingly, temperature measurements show that the world has heated by 1°C over the past 150 years.

Methods for disordered systems

The Nobel committee has awarded half the Physics prize to **Giorgio Parisi** of Italy "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales". This is a very complicated area of research.

Around 1980, Parisi discovered hidden patterns in complex materials which were *not ordered*. For example, you may know that **crystals** like common salt (Sodium chloride or NaCl) are placed in *regular* arrangements on a lattice. *Disordered systems* do not show such periodic arrangements.

One such example is that of *spin glasses*. You know that each iron atom in a magnet behaves like a small magnet, or *spin*, which is affected by the other iron atoms close to it. In an ordinary magnet, all the spins point in the *same* direction, so we say they are *magnetised*. In a spin glass they are *frustrated*; some spin pairs want to point in the *same* direction and others in the *opposite* direction – so how do they find an optimal orientation?

Parisi's solution to this and similar problems are among the most important contributions to the theory of complex systems. His insight made it possible to understand very different materials in physics. It also led to understanding in various fields such as mathematics, biology, neuroscience and machine learning.

Parisi has also studied many other phenomena in which random processes play a decisive role. The fundamental questions are, how structures are created and how they develop? For instance, Why do we have periodically recurring ice ages? Is there a more general mathematical description of chaos and turbulent systems?

Parisi says that most of his research has dealt with how **simple** behaviours give rise to **complex collective** behaviour. This is also the case with Earth's atmosphere models and understanding climate change.

Adapted from the popular information on the Nobel Prize pages; Figures from Wikipedia and nobelprize.org

Nobel Prize in Chemistry: Organo-catalysis

D. Indumathi
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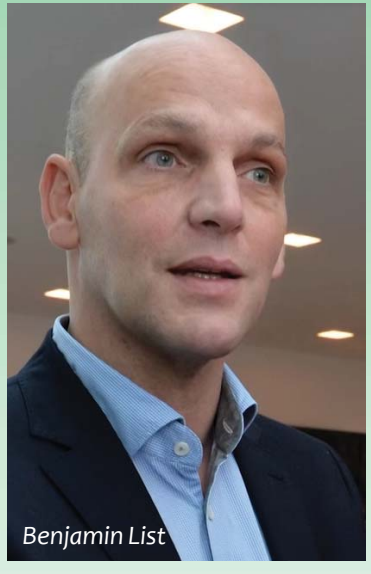
This year's Nobel Prize in Chemistry 2021 was awarded jointly to **Benjamin List** and **David W.C. MacMillan** "for the development of asymmetric organocatalysis."

Here we have to understand the meaning of "asymmetric" and "organo-catalysis". Basically, the work involves building tools that revolutionised the *construction of molecules*. Benjamin List works in Germany and MacMillan in the USA.

A tool for building molecules

Building molecules is a difficult art. Benjamin List and David MacMillan were awarded the Nobel Prize in Chemistry 2021 because of their development of a precise new tool for molecular construction: **organo-catalysis**. This has had a great impact on pharmaceutical research, and has made chemistry greener.


Benjamin List


David MacMillan

The word organo-catalysis has two parts: one is *catalysis*, and the other is *organic*. Hence the process involves **catalysis** using organic compounds.

What is a catalyst?

Catalysts are substances that control the *rate of chemical reactions*, without themselves changing in the process. A common example is that of *platinum* in cars. When fuel burns in a car engine, harmful gases like *carbon monoxide* (CO) are produced. In the presence of air (which contains oxygen), this is converted to *carbon dioxide* (CO_2), which is less harmful: $2\,CO + O_2 \rightarrow CO_2$.

However, this process occurs very slowly and so most of the gas that comes out will comprise the harmful monoxide. In the presence of platinum, however, this reaction speeds up. So in the catalytic converter of cars, platinum is used to *catalyse* the conversion of carbon monoxide to carbon dioxide. The platinum is not used up in the reaction. The process is called **catalysis**.

Metals are excellent catalysts, but they are very sensitive to oxygen and water. So they work best in an environment free of oxygen and moisture. This is difficult to achieve in large-scale industries. Also, many metal catalysts are heavy metals, which can be harmful to the environment.

What are organo-catalysts?

The second form of catalyst is comprised of the proteins known as *enzymes*. All living things have thousands of different enzymes that drive the chemical reactions necessary for life. They also work side by side; when one enzyme is finished with a reaction, another one takes over. In this way, they can build complicated molecules with amazing precision, such as **cholesterol**, **chlorophyll** or the toxin called **strychnine**, which is one of the most complex molecules we know of.

Think of organic compounds such as the proteins and enzymes in our body. When any of them function as a catalyst, they are called **organo-catalysts**. Many thousands of natural enzymes in our body act as catalysts.

Organic catalysts have a stable framework of carbon atoms, to which more active chemical groups containing elements such as oxygen, nitrogen, sulphur or phosphorus, are attached. This means that these catalysts are both environmentally friendly and cheap to produce since metals are costly.

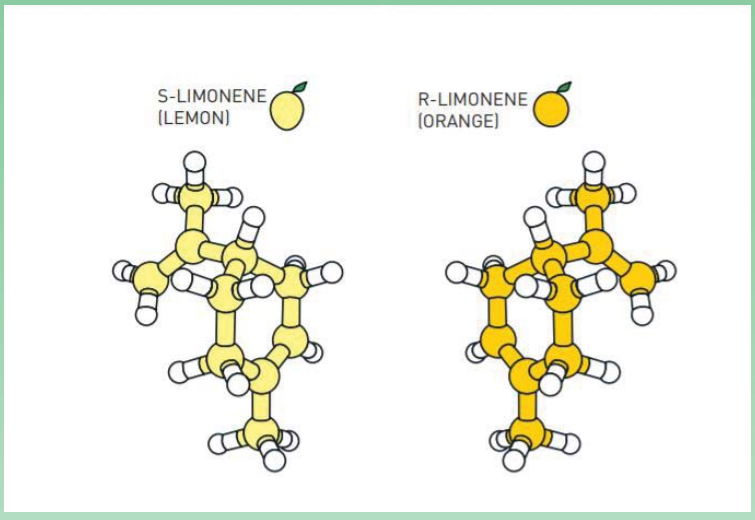
Chemists have discovered several catalysts that can break down molecules or join them together. Using these, we can make thousands of different substances we use in our everyday lives, such as pharmaceuticals, plastics, perfumes and food flavourings. The fact is, it is estimated that 35 per cent of the world's total GDP in some way involves chemical catalysis.

Catalysts are thus fundamental tools for chemists. Many industries depend on chemists' ability to build new and functional molecules. These could be anything from substances that capture light in solar cells or store energy in batteries, to molecules that can make lightweight running shoes. Or they can even slow down the spread of disease in our body!

In principle, all catalysts discovered before the year 2000 belonged to one of two groups: they were either *metals* or *enzymes*. When scientists began to discover how nature uses catalysts, they realised that their understanding was very limited. Whenever they tried to copy these natural molecules, they ended up with a lot of unwanted by-products. It felt like they were using stone-age tools while Nature was using sophisticated ones!

A new type of catalyst

Researchers thought that there were just two types of catalysts available: metals such as platinum, and enzymes. Benjamin List and David MacMillan independently developed a *third type of catalysis*. It is called **asymmetric organo-catalysis** and builds upon small organic molecules. How do we understand "asymmetric"?



Limonene molecules

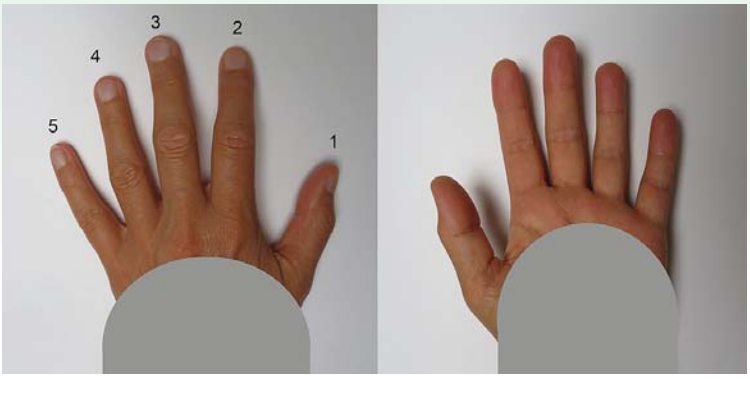
When molecules are being built, two different types of molecules can form, which – just like our hands – are each other's mirror image. If you turn your left hand around, it will not be identical to your right hand. But if you see your left hand in the mirror, it will look like your right hand. Chemists will often only want one of these mirror copies, particularly when producing pharmaceuticals (medicines). Hence these molecules are **asymmetric**.

