contents

Biographical sketches

MVN Murthy
Chennai

The Royal society is one of the oldest scientific academies founded in 1662 in London. Every year it elects as its fellows eminent scientists from around the world. There are nearly 1600 Fellows many of whom have gone on to win the Nobel Prize. To be called a "Fellow of the Royal Society" (FRS) is considered an exceptional honour. Every year about 50 fellows are admitted to this list of honour.

There are many Indian Scientists among the Fellows at present. The first Indian to be elected Fellow was a shipbuilder named **Ardsheer Cursetjee Wadia** in the year 1841. Eminent Indian scientists **Jagdish Chandra Bose**, **C V Raman**, **G N Ramachandran**, **Meghnad Saha** and others have been Fellows of the Royal Society.

The list announced this year (2019) has two eminent Indian Scientists—**Yusuf Hamied** and **Gagandeep Kang,** both of whom are very special choices. Dr. Gagandeep Kang is the first Indian woman to be elected as a fellow while Dr. Hamied is elected as an honorary fellow for his work in providing affordable health-care to very poor people all over the world. Here is a brief biographical sketch of these two people.

Yusuf Hamied

Dr Yusuf Hamied is the chairman of the pharmaceutical company **Cipla** (Chemical, Industrial and Pharmaceutical Laboratories) which was founded in 1935 by his father, Khwaja Abdul Hamied, a disciple of Mahatma Gandhi. It came about to combat shortage of medicines in India at that time. Hamied's company Cipla is one of the big Indian drug manufacturing companies that is saving millions of lives through the production of low-cost medicines worldwide.

Hamied was educated in Xavier College, Mumbai and earned his Ph.D in chemistry from Christ's College Cambridge. He is well known for defying big multi-national pharma companies to provide affordable health care for people in poor countries.

A significant achievement of Hamied and Cipla is the production of low cost medicine for combating the Human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS) epidemic. It is a particular life threatening disease which affects the immune system of the body. If left untreated, even a minor infection like common cold may become severe causing death. Not only does the virus attacks cells, it uses the cells to make more of the same virus. This can spread to other people through any contact with the affected person through body fluids like blood, breast milk etc. It is enough to come in contact with the needle used by the affected person to be infected.

The disease became an epidemic in the nineties with millions of deaths mainly in Africa. At the same time, it spread very quickly to the rest of the world. AIDS epidemic was responsible in bringing down the life expectancy in South Africa to below 45 years in the nineties. Combating AIDS required development of medicines which became available in the early phase of the spread of the disease itself. However, the multi-national drug companies that held the patent (monopoly) for these medicines sold it at such a exorbitant price (approximately about Rs.10 lakhs per year per person) that it became almost impossible for poor people world over to get any meaningful treatment.

The turning point in the treatment happened when Cipla introduced a cocktail made of three essential drugs to combat AIDS in the year 2001. Cipla offered the combination drug at a price which was almost thirty to forty times cheaper than the prevailing price at that time (cheaper than Rs.100 per day per person now). This prompted the big drug companies also to lower their prices eventually but not before challenging Cipla through various legal challenges or the threat of sanctions by the US government where these big companies were based.

Such a move as what Cipla did would have been unimaginable in Europe or the Americas due to legal restrictions. Cipla was aided by an Indian Government policy, in place since 1972, that in matters of health and in times of epidemics when saving lives is a serious issue, patent is allowed for a process but not the product itself. This means that you are allowed to manufacture the same medicine which is patented elsewhere provided you do it in a different way.

The world opinion in matters of life-saving drugs also turned in favour of what Hamied was trying to achieve. At present, one in three people with HIV infection is taking the cocktail devised by Cipla all over the world.

Through Dr. Hamied's pioneering efforts, Cipla is now a leading drug manufacturing company that is helping millions of people across some 170 countries by providing life saving drugs at affordable cost. He has also worked with governments in sharing the technologies in critical areas with other drug companies the developing world. He has said "I don't want to make money off these diseases which cause the whole fabric of society to crumble".

The honorary FRS awarded to Dr. Hamied is in recognition of his contributions to the state of affordable health-care.

Gagandeep Kang

Dr Gagandeep Kang is a medical scientist, and the first Indian woman elected to the Royal Society. She had her education in Christian Medical College (CMC), Vellore where she obtained her MBBS, MD and Ph.D. She worked as a post-doctoral at the Baylor College of Medicine in Houston. She has since returned to the CMC, Vellore.

Diarrhoea is one of the most common diseases in India (and in many developing countries). It has been a serious public health issue for a long time. Dr Kang's has focussed on the vaccines, infections and nutrition in small children especially in disadvantaged communities.

The severe diarrhea among children is caused mainly by an infection caused by *Rotavirus*. Dr Kang played a significant role in developing a vaccine called **Rotavac** which is now used made in India. These vaccines prevent substantial cases of severe diarrhea in the world. It also decreases the risk of death among children.

She was a Professor in the Department of Gastrointestinal Science at cMC, Vellore and is currently the executive director of the Translational Health Science and Technology Institute, Faridabad.

The FRS awarded to Dr. Kang is in recognition of her work in "investigating the complex relationships between infection, gut function and physical and cognitive development, and seeking to build a stronger human immunology research in India."

(Source: Wikipedia)

Try it out

What mathematical symbol can be put between 5 and 9, to get a number bigger than 5 and smaller than 9?