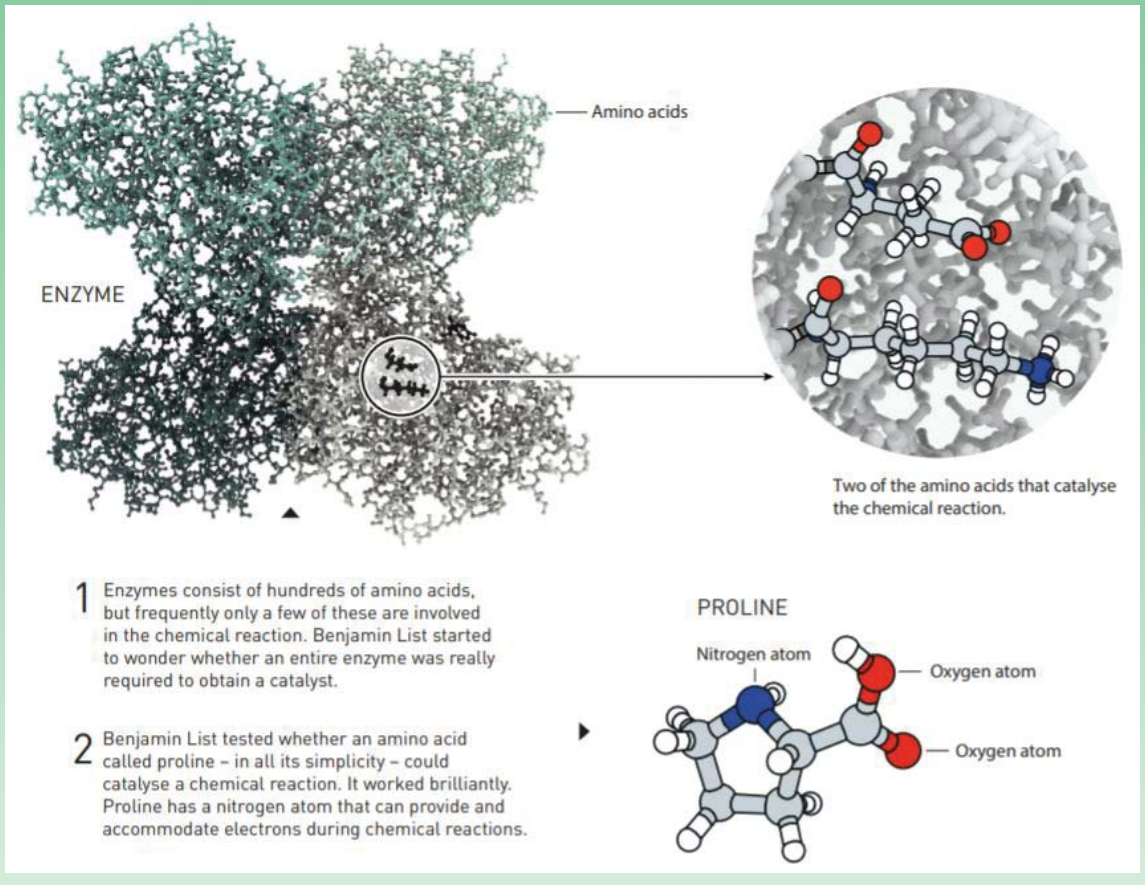
These mirror copies often have completely different effects in the body. For example, one version of the **limonene** molecule has a *lemon* scent, while its mirror image smells like *orange*. Sometimes, as in the case of **thalidomide**, one version tragically causes deformities in developing embryos and should be completely removed. Many enzymes are specialists in asymmetric catalysis and, in principle, always form one mirror image out of the two that are possible.

Natural catalysts

Because enzymes are such efficient catalysts, researchers in the 1990s tried to develop new enzyme variants to drive the chemical reactions needed by humanity. **Benjamin List** worked with **catalytic anti-bodies** at the Scripps Research Institute in California, USA. Normally, anti-bodies attach to foreign viruses or bacteria in our bodies: for instance, you must all know by now that the Covid-19 vaccine contains anti-bodies to the Covid-19 virus. But he and his colleagues redesigned them so they could drive chemical reactions instead.

During his work with





catalytic anti-bodies, Benjamin List started to think about how enzymes actually work. They are usually huge molecules that are built from hundreds of amino acids. In addition to these amino acids, a significant proportion of enzymes also have metals that help drive chemical processes. But many enzymes catalyse chemical reactions *without* the help of metals. Instead, the reactions are driven by one or a few individual amino acids in the enzyme. Benjamin List's question was: *do amino acids have to be part of an enzyme in order to catalyse a chemical reaction?* Or could a single amino acid, or other similar simple molecules, do the same job? If this is true, then you do not need to make the whole complicated enzyme, but only the smaller amino acid.

He knew that there was research from the early 1970s where an amino acid called **proline** had been used as a catalyst – but that was more than 25 years ago. Surely, if proline really had been an effective catalyst, someone would have continued working on it?

This is more or less what Benjamin List thought; he assumed that the reason why no one had continued studying the phenomenon was that it had not worked particularly well. Without any real expectations, he tested whether proline could catalyse a particular reaction in which carbon

atoms from two different molecules are bonded together. It was a simple attempt that, amazingly, worked straight away.

Proline

With his experiments, Benjamin List not only demonstrated that proline is an efficient catalyst, but also that this amino acid can drive *asymmetric catalysis*. Of the two possible mirror images, it was much more common for one of them to form than the other.

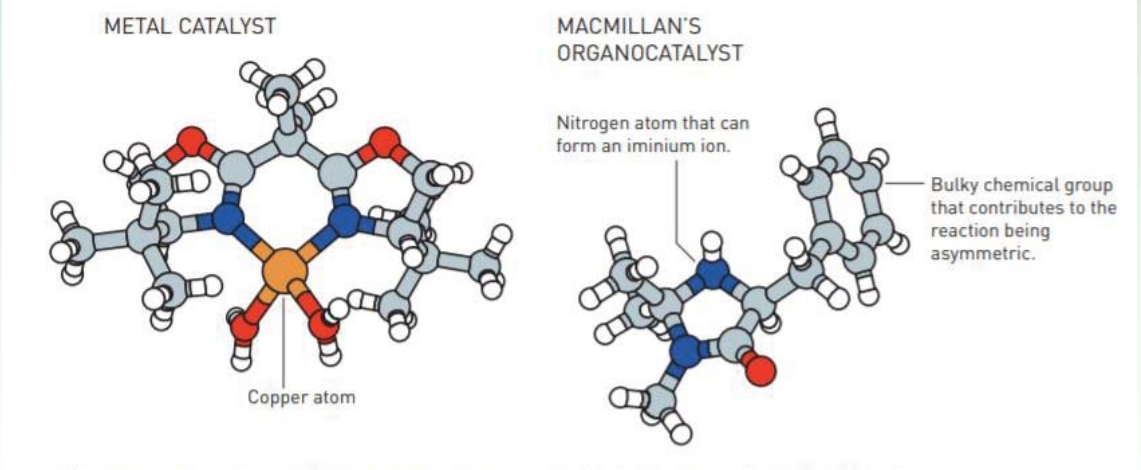
Unlike the researchers who had previously tested proline as a catalyst, Benjamin List understood the enormous potential it could have. Compared to both metals and enzymes, proline is a dream tool for chemists. It is a very simple, cheap and environmentally-friendly molecule. When he published his discovery in February 2000, List described asymmetric catalysis with organic molecules as a new concept with many opportunities.

However, he was not alone in this. In a laboratory at the University of California, Berkeley, **David MacMillan** was also working towards the same goal.

David MacMillan realised that metals are good catalysts because they can lose or gain electrons easily. He started to design simple organic molecules which – just like metals – could temporarily provide or accommodate electrons. Out of several that he tested, he found the right one, containing a nitrogen atom, which could form a special ion called an **iminium** ion. He not only found asymmetric organo-catalysts, but also gave them this name!

Efficiency is the watch-word

Over the years, List and MacMillan have designed many cheap and stable organocatalysts, which can be used to drive a huge variety of chemical reactions. Previously, in a chemical process, it was necessary to isolate and purify each intermediate product, since many by-products were formed at the same time. Apart from the complexity and loss of time, this also led to the loss

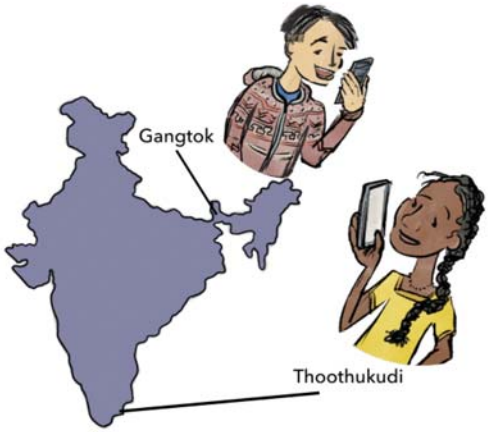


1 David MacMillan worked with metal catalysts that were easily destroyed by moisture. He therefore started to wonder whether it was possible to develop a more durable type of catalyst.