Answer on page 11`

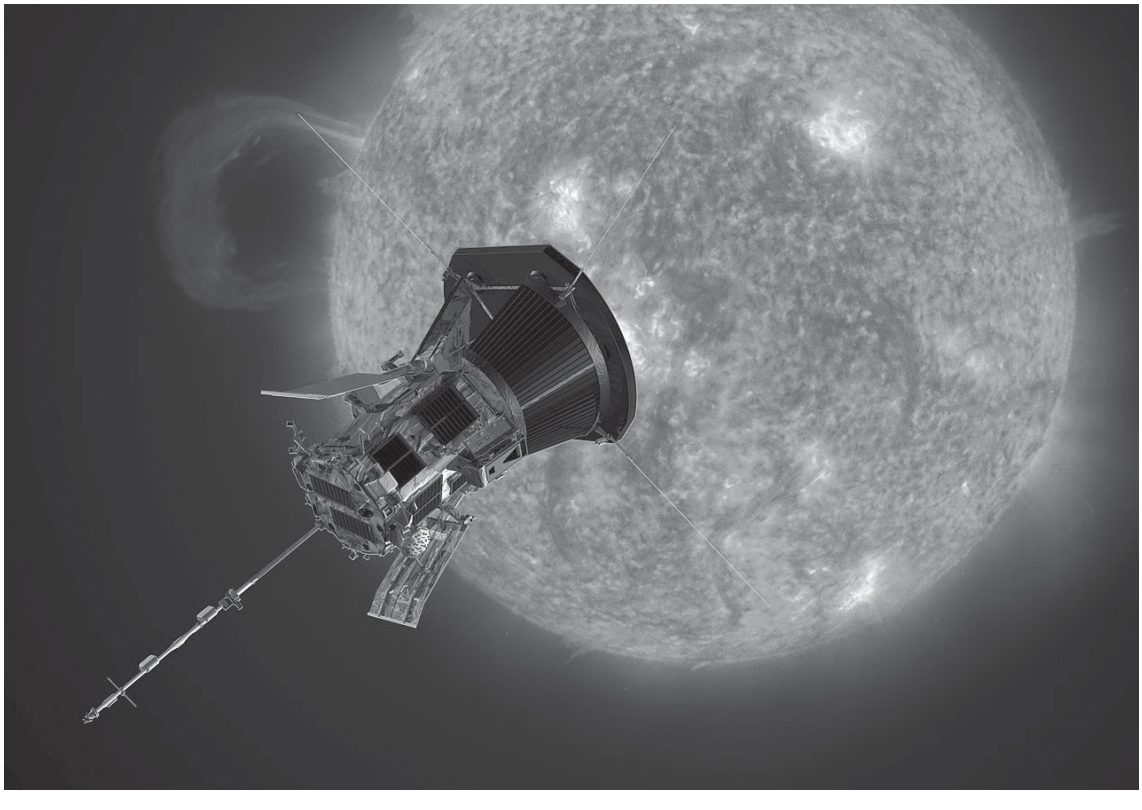
FIERY FALL

Kamal Lodaya

In this Space diary, we talk about a spacecraft launched by the United States last year, called the **Parker solar probe**. The idea behind ths probe is equally simple: to get into the Sun's *corona*, the white-hot outer atmosphere that we see during a total solar eclipse.

The Sun's interior is extremely hot, millions of degrees, so hot that hydrogen atoms fuse into helium. This is the ultimate source of solar energy. The Sun's surface, which we see every day, is about 6000 degrees Celsius. It is so hot that if we look at it with some magnification for some time, we will eventually lose our eyesight. This is what happened to the 16th century Italian scientist Galileo Galilei with his primitive telescope.

The corona spreads far outside from the Sun's surface. Its temperature reaches



Annular solar eclipse this year

Annulus means "ring". An annular solar eclipse happens when the Moon covers the Sun's center, leaving the Sun's visible outer edges to form a "ring of fire" or annulus around the Moon.

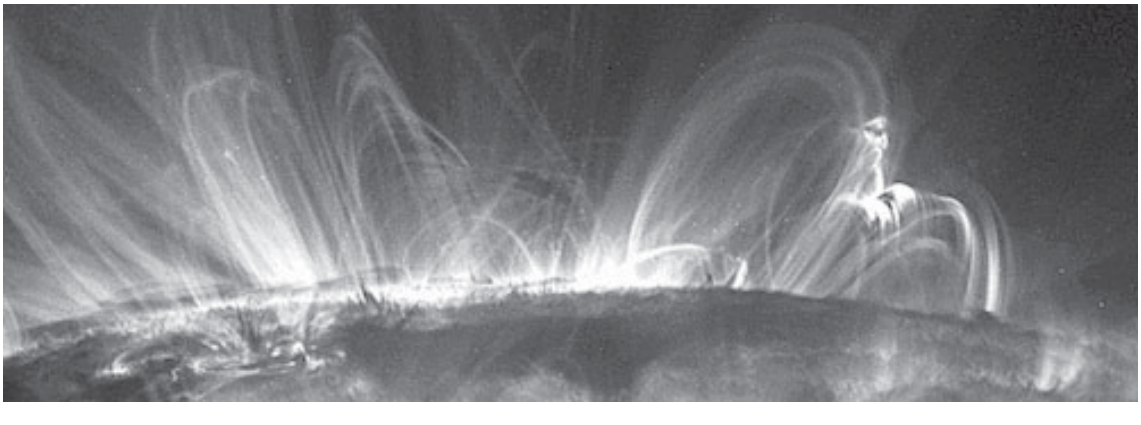
Solar eclipses happen when the Moon casts a shadow on Earth. Annular solar eclipses can only take place when it is new moon. At the same time, the Earth, the Moon, and the Sun are aligned in a straight (or nearly straight) line. This does not happen all the time since the orbits are tilted a little with respect to each other. In addition, the Moon is not in a circular orbit around Earth, but it is squashed into an elliptic orbit. So the distance to Earth varies. When the Moon is near its farthest point from Earth, called apogee, it cannot fully cover the Sun. The outer edge of the Sun then remains visible as a ring of sunlight. If the Moon were closer, it would fully cover the Sun and we would get a total solar eclipse.

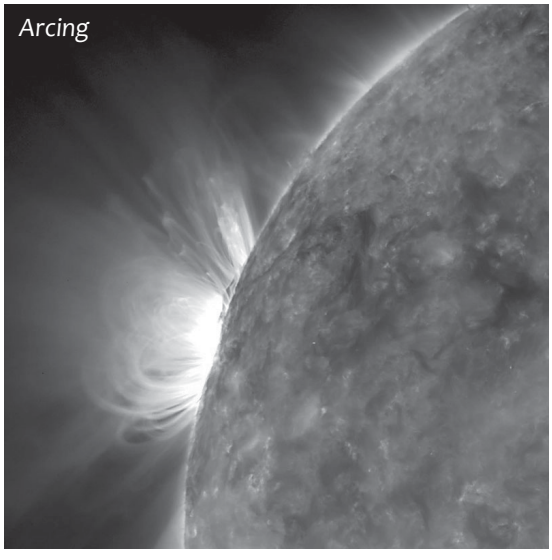
Annular eclipses can last over 3 hours in locations where annularity is visible. The annularity, when only a ring of fire is visible in the sky, can range from less than a second to over 12 minutes. Look out for the annular solar eclipse that will be visible from India on the morning of Dec 26, 2019. (Can you tell why the eclipse will be in the morning?) The regions where you can see at least partial annularity will be over south India. In places such as Coimbatore you will see full annularity.

around 20 lakh degrees C. So, travelling from the centre of the Sun outwards, its temperature decreases to thousands of degrees at the surface, and then going out further, increases to lakhs of degrees. Then it decreases out into space, for example the temperature of the Moon's surface (150 million kilometres from the Sun) is only a few hundred degrees. The Earth's surface is a little cooler because its atmosphere shields the planet.

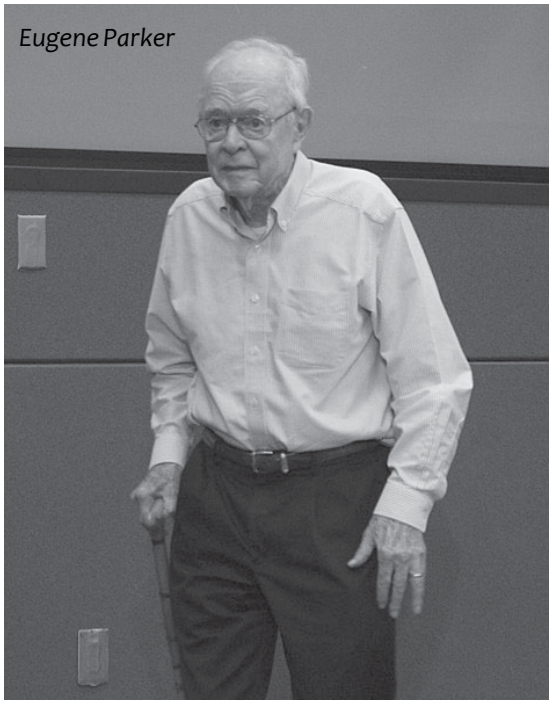
Why is the corona hotter than the surface? You couldn't have asked a simpler question. We don't know. This is one of the great mysteries of astronomy.

From satellites which are placed in space going around the Sun, we can see that there are very strong magnetic forces which connect the Sun to its corona. Charged particles, called plasma, are transported from the Sun to the corona in solar flares and by *coronal streamers*. From




Arcing

the corona they emanate outwards as the *solar wind*. This was first described by American scientist Eugene Parker. He also connected the solar wind to the ion tail formed behind a comet as it goes around the Sun. The Parker solar probe is the first spacecraft named after a living person, he is in his nineties.


Eugene Parker

Somehow these magnetic forces and travelling particles build up the temperature of the corona. How? Again, a simple question, we don't know the answer. When he was 60, in 1987, Parker suggested a mechanism of very small *nano-flares* happening on the Sun's surface, which we cannot see, which take particles into the corona. It is now theorized that these might transmit "blobs" of plasma every 90 minutes. Can we get into the corona and see? That is the job of the Parker solar probe.

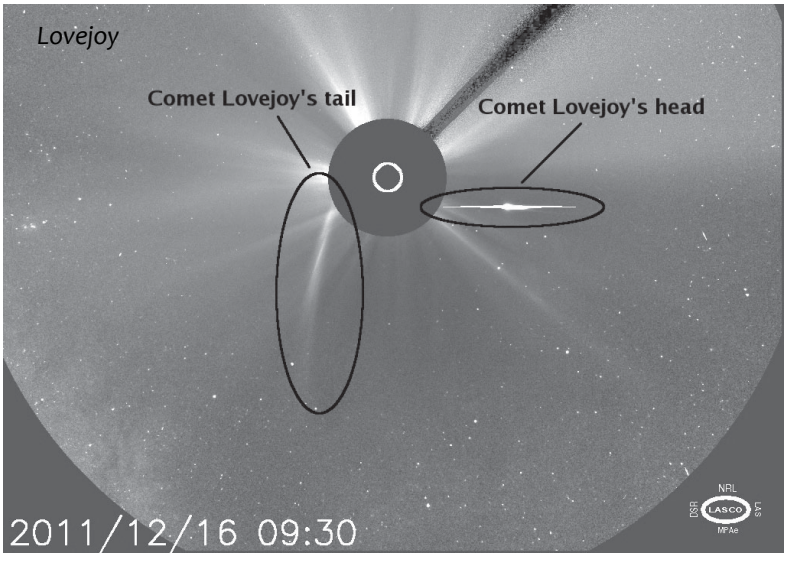
Engineering sungrazer comets

What happens if you, or your spacecraft, gets heated to lakhs of degrees? Both will vapourize. So how do we get into the corona?

We learn from comets

A few years ago comet *Ison* went behind the Sun and disintegrated, all that came out was dust. The picture shows comet *Lovejoy W3* emerging after it passed very close to the Sun in December 2011.

Like most other sungrazing comets, Comet Lovejoy was not expected to survive its close encounter with the Sun. But it did. This image in the picture was taken from a coronograph on the SOHO spacecraft which keeps staring at the Sun. You can see the remnants of the tail, with the brilliant head or *coma* emerging from the solar glare, on December 16, 2011. The Sun's position has been "blackened" out to block the glare and is indicated by the white circle. Separated from its tail, Comet Lovejoy's coma is so bright it saturates the camera's pixels creating the horizontal



streaks. However, the comet disintegrated soon after.

In 1965, comet *Ikeya-Seki* went very close to the Sun and came back out again, displaying a splendid tail of dust and ions knocked out from its nucleus. The picture shows a painting by David Nicholls from Canberra, Australia. The nucleus did not disintegrate.

What is the secret of their survival?