2 He designed some simple molecules that could create iminium ions. One of these proved to be excellent at asymmetric catalysis.

continued on page 20

Does the Sun Really Rise in the East?



Kaviya and her family moved to Thoothukudi, Tamil Nadu in September. She has been messaging her old classmate Dawa in Gangtok, Sikkim.

Varuni - Vijay
IMSc Chennai

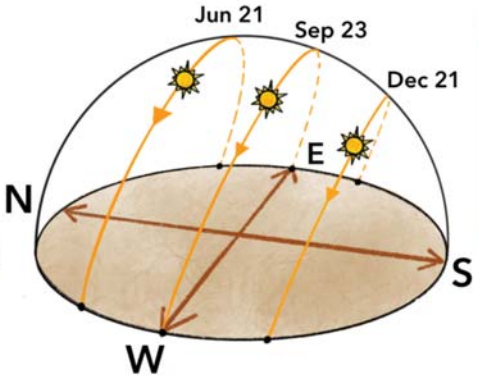
In Thoothukudi, I can see the sunrise over the beach every morning. It has not been rising from exactly East! Is the sun rising exactly in the East in Gangtok?

I just watched the sunrise over the mountains today. I checked on a compass: the sun didn't rise exactly in the East in Gangtok either!

I also noticed that the position of the sunrise changes a little every day. Have you noticed that in Gangtok?

Interesting! Let's both observe the sunrise once a week for the next few months and see what happens.

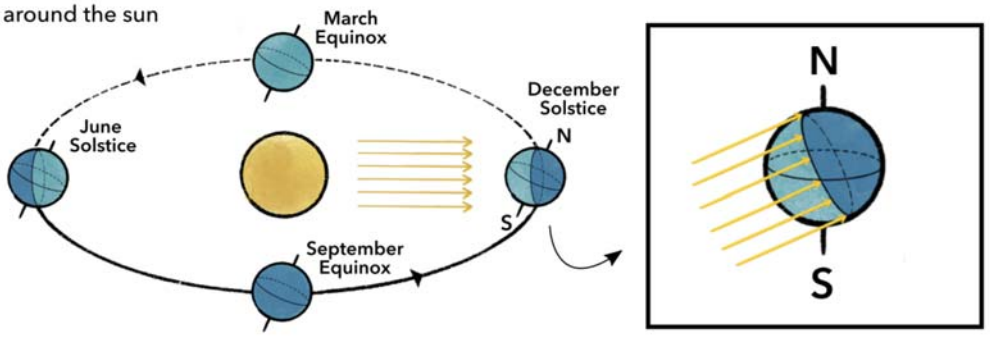
From September to December, the sunrise was further and further South in Gangtok. Also, the days are getting shorter and the nights are getting longer. Is that what you see in Thoothukudi too?



Yes, from September to December the sunrise was further and further South in Thoothukudi also!

From 21 June to 21 December, the sun appears to move southward, this is called Dakshinayan. From 21 December to 21 June, the sun appears to move northwards, this is called Uttarayan.

The sun rises exactly in the east and sets exactly in the west only on the equinoxes (20 March and 23 September). On any other day, the sunrise and sunset points are equally away from the east and west. This happens because of the tilt of the earth's axis and the revolution of the earth around the sun



During the December solstice, the southern hemisphere faces the sun, so at sunrise and sunset, the sun's rays will come from the south.
The June solstice is the northernmost sunrise and sunset. The December solstice is the southernmost sunrise and sunset. This is true for any place on Earth.

The December Solstice is on 21 December. I will observe the southernmost sunrise in Thoothukudi.

And I will observe the southernmost sunrise in Gangtok on 21 December. Let's see how far south the sun rises!

You can all do this too! Observe the sunrise or sunset on 21 December: this will be the southernmost sunrise or sunset of the year. You can find more information and experiments about the December solstice here:
https://astron-soc.in/outreach/activities/shadows-decem-solstice/

continued from page 18

of a part of the needed product.

In contrast, with organo-catalysts, several steps in a production process can be performed in an unbroken sequence. This is called a *cascade reaction*, which can considerably reduce waste in chemical manufacturing. One example is the synthesis of the *strychnine* molecule. Many people will recognise strychnine as a poison used in books by **Agatha Christie**, queen of the murder mystery.

When strychnine was first synthesised in 1952, it required 29 different chemical reactions and only 0.0009 percent of the initial material formed strychnine. The rest was wasted. In 2011, researchers were able to use organo-catalysis and a cascade reaction to build strychnine in just 12 steps, and the production process was 7,000 times more efficient.

Using organo-catalysis, researchers can now make large volumes of different asymmetric molecules relatively simply. For example, they can artificially produce medicinal substances that can otherwise only be isolated in small amounts from rare plants or deep-sea organisms.

At pharmaceutical companies, the method is also used to streamline the production of existing pharmaceuticals (medicines and drugs). Examples of this include **paroxetine**, which is used to treat anxiety and depression. The same method is used to produce the antiviral medication **oseltamivir**, which is used to treat respiratory infections and is one of the drugs used to treat Covid. Organocatalysts are thus bringing – right now – the greatest benefit to humankind.

•

Puzzles to Puzzle You

Magic Belt

A magic rectangular belt always shrinks its length to 1/2 and width to 1/3 whenever its owner wishes something.
After three such wishes, its surface is now 4 cm^2.
What was the original length, if the original width was 9 cm?

Answer upside down:

Let the length be L and its width W. After the first wish, they are L/2 and W/3. After the second, it was (L/2)/2=L/4 and (W/3)/3=W/9. After the third wish, it was (L/4)/2=L/8 and (W/9)/3=W/27. The area of this thrice-decreased belt is given to be 4. So (L/8)x(W/27)=4, or LxW=4x8x27. But we know that W=9. So L=4x8x27/W=4x8x27/9=96 cm.

Nobel Prize in Physiology or Medicine: How do we perceive the world?

D. Indumathi,

The Institute of Mathematical Sciences, Chennai

The Nobel Assembly at the Karolinska Institute has awarded the 2021 Nobel Prize in Physiology or Medicine to **David Julius** and **Ardem Patapoutian** "for their discoveries of receptors for temperature and touch".

Winter is approaching and the days are getting colder. Your skin feels the cold, your bladder wishes to empty itself several times a day, and your nose smells the fresh and cold air around you. Your eyes see the fog on a winter's morning, or the sun on a hot summer day. This is how we perceive the world around us through our senses.

We have always known this. But what is the exact mechanism by which we feel hot or cold, or the sensation of pressure or touch? How exactly do our nerves respond so that we sense these things? This is the subject of research for which the Nobel laureates won the physiology prize this year.

David Julius

Ardem Patapoutian

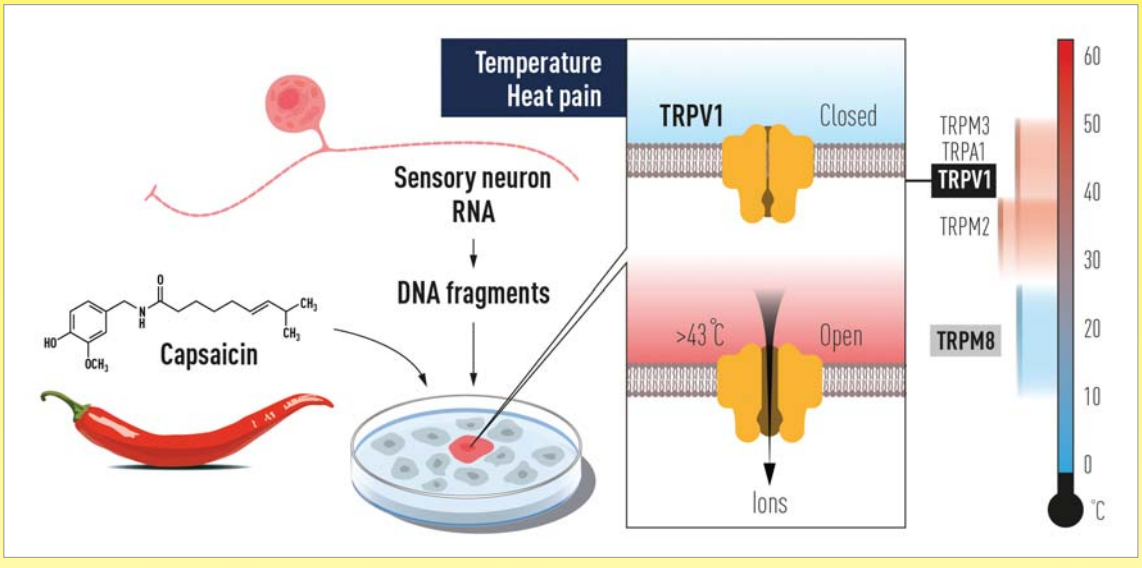
How do we perceive the world?