Here is the sungrazer comet's trick. If you go to a place which is at a temperature of lakhs of degrees, and you *stay* there, you will rapidly be heated up to lakhs of degrees, of course disintegrating long before that. But if you **whiz** through the corona at very high speed, travelling kilometres per second, the corona is so sparse that you may not get that heated up, you may escape. The comet's elliptical orbit keeps it falling closer and closer to the Sun, and its orbital speed brings it back out.

This is the trick adopted by the Parker solar probe. It first got to the planet Venus. By using its gravity, it got shot into a highly elliptical comet-like path taking it very close to the Sun. On November 6 last year, it reached within 2 crore km of the Sun, travelling at 95 kilometres per second. It came back out unhurt! Over the next few months it has sent back the data it collected. On April 4 this year it did its second graze of the Sun. The third perihelion was on September 1st. The data collected will soon be analysed and released.

Over the next six years, the spacecraft will keep using Venus to make its orbit shorter and faster, and its perihelion closer and closer to the Sun. In December 2024 it

will reach within 7 million kilometres of the Sun, travelling at 192 kilometres per second. For a comparison, comet Ikeya-Seki was just half a million kilometres from the Sun.

The Parker Solar Probe has used its WISPR (Wide-field Imager for Solar Probe) instrument to photograph a coronal streamer from a distance of about 27 million kilometers. (In contrast, our Earth is about 150 million km away from the Sun.) It could do this because of a reinforced carbon composite solar heat shield that can withstand about 1300 degrees C.

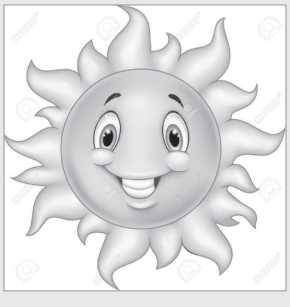
It may not seem very exciting to you but for astronomers this is among the first ever pictures from *inside* the corona. The spacecraft gets measurements of the magnetic field, coronal plasma and solar wind speed.

We have to wait and see whether PSP survives all its encounters. Meanwhile solar astronomers are eager to see the data from the second encounter.

Fun Science Facts

- There is enough DNA in the average person's body to stretch from the Sun to Pluto and back — 17 times
- The average human body carries ten times more bacterial cells than human cells
- It takes light up to 40,000 years to travel from the core of the sun to its surface, but only 8 minutes to travel the rest of the way to Earth
- You can't taste food without saliva
- Octopuses have three hearts, nine brains, and blue blood
- An individual blood cell takes about 60 seconds to make a complete circuit of the body.

From https://www.zmescience.com



Answer to Try it out on Page 6

A decimal point. The number 5.9 is larger than 5 and smaller than 9.

From mathisfun.com

What is in a Name?

S.Narayani

"What's in a name?
That which we call a rose
By any other name would smell as sweet,"

said Shakespeare. Applying the same logic, a monkey by any other name will still jump from tree to tree, a dog by any other name would still bark and a fish by any other name would still swim. Studies in animal consciousness have also shown similar results. We kept names for the animals and plants around us just for convenience. But as a very creative species, humankind has really given some very interesting names for the variety of life around us. The stories behind such names are amusing and extremely entertaining.

From the Greek

Consider the **chameleon** for example. The name chameleon is derived from a latin root word which in turn is derived from the greek words meaning *Lion on the Ground.* This name indicates the slow movements

Chameleon

of the chameleon as it approaches its target insect. Funnily, the chameleon is more famous now for its amazing colour changing abilities, but the person who named it saw the movement and decided to give a name based on it. What name would you give the chameleon if you had the power? Let us know!

A lot of such examples come to mind.... Consider the **hippopotamus**. Even though it resembles a large pig, its closest relatives are dolphins and whales. Yet the common name hippopotamus comes from the greek words meaning *River horse*. How an animal like this was called a horse of the river is beyond our imagination!

Wild imagination

Aha ha. This is not me having a Eureka moment right in the middle of this article. This is actually the scientific name of an Australian Wasp. *Aha ha* was a name given by Arnold Menke in 1977 after he received some wasp samples for investigation. When he opened the package and saw the wasps, he exclaimed, "Aha, a new genus" and proceeded to name the wasp *Aha ha*. He had also noted later that if he gets one more genus, he is going to name it **Ohno**. Imagine a genus based on "Oh, no"!

Of mermaids and animals

The oceans have always fascinated mankind. We have been in wonder of its many unanswerable mysteries. We have a rich concoction of various stories about animals and plants in the ocean, their strange shapes and fascinating activities. The existence of **mermaids** is one such fantasy. They are supposed to be half-woman half-fish. Although science has proven that mermaids do not exist, the animals and plants named after the mermaids still retain the memories of magical storytelling.

Mermaid's wineglass is a common species of algae in many tropical seas. Even though


Mermaid's wineglass

Mermaid's sea fan

it is uni-cellular, its size makes it easier to see without any microscope. The shape of the algae resembles a small cup, so it was named as the wineglass of mermaids.

Mermaid's sea fan is another algal species named after the mermaids. It is a species of brown algae with funnel shaped leaves with lines and curled edges. It is consumed

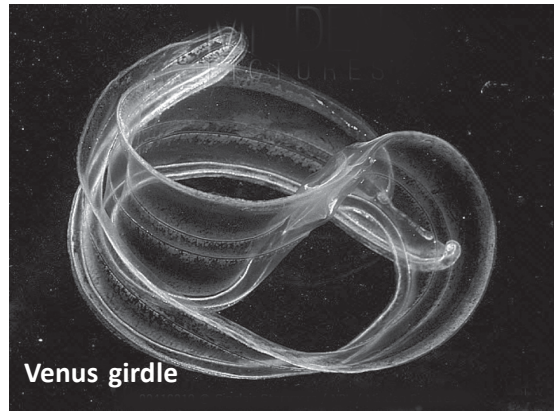

Mermaid's purse

by some coastal communities.

Mermaid's purses are not actually purses but the egg cases of dogfishes and skates. It is a tough leathery pouch that protects a developing embryo. Each egg case contains one embryo. Sometimes the egg cases contain tendrils in the end which help them to anchor themselves to the seaweeds. The shape, size and colour of the mermaid's purses help biologists in identifying the type of sharks or skates that laid the eggs.