In the 17th century, the philosopher **René Descartes** imagined that different parts of the skin were connected by threads with the brain. In this way, a foot touching an open flame would send a mechanical signal to the brain. These cells were later found to exist and were called *nerve cells* or *neurons*. Each of these neurons were highly specialised to detect changes in our surroundings, such as light, sound, heat.

Joseph Erlanger and **Herbert Gasser** received the Nobel Prize in Physiology or Medicine in 1944 for their discovery of different types of **sensory nerve fibres**. For example, different fibres respond to painful and non-painful touch. So, a pat on the cheek will not be confused for a blow to the face.

The science heats up!

We all know that if you touch chillies and then touch



your eyes or even your skin, you feel a burning sensation. This is because of the chemical called **capsaicin** in chillies. The hotter the chilli, the more capsaicin it contains. Why does touching capsaicin cause us to feel pain? This was solved by **David Julius**, who was working at the University of California, San Francisco, USA, in the late 1990s.

DNA and genes

DNA is a molecule called *Deoxyribonucleic acid*. DNA carries genetic instructions for the functioning, growth and reproduction of all known organisms. All living cells contain DNA. The instructions for growth and reproduction is coded into **genes**. A gene is the basic physical and functional unit of heredity. Genes are made up of DNA. Some genes act as instructions to make molecules called **proteins**.

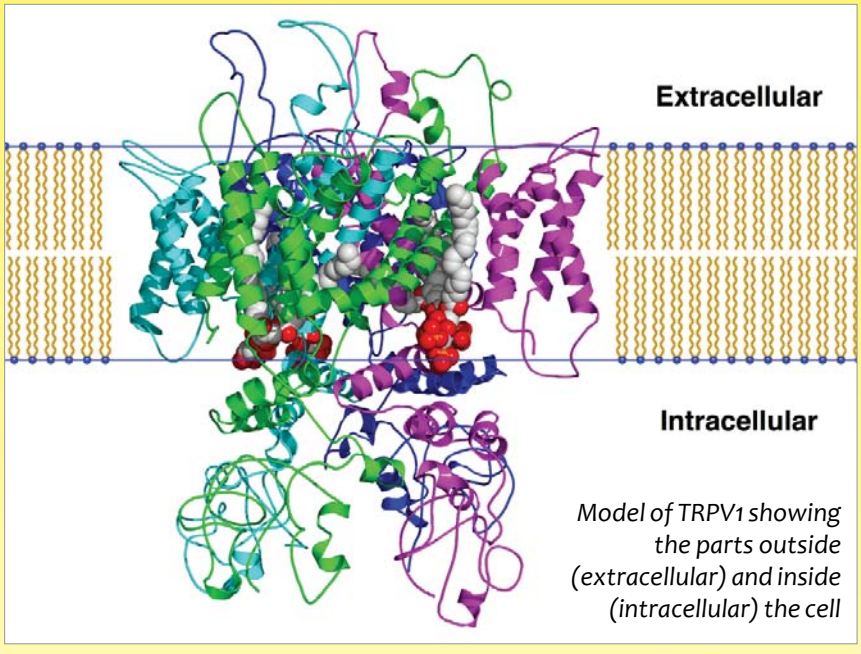
When a gene is activated, we say that it is *expressed*. When neurons respond to pain or heat, certain genes in them are expressed. Julius and his colleagues created a library of millions of DNA fragments. Each of them corresponded to genes that are expressed in the sensory neurons which can react to pain, heat, and touch. Julius thought that there should be at least one DNA fragment that contains the actual protein which reacts to capsaicin.

After hunting through this library, they finally found a single gene that was able to make cells sensitive to capsaicin (see figure). The gene for capsaicin sensing had been found!

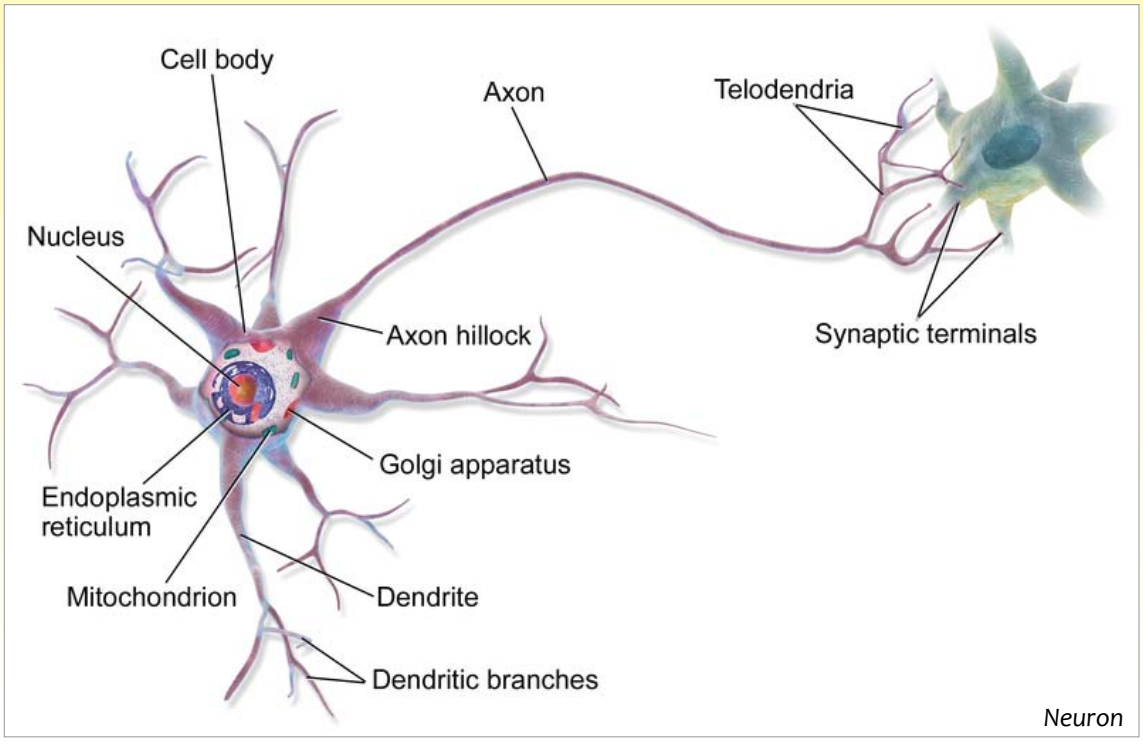
The capsaicin gene TRPV1

You may know that sensations travel through neurons as electrical signals (of a few millivolts). These electrical signals are created by having charged *sodium* and *potassium ions* that move across the nerve membrane. So for a nerve impulse to be transmitted, it is necessary to have special "gates" in the membrane where these ions can cross into or out of the nerve. These are called **ion channels**. In fact, these channels are specialized proteins that open and close to provide a passage for the charged ions.

The gene that had just been discovered actually encoded (produced) a new ion channel protein called **TRPV1**. This acts as a capsaicin receptor (it responds to the presence of capsaicin). Julius studied the effect of heat on this protein. He found that this protein is a heat-sensing receptor. It is activated at temperatures felt to be painful; hence, the effect of eating or touching capsaicin (or chillies) is the same as touching something hot! See the figure. You can see that when the temperature increases, the new ion channel closes and the nerve signals the brain indicating the presence of painful heat. So the work of Julius showed how



Model of TRPV1 showing the parts outside (extracellular) and inside (intracellular) the cell



Neuron

temperature can induce electrical signals in the nervous system.

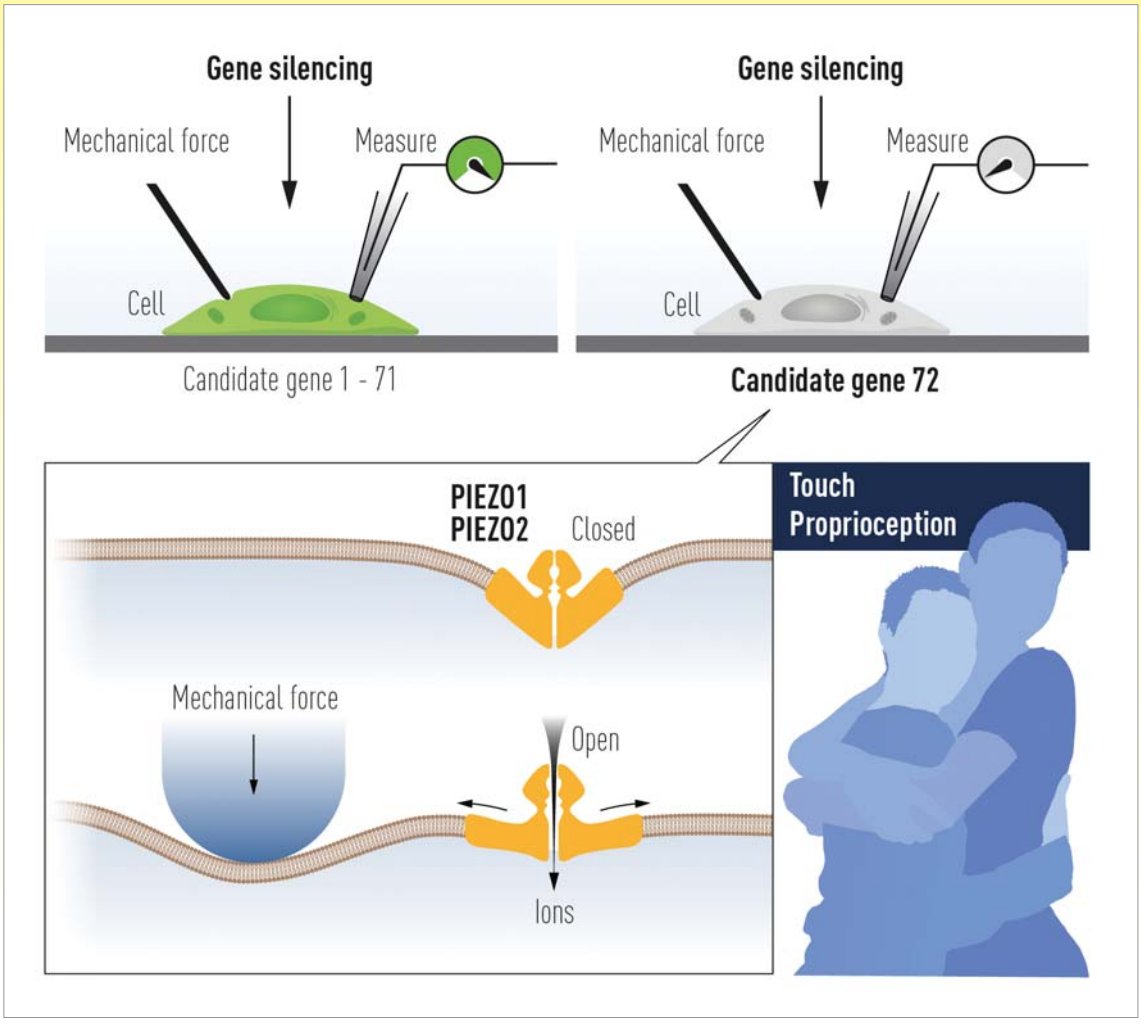
Hot or cold

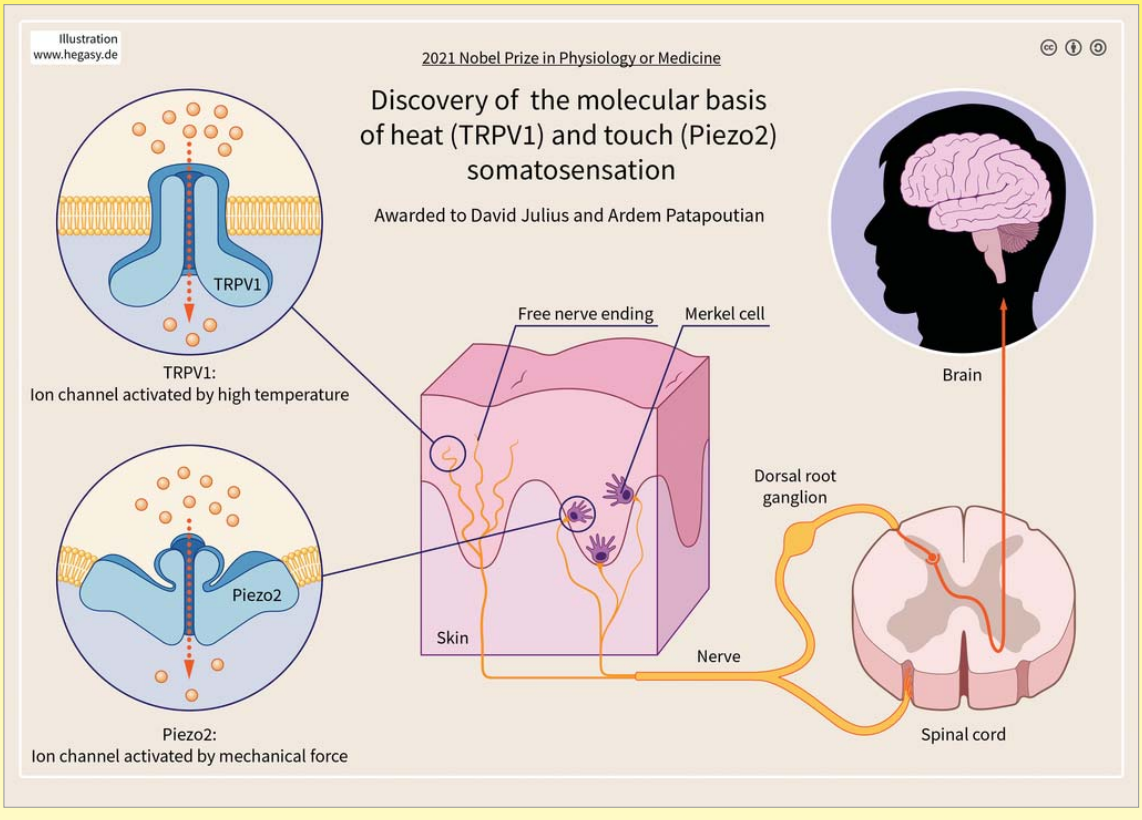
The discovery of TRPV1 was a major breakthrough and led to the discovery of additional temperature-sensing receptors. Independently of one another, both **David Julius** and **Ardem Patapoutian** used the chemical substance **menthol** to identify the receptor **TRPM8**. This was shown to be activated by *cold*. All of you must have felt the cold sensation when you eat mint peppermints! Now you know, this is due to TRPM8!!

Many more ion channels were found that are activated by different range of temperatures. The procedure was the same in all cases: start with a cell that does not respond to temperature, introduce a gene from the library, and see if that generates a new response/sensation to temperature. Genetically modified mice were used to study many such genes.

Research under pressure!

So much for chillies and heat. What about *touch*? Pressure applied on the skin can also be felt by our sense





of touch. How does this happen? Are there also genes for this?

Ardem Patapoutian, working at Scripps Research Institute in California, USA, tried to identify the receptors that are activated by a mechanical stimulus such as pressure. Patapoutian and his collaborators first poked individual cells with a micro-pippette. One such cell gave a measurable electric signal when poked. They assumed that this receptor is an ion channel and listed 72 possible candidate genes that were responsible for encoding (producing) this channel.

Each gene was inactivated one by one and it was tested again. If this is the gene sensitive to touch, then there will be no electrical signal in the nerve when it is inactivated. They found a completely new and unknown ion channel that was responsible for sensitvity to touch/pressure. It was given the name name **Piezo1** (*piezo* means pressure in Greek). Soon a second gene called **Piezo2** was found. Both are activated (that means sensory neurons in your skin express these genes) when you exert pressure on cell membranes (see the figure).

Soon it was found that the Piezo2 ion channel is essential for the sense of touch. It also plays a key role in the critically important sensing of body position and motion. This is called

proprioception. Later, Piezo1 and Piezo2 channels have been shown to regulate other important physiological processes including *blood pressure*, *respiration* and *urinary bladder control*.

It all makes sense!

Thus the efforts of the Nobel laureates and the discovery of the TRPV1, TRPM8 and Piezo channels helped us understand how heat, cold and mechanical force can trigger nerve responses. This in turn allows us to sense and adapt to the world around us.

The TRP channels are needed for our ability to perceive temperature. The Piezo2 channel gives us the sense of touch and the ability to feel the position and movement of our body parts. Both the TRP and Piezo channels also contribute to numerous additional physiological functions that depend on sensing temperature or mechanical stimuli.

These led to more research in trying to understand their functions in different physiological processes. For example, this knowledge is being used to develop treatments for a wide range of disease conditions, including *chronic* (constant) pain.

Adapted from the popular information on the Nobel Prize pages;

Figures from Wikipedia and nobelprize.org

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Water water everywhere

Narayani Subramanian

"Water water everywhere and not a drop to drink",

claims the poem by Samuel Taylor Coleridge. It talks about how man cannot drink seawater. One of the first survival instructions for people who get stranded in a remote island is to never drink seawater, however thirsty you get. Seawater is toxic to humans. If there is too much salt in your body, your kidneys cannot function properly and that can be deadly.

What about the animals that live in salty water? What about their kidneys?