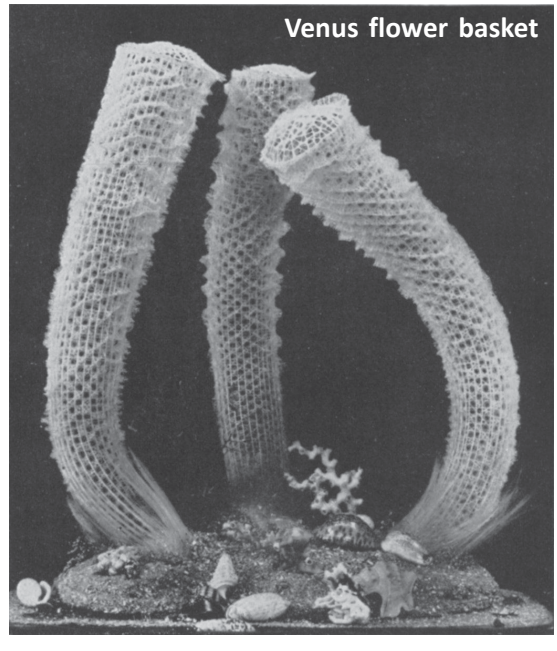
Beautiful Venuses

We have all heard about the planet *Venus*. It was named after Venus, the Roman Goddess of Love and Beauty. Some scientists have named some beautiful sea creatures after her. The **venus girdle** is a ribbon shaped comb jellyfish. Since it resembles a round ornament worn by women around their waist (Girdle), it is called the venus girdle. The **venus flower basket** is a beautiful sea sponge with a silica based skeleton. It is a stationary animal commonly found near the Philippines. If we look at the images of these intricately woven silica skeletons which look more like artwork than a living form, we can appreciate the name Venus flower basket.


Venus girdle

War Games

Portugese man-of-war — the name sounds like the honorary title of a knight. But in reality, it is a common species of jellyfish. It was named after the shape of an 18th century warship since the jellyfish resembled the ship at full sail. This is a jellyfish worthy of its name. Armed with powerful stinging cells, it wages war at all its prey. It even stings humans!


Venus flower basket

Portugese man-of-war

Migrating names

There is a marine crustacean called the **barnacle**. We can commonly see such rock-boring barnacles in many rocky shores and harbour areas. One species of barnacle is commonly called as the **Goose barnacle**. But they have absolutely no connection to a goose. Then how did this name come about? In olden days, people did not know that birds migrate. In the 12th century, in many European countries, people suddenly saw migratory geese which were not seen previously in that area. Someone came up with the theory that these birds came from the barnacles. Some other people even claimed that they saw the birds coming out of these tiny barnacles. So the name Goose barnacle was given to this species! This belief existed till the 18th century. This migratory goose species was called as barnacle geese based on this belief.

Goose barnacle

Many common fish names are derived from their resemblance to their terrestial counterparts or even common objects — Lizard fish, frog fish, rat fish, cow fish, razor fish, tripod fish, sun fish, saw fish, sword fish and moon fish are some examples. There is a fish called **stargazer** which lives on the seafloor. Its eyes which are fixed on the top of the head has earned it the name Stargazer!

Misnomers

There are also some *misnomers* (meaning wrongly named) which tend to confuse us. The **ladybird** is not a bird but a type of bug. The **starfish** is not a fish but a member of the urchin family. The **killer whale** is not a whale but a type of oceanic dolphin. The **guinea pig** is not a pig but a type of rodent.

The names that we give to animals create prejudices among people. We cannot imagine a friendly animal if it is called a **Killer whale** or a **Devil Ray** or a **Vampire Squid**. These perceptions are very important when we are trying to conserve these animals.

The next time you hear the name of a species, do spend some time in learning how the name was finalised and why it was named so. As they always say, sometimes reality is stranger than fiction!

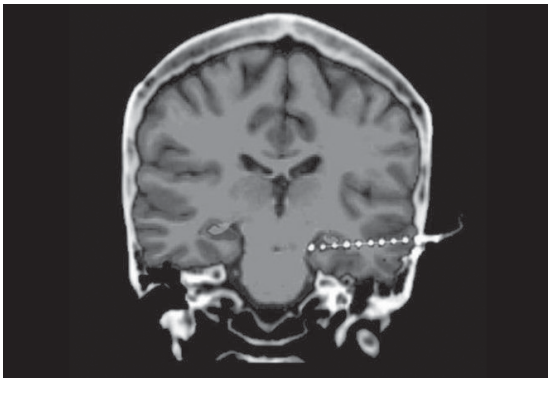
How does the brain recall Memories

D Indumathi,
Chennai

Have you ever struggled to find a word or a formula, just when you thought you knew it very well? Especially just at the beginning of an exam? And, then when you have cooled off a little, and de-stressed, the word pops back in your memory and you heave a sigh of relief. Or perhaps you remember it only after the exam is over!

Why does this happen? How do we remember? First of all, how do we store memories, and secondly, how do we recall them?

The human brain is a complex collection of cells called *neurons* which transmit and store information. You may have heard that there are two types of memory: short-term and long-term. Short term memory is usually stored in the frontal lobe of the brain, especially the pre-frontal cortex. On the other hand, long-term memories are made by more stable and permanent changes in neural connections that are widely spread throughout the entire brain.



Hippocampus

One of the important parts of the brain for making and storing memories is the hippocampus. It is a seahorse-shaped region of the brain. It is thought to be the center of emotion, memory and the involuntary nervous system. It is essential for learning new information as well as in converting short-term to long-term memory although it does not seem to store any memory itself. There is still a lot of research going into how we actually store and recall memories and the subject is fascinating.

In recent research, scientists have made progress in locating the centre in the brain that helps in memory recall.

Putting electrodes in the brain

Studying brain cells in action inside the human head is not easy. Putting electrodes in someone's brain requires surgery. It's not something researchers do without a good reason. The new study involved people who already had electrodes put in their brains for some medical purpose.

These participants all had epilepsy. This brain disorder causes storm-like surges of electrical activity in the brain, known as seizures. Doctors put the electrodes in the

patients' brains so they could pinpoint those surges. The photo shows the cross section of the brain with bead-like electrodes inserted at the bottom right of the brain.

In the new study, **Yitzhak Norman** of the *Weizmann Institute of Science* in Rehovot, Israel, and his colleagues, studied signals from cells in the brain's hippocampus. That's a key memory center.

Triggering memory waves

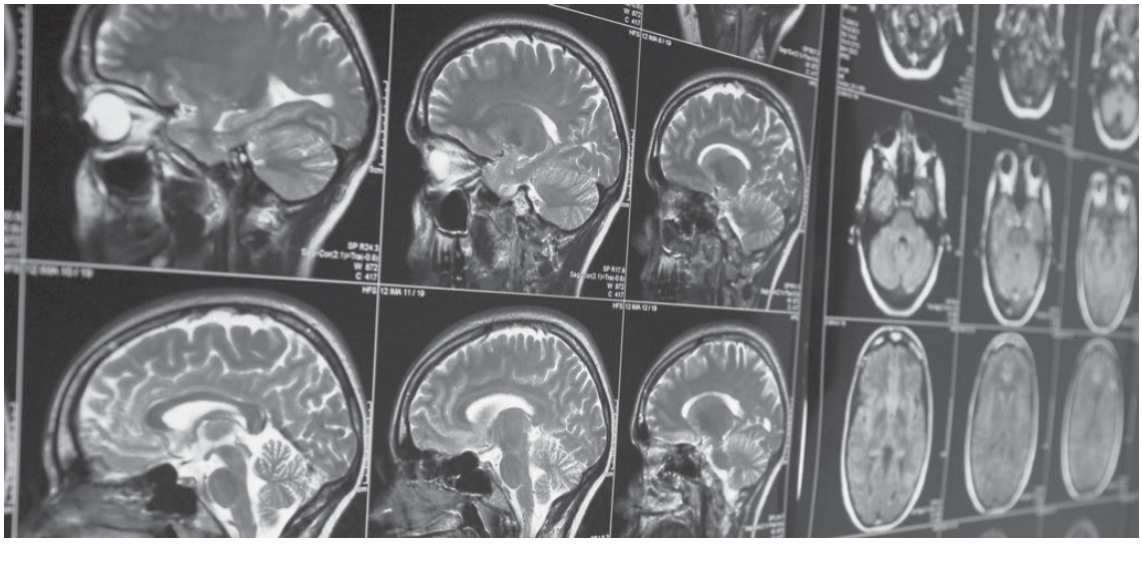
First, patients were shown images of people and places they already knew. For example, they might see a picture of former President Barack Obama. Or they might view an image of the Eiffel Tower in Paris, France. As each picture appeared, electrodes picked up bursts of activity in the brain. These so-called sharp-wave ripples happen when many nerve cells fire together.

Earlier studies suggested that these ripples in the hippocampus were important for forming memories. But it wasn't clear if the ripples also had a role in recalling memories.

To test that, Norman's group blindfolded the patients. Then they asked each to recall the pictures they'd seen. A second or two before the participants began describing each picture, researchers noticed an increase in sharp-wave ripples in the hippocampus. Those ripples were very similar to the ones seen earlier. The photo shows how different parts of the brain especially in the hippocampus area lights up as the patients recall the pictures they have already seen.

Norman's team shared its new discovery on August 16 in the journal *Science*. The authors say their data suggest those ripples help people make and recall memories. This new finding sheds light on how the brain stores and recalls information.

Adapted from
Science News for Students,
by Laura Sanders
<https://www.sciencenewsforstudents.org/author/laura-sanders>



The Youth Climate Summit

At the United Nations

R. Ramanujam,
Chennai

On September 20, 2019, a Friday, students from some 150 countries skipped school to participate in the largest climate protests ever. This was a huge gathering of protest considering that it started roughly a year ago, with just one teenager from *Sweden*, **Greta Thunberg**, now 16, taking action. She is among four people named as the winners of a Right Livelihood Award, also known as the "*Alternative Nobel*." She sat outside the Swedish parliament again and again demanding action for climate change. Later she spoke to delegates of a ***United Nations Climate Change Conference*** in Poland.

The next day, on September 21, Greta and more than 700 other young climate leaders convened at the first ***United Nations Youth Climate Summit***. It began with Thunberg addressing the gathering. She

António Guterres

started with a blistering attack on inaction by governments on the issue of climate change.

"For more than 30 years the science has been crystal clear. How dare you continue to look away and come here saying that you are doing enough, when the politics and solutions needed are still nowhere in sight."

"How dare you pretend that this can be solved with business-as-usual and some technical solutions. With today's emissions levels, that remaining CO_2 budget will be entirely gone in less than eight and a half years."

It takes courage and commitment to say that to world leaders.


Komal Karishma Kumar

The UN Secretary General **António Guterres** participated. Guterres was titled the "keynote listener". Usually in conferences he would be called "keynote speaker", but here his job was to listen learn from young leaders.

Komal Karishma Kumar, a young climate activist from *Fiji*, participated. She came ready with a list of demands. These included the phasing out of fossil fuels and a boosting of climate education. She also demanded the inclusion of youth in policy decisions. She called upon global leaders to fulfill their commitments to the ***U.N. Green Climate Fund***. This international agreement assists low-income countries affected by the climate crisis. Fiji is one of those nations.

All of these commitments are necessary to fulfill the goals of the ***2015 Paris Accord***. At that time, 195 nations agreed to a goal of limiting global warming to less than 2° Celsius. Reaching this goal will be difficult.


Wanjuhi Njoroge

That is because much the world depends on burning fossil fuels such as oil and coal for energy. (Moreover, the *United States of America* has withdrawn from the agreement.)

Young people are now organizing and calling on those in power to act because they feel that time is limited. The longer it takes to

cut greenhouse-gas emissions, the more the Earth's atmosphere will eventually warm up further. To meet global climate goals, youth activists say they need to be included in solutions. The U.N. Youth Climate Summit is one step towards increasing their involvement.