Let us take fish as an example and see what happens to them in two different types of enviroment : Freshwater and Seawater.

Types of solutions

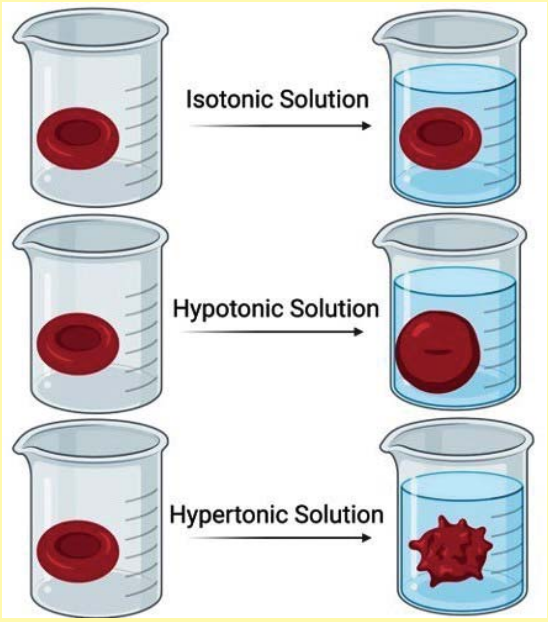
As you may have read in school, solutions that have a high concentration of a soluble substance (solute) are called **hypertonic**. Solutions with low concentrations of solute are called **hypotonic**. In the case of sea water, the solute is salt. So seawater is a hypertonic solution and freshwater is a hypotonic solution.

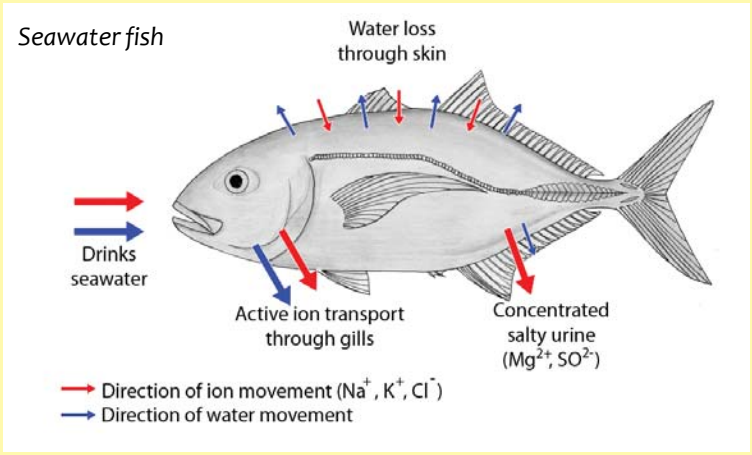
In a hypertonic solution, that is seawater, the cells inside the fish tend to shrink by losing their liquid. In a hypotonic solution that is freshwater, fish cells tend to swell up by taking in all the water and bloat (see picture). Both these scenarios are deadly for the fish cells, as swelling or shrinking leads to cell death.

Osmoregulation

Fish keep themselves safe by a process called "osmoregulation" which is the act of balancing the salt and water content of the body in comparison to the outside environment.

By logic, we can understand shrinking cells can be saved by addition of more water and swollen cells can be saved by water removal. Marine fish drink a

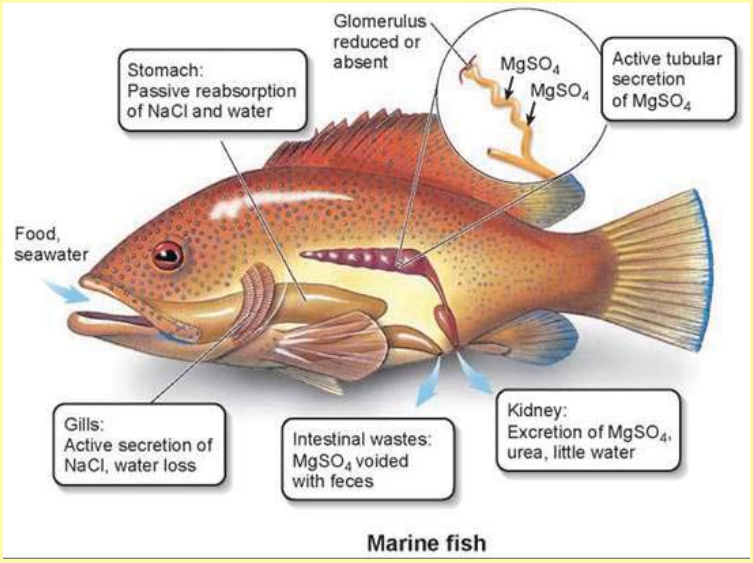




lot of seawater to prevent their cells from shrinking. While this maintains the water balance, this brings an additional problem: the incoming seawater has a lot of salt, which is dangerous for the body.

The fish have a lot of mechanisms to get rid of the salt. The blood of fish consists of liquid plasma and lots of cells (just as in humans). Fish filter out the excess salt inside the plasma with the help of their gills and kidneys. There is an enzyme called *Sodium Potassium ATPase* which helps in pumping the excess salt to the outside environment through the gills. The kidneys also help in filtering out the excess salt through urine.

In freshwater fish, water-salt regulation happens through excessive urination. They need to concentrate the salt content inside the body to compensate for the low salinity environment. So they keep producing dilute urine in excessive amounts throughout the day. They can urinate a volume of upto one-third of their body weight per day!

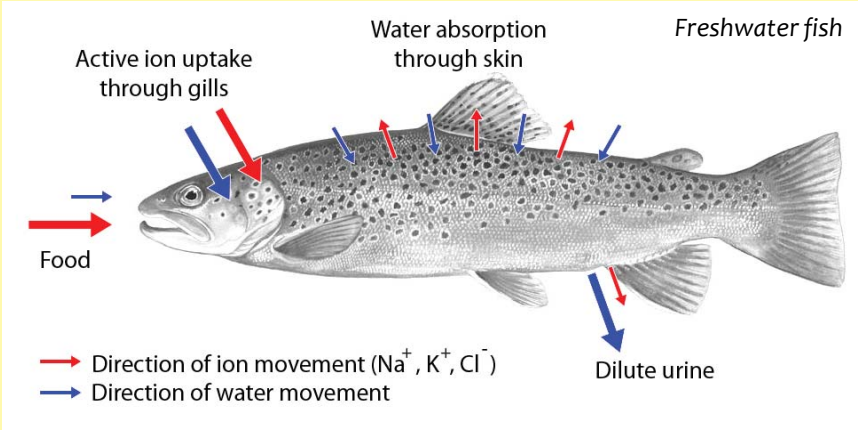


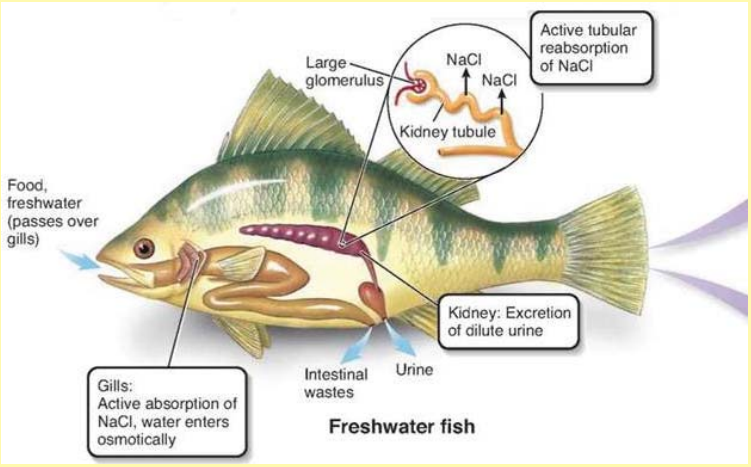
The case of the migrating fish

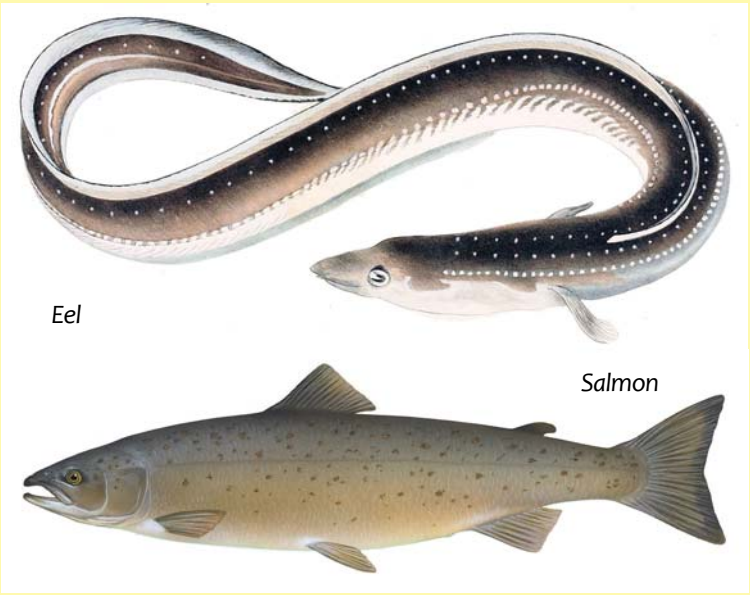
Ok... now the question arrives.