Wanjuhi Njoroge, a climate activist in her 20s from *Kenya*, said that the voices of youth should not only be heard but also allowed to influence decisions on climate change. Another speaker at the summit, **Nina Möger Bengtsson** from *Denmark*, emphasized this. "We speak up in our local communities. We change our diets. We change our habits. We take to the streets", she said.

"Yet we are not included in the formal decision-making process". Denmark has actually taken some action: it has established a national youth council with direct access to the prime minister.

The summit also marked the launch of the *Kwon-Gesh Pledge*. It asks U.N. leaders to include youth in carrying out goals of the Paris Accord. This pledge is perhaps the most concrete measure to include youth in policymaking.

Kwon-Gesh Climate Pledge

The photo shows, from left, **Monica Skadbor** (Denmark), **Nanoua Lilivau Ewekia** (Tuvalu) and **Anfernee Nenol Kaminaga**

(Marshall Islands) as they discussed the Kwon-Gesh Climate Pledge with moderator **Steve Chiu** at the U.N. Youth Climate Summit.(*Photo Credit: G. Moran*).

Many young climate leaders at the summit said they were acting to save not just their future, but also their current homes. Climate change is already disrupting the environment, with many all over the world losing their homes.

Kristen Brown, 17, from the Hawaiian island of *Oahu*, pointed out: "On different parts of my island there is a lot of coastal erosion causing the roads to crumble into the sea". Erosion is just one of the many impacts she has seen near her home. She is the Hawaii State Logistics Director with the U.S. Youth Climate Strike Hawaii. "We need to fight for climate justice", she told the summit. Photo shows Kristen in middle, with other climate change activists.

"Climate justice" is a framework for thinking about equality and social issues alongside climate change. It is the poor who are most vulnerable all over the world, losing homes and livelihoods due to the havoc caused by global warming and climate change. Climate justice seeks to address this issue.

Faatupu Simeti, 24, is working to protect her country of *Tuvalu*. This low-lying island nation is quickly being engulfed by rising seas. As a data analyst for the little country's Department of Climate Change and Disaster, she is working to better assess the island's vulnerabilities and then to come up with solutions.

While some places are more vulnerable to climate change than others, no place is immune. Even the very ground along the East River in New York city, on which the U.N. headquarters sits, could flood due to sea-level rise by 2100.

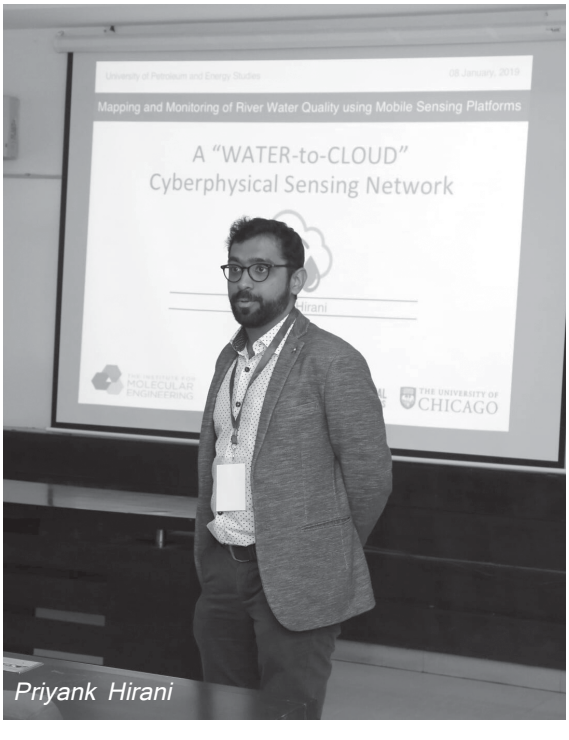
Young activists did not just demand action from global leaders. They also came ready with solutions and turned to other young adults for solutions. Before a panel of judges, climate leaders under 30 pitched some of their proposals to address climate change and related inequalities through technology.

Brighton Mabasa was one of them. He is a young meteorologist, working at the *South African* Weather Service, near Johannesburg. He has proposed a weather app for small, rural farmers. These farmers often fail to get

Faatupu Simeti

Brighton Mabasa

the climate information they need. When they do get it, he said, it is not widely understood. His app works by crowdsourcing data so that farmers can have more accurate, localized data. Farmers can use the sensors on their smartphones to collect information for use by others. In this way, the farmers become citizen scientists.



Priyank Hirani

It is not just "high tech" solutions that will solve problems triggered by a changing climate. Throughout the summit, youth climate leaders emphasized the need for political, economic solutions to address emerging crises.

This was emphasized by **Priyank Hirani**, a young electronics engineer from *India*, who leads Water-to-Cloud, a project that builds platforms for monitoring river pollution in India. Hoe pointed out the fact that the greenhouse gases contributing to climate change have come mostly from wealthy countries. Yet low-income nations will feel many of the effects.

Youth leaders made it clear that they are not afraid to fight for a world where climate justice flourishes.

The last word on the UN Youth Climate Summit has to be from 16 year old Greta Thunberg. Her photo with U.N. Secretary-General António Guterres is shown. Her inaugural speech ended with the following words:

"You are failing us. But the young people are starting to understand your betrayal. The eyes of all future generations are upon you. And if you choose to fail us I say we will never forgive you. We will not let you get away with this. Right here, right now, is where we draw the line. The world is waking up. And change is coming, whether you like it or not."

—Compiled from several sources; pictures from UN and Science News for Students; AP Photo/Eduardo Munoz Alvarez, File)

Do You Know?

1. Do radioactive things glow in the dark?

2. Is vacuum matter, or a state of matter?

3. If you jumped into a pool of liquid oxygen, would your body instantly crystallize?

4. What is the brain doing when we are at rest?

5. Why do we swing our arms when we walk?

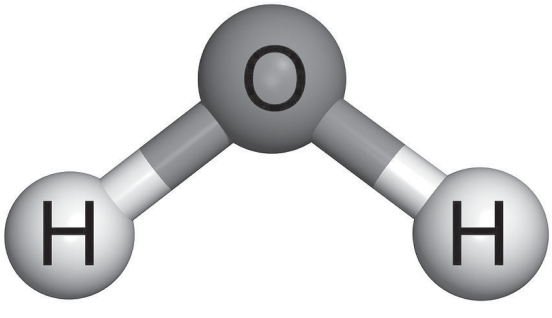
Answers to last issue's Do You Know?