What about the fish that migrate to other environments? We have heard of marine (that is, saltwater) **salmon** going to rivers for spawning (laying eggs), and freshwater **eels** migrating to the ocean. If they are hard-wired or pre-programmed to either remove or add water into the body, how do they manage to survive when the salinity suddenly changes?

Nature has its tricks. These are what the scientists call "Euryhaline" species, or species with a tolerance for a wide range of salinities. They can regulate their internal mechanisms according to the external environment whenever it is necessary, as long as the salinity transition







is gradual. The gradual transition is achieved as the fishes migrate slowly into the new environment.

The case of marine mammals

While this works for fish, drinking of seawater is not a common behaviour in marine mammals such as whales, dolphins, seals and walruses. They maintain water balance through **metabolic processes** (chemical changes that go on inside organs that allow normal functioning of hte body). They also have mechanisms to reduce loss of water, thereby maintaining a stable level of liquids and salt inside their body.

How do you think **sea snakes** evolved the ability to maintain the water and salt balance? Write to ***JM*** and let us know!

Nature Diary

Woodpecker and its tongue

Woodpeckers are found all over the world. They mostly eat insects which they search for on tree branches. Their characteristic behaviour is to drum on tree trunks with their powerful beaks, which is their way of communicating. This produces a loud sound and vibration that can be heard from afar.

Some species eat fruits, birds' eggs, small animals, tree sap, and human scraps. They also nest in the holes they make. The abandoned holes are also used by other

nesting birds. They are useful to himans because they remove insect pests from trees.

What is fascinating about woodpeckers is their **tongue**. They have a truly enormous tongue. They need this to dig deep into holes to search for insects and grubs like the larvae of beetles.

But they are such small birds. Are their mouths big enough to hold their tongues? The answer is amazing.

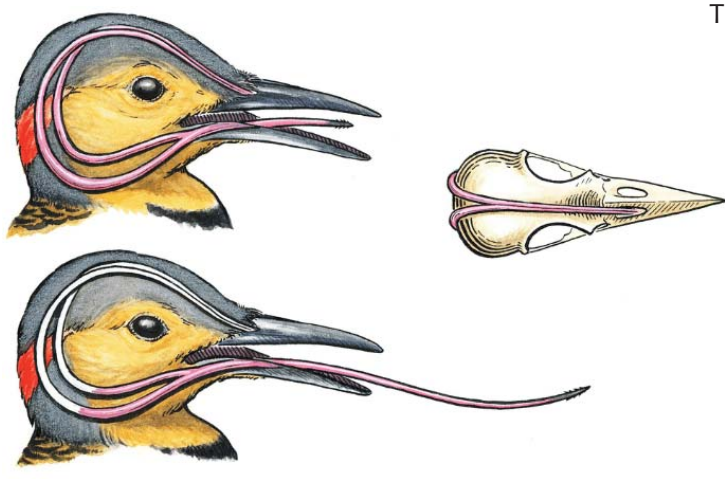
How does a woodpecker's tongue work?

In both humans and birds, the tongue is supported by a bone called the *hyoid*. This is a horseshoe-shaped structure under your jaw. The muscles in your tongue and mouth (floor) attach to this bone. It helps us breathe, swallow, and speak.

A woodpecker's hyoid bone, however, is very different. The center of the woodpecker's muscle-wrapped hyoid is in the nostrils, in the bird's upper beak. It splits into a V between the eyes, and its two arms wrap completely around the woodpecker's skull, passing over the top of it and around the back before meeting up again at the base of the lower beak.

When the muscles surrounding the hyoid contract, the tongue projects forward, through the length of the beak and beyond. But when those muscles relax, the woodpecker's tongue retracts (goes back) along the length of the hyoid and is coiled around the back of its owner's skull!

So how long is a woodpecker's tongue? The



total length of a woodpecker tongue can be up to a third of the bird's total body length, although the exact proportions vary from species to species. This includes both the part that sticks out past the end of the beak, and the part that stays anchored in the head. If our tongues were the same proportion, they would be around two feet long!

Occasionally those long tongues can even get woodpeckers into trouble. Scientists who catch woodpeckers for study sometimes have to carefully disentangle the birds' tongues from their nets.

Does a woodpecker's tongue protect its brain?

Yes. Having its tongue wrapped around the back of its brain doesn't just give a woodpecker somewhere to store a long appendage; it also helps protect the bird's brain from injury during high-speed pecking.

When the muscles that surround the woodpecker hyoid bone contract, they don't just cause the woodpecker to stick out its tongue. That tensing-up action also helps hold the skull and spine snugly in place as the bird's beak collides with a tree, just like a seat belt keeps you from flying forward if someone slams on the brakes.

Tongues aren't the only part of a woodpecker's cranial anatomy that helps to keep the bird's brain safe. There are also extra plates of spongy bone in the front and back of the skull. Sandwiched between layers of denser, more compact bone, these softer bones help absorb and distribute the shock each time a woodpecker strikes a tree.

Sources: American Bird Conservancy and Wikipedia

Seasons from the Sun

Kamal Lodaya
Bengaluru

This is the eighth in the series about calendar makers from history.

Earlier articles talked about three different kinds of calendars: **lunar** calendars based on *phases* of the Moon, **seasonal** calendars based on *seasonal happenings* (such as rains or river flooding which were important for farmers) and **intercalary** calendars whose years were seasonal but whose months were based on the Moon's phases.

There are several calendars in India, using different **Eras**. **Aryabhata** in 499 CE adapted the Tamil calendar by calculating the beginning dates of months.

Months from Moon with seasons from Sun

If you remember, this year **Deepavali**, falling on the *amavasya* (New Moon) of ***Karthikai*** *lunar month*, was on 4th November. This is nowhere near the *seasonal month* of ***Karthikai***, which is from 17th November to 15th December this year. So isn't the seasonal calendar all wrong?

But yes, **Pongal** is on the first day of ***Thai***, which is 14th January. So the seasonal calendar is *not* followed for Deepavali, it *is* followed for Pongal. Some festivals are determined from the Moon and some from seasons!

This goes back to 575 CE, when **Varahamihira** compiled all the calendars known to him in his *Panchasiddhanta* (five

Vikram Samvat 2078-79 (2021-22 CE)

Month	Begins	Amavasya	Purnima	Days	Sankranti	Festivals
Phalguna			28 Mar			
Chaitra	29 Mar	12 Apr	26 Apr	29	Mesha 14 Apr	Ramanavami, Mahavirjayanti
Vaishakha	27 Apr	11 May	26 May	30	Vrishabha 15 May	Buddhapurnima
Jyeshtha	27 May	10 Jun	24 Jun	29	Mithuna 15 Jun	
Ashadha	25 Jun	10 Jul	23 Jul	29	Karka 17 Jul	Gurupurnima
Shravana	24 Jul	8 Aug	22 Aug	30	Simha 17 Aug	Rakshabandhan
Bhadra	23 Aug	7 Sep	20 Sep	29	Kanya 17 Sep	Janmashtami, Ganeshchaturthi
Ashwina	21 Sep	6 Oct	20 Oct	30	Tula 18 Oct	Navaratri, Vijayadasami
Kartika	21 Oct	4 Nov	19 Nov	30	Vrischika 17 Nov	Deepavali
Mrigashira	20 Nov	4 Dec	19 Dec	30	Dhanu 16 Dec	
Pausha	20 Dec	2 Jan	17 Jan	29	Makara 14 Jan	
Magha	18 Jan	1 Feb	16 Feb	30	Kumbha 13 Feb	
Phalguna	17 Feb	2 Mar	18 Mar	30	Meena 15 Mar	Mahashivratri, Holi
Chaitra	19 Mar	1 Apr	16 Apr		Mesha 14 Apr	

Vikram Samvat 2077-78 (2020-21 CE)					
Month	Begins	Amavasya	Purnima	Days	Sankranti (Surya Siddhanta)
Phalguna			9 Mar		
Chaitra	10 Mar	24 Mar	8 Apr	30	Mesha 9pm 13–14 Apr
Vaishakha	9 Apr	22 Apr	7 May	29	Vrishabha 7pm 14 May
Jyeshtha	8 May	22 May	5 Jun	29	Mithuna 5am 15 Jun
Ashadha	6 Jun	21 Jun	5 Jul	30	Karka 9pm 16–17 Jul
Shravana	6 Jul	20 Jul	3 Aug	29	Simha 8am 17 Aug
Bhadra	4 Aug	19 Aug	2 Sep	30	Kanya 8am 17 Sep
Adhika Ashwina	3 Sep	17 Sep	1 Oct	29	–
Ashwina	2 Oct	16 Oct	31 Oct	30	Tula 7pm 17 Oct
Kartika	1 Nov	15 Nov	30 Nov	30	Vrischika 5pm 16 Nov
Mrigashira	1 Dec	14 Dec	30 Dec	30	Dhanu 5am 16 Dec
Pausha	31 Dec	13 Jan	28 Jan	29	Makara 12nn 14 Jan
Magha	29 Jan	11 Feb	27 Feb	30	Kumbha 11pm 13–14 Feb
Phalguna	28 Feb	13 Mar	28 Mar	29	Meena 7pm 14 Mar

texts). He combined earlier Hindu and Jain calendars based on the Moon with Aryabhata's calculations of the **Kaliyuga** calendar. From 8th century CE, the **Vikram Samvat** calendar began to be used in North India. It is based on these texts. Below are the dates for this year. As you can see, *Kartika amavasya* or **Deepavali** falls on 4th November. The dates of the **sankrantis** as calculated from Aryabhata are also shown. (Recall from the earlier articles that the the Sun's path in the sky is divided into 12 *solar rashis* or signs of the Zodiac. The apparent movement of the Sun from one *rashi* to another is called a **sankranti**. Since there are 12 divisions in a year of 365 days,

Panchangs and horoscopes

A number of different *panchangs* (calendars) are used today all over India, keeping track of five kinds of information required for the calendar. Most calendars are based on the *Rashtriya Panchang* published by the Positional Astronomy Centre, Kolkata, which uses Aryabhata's idea but with modern data.

Jyotishis (astrologers) also make horoscopes from panchang dates. These have little to do with the Sun and Moon. Indians were delighted to use their calculation skills and they decided to also plot the positions of other *grahas* (this is how the planets Mercury, Venus, Mars, Jupiter and Saturn were known then) into a horoscope. They also added two imaginary *grahas* called Rahu and Ketu with the same path in the sky as Moon. How can you be sure they are imaginary? Well, when India's *Chandrayaan* went to the Moon, there was no need to calculate anything about Rahu or Ketu.

sankrantis will happen every 30 or 31 days.)

As seen in the Aryabhata calendar, **Mesha sankranti** on 14 April determines the *seasonal* month of **Chaitra** or **Chittirai**. The Full Moon after it on 26 April is called **Chaitra purnima**. The New Moon before the Full Moon (*purnima*) on 12 April is called **Chaitra amavasya**. This Vikram Samvat calendar is *purnimanta*, where the Full Moon indicates the *end* of a month and the next day a new month begins. (There are other Indian calendars which are *amanta*, with New Moon (*amavasya*) ending a month.)

So the Vikram month of **Chaitra** begins the day after **Phalguna purnima** and ends with Chaitra purnima. Now if you know how a festival day is determined, you can calculate it yourself. **Navaratri** is the first nine days of *Ashwina*, the tenth day is **Vijayadasami** or **Dasara**. Can you calculate when they are in 2021?

The seasonal year takes 365 days, from 14 April this year to 14 April next year. The Vikram Samvat year is shorter, from 29 March to 19 March next year. The months are also shorter, taking 355 days in all. Chaitra purnima next year will be just two days after Mesha sankranti.

Accurate planet positions require more than mathematics, they require *observation*. The problem of figuring them out was solved by **Johannes Kepler** of Prague in the 17th century CE with years of observational data gathered at the observatory of **Tycho Brahe** of Denmark, with whom he worked as an assistant.

Mixups in the mixed calendar

To see problems that may come up, step one year back. In the year 2020 CE, **Kanya sankranti** was on 17 September and **Tula sankranti** was on 17 October. So in-between, the Sun was in *Kanya rashi*. There were *two* amavasyas, 17 September and 16 October, and *one* purnima, 1 October, between these two sankrantis. By following the 354-day calendar based on the Moon from earlier years, the month of **Bhadra** was already over! Such situations were anticipated by Varahamihira. He said this condition required an *adhika* (extra) month.

An *adhika* **Ashwina** was added last year, preceding the regular month of Ashwina ending with the purnima after Tula sankranti. Adhika Ashwina amavasya was on 17 September and Adhika Ashwina purnima on 1 October. Ashwina amavasya was on 16 October and Ashwina purnima on 31 October.

Below is the Vikram Samvat calendar for 2020, it has 384 days! The combined month of Ashwina has 59 days. In the earlier part of the year, both amavasya and purnima (say for Chaitra) happen before the associated (Mesha) sankranti. Can you figure out how this mixup of purnimas and sankrantis happened when calendars based on Moon and seasons were put together? When will such a thing happen again? Answers in the next issue of ***JM***.

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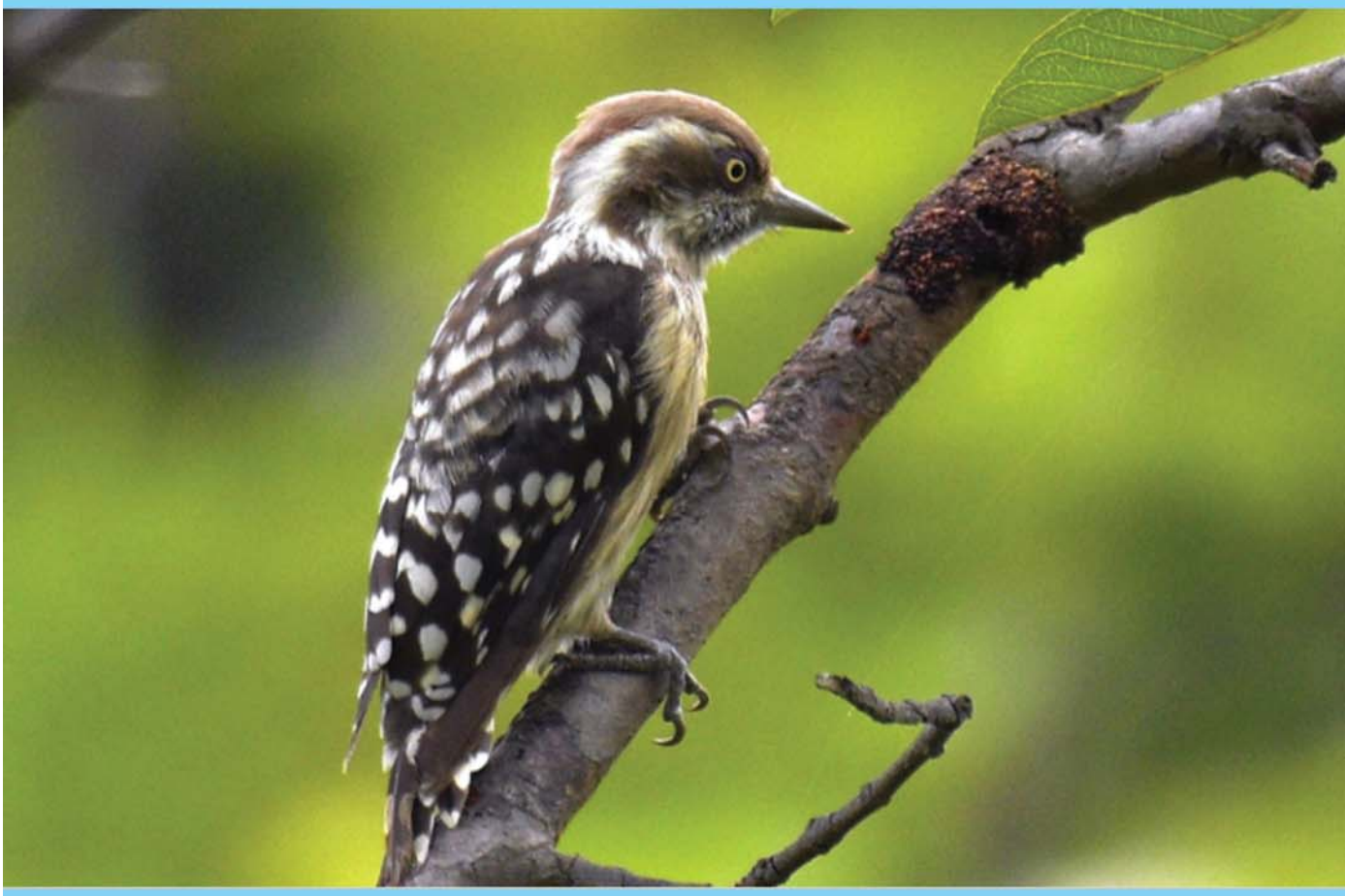

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