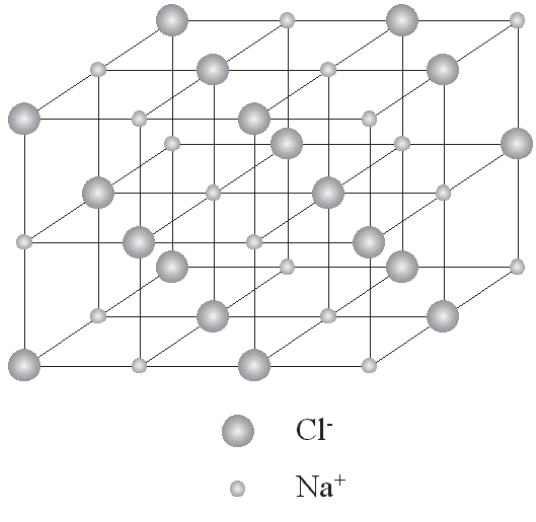
1. We say water is a molecule. But isn't it also a compound because hydrogen and oxygen have been chemically combined? If so, how do you determine whether a substance is a compound or a molecule?

Answer: Whether something is a compound or not depends on how many kinds of elements make it up. Compounds contain two or more different elements.

Whether something is a molecule or not depends on the type of bond that is formed when its atoms join together. In general, electrons can be shared between atoms (**a molecular bond**), or electrons can be completely removed from one atom and given to another (**an ionic bond**). Molecules have molecular bonds.

Water is a molecule because it contains molecular bonds. Water is also a compound because it is made from more than one kind

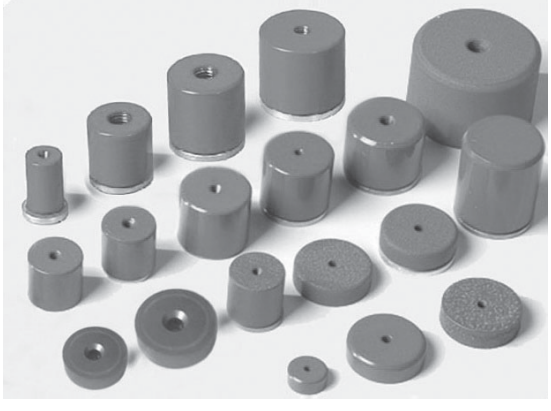




of element (oxygen and hydrogen). We could say that water is a molecular compound.

Something like table salt (sodium chloride) is a compound because it is made from more than one kind of element (sodium and chlorine), but it is not a molecule because the bond that holds it together is an ionic bond. (Some people would label salt as an ionic compound.)

Oxygen in the atmosphere is a molecule because it contains molecular bonds. It is not a compound because it is made from atoms of only one element - oxygen.



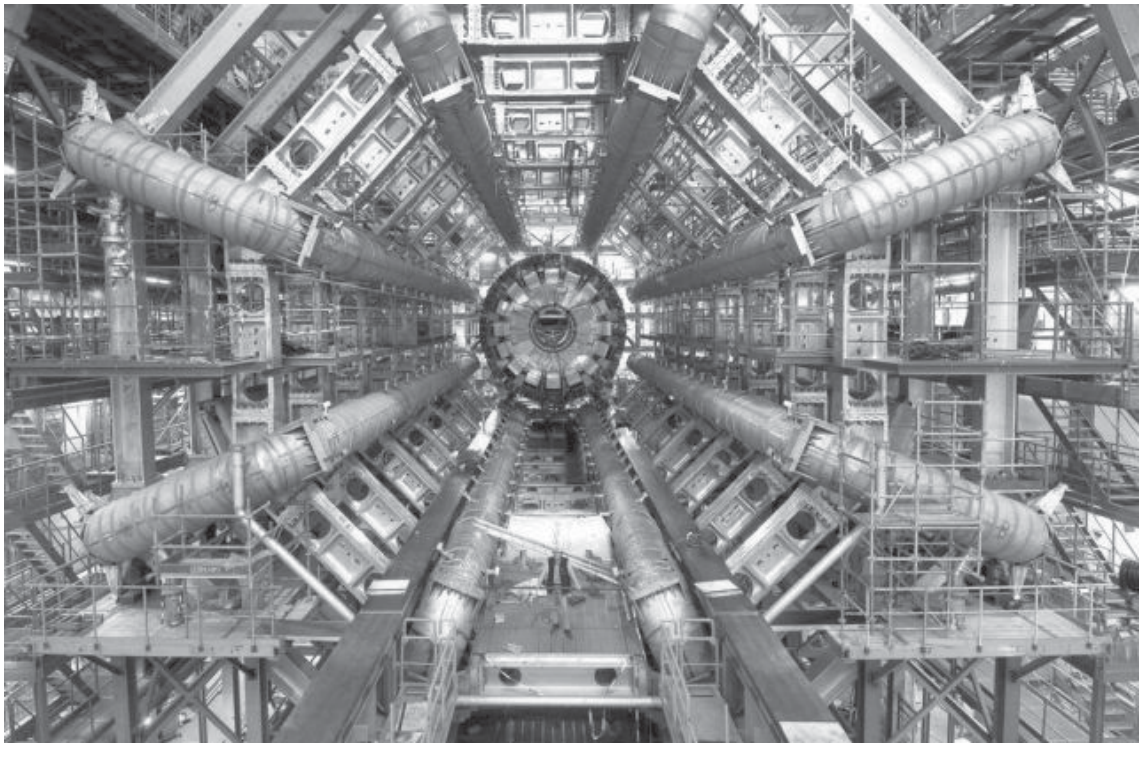
2. Does increasing the size of a magnet make it stronger?

Answer: Increasing the size is indeed one way to increase the strength of a magnet. However, it can be very difficult and expensive to simply make a magnet bigger. The other way is to make it **better**, so that with the same size, it can generate a stronger magnetic force.

What does it mean to make it better? One way is to carefully choose the material from which it is made. The standard strong magnet found in laboratories is usually made from ALNICO - a special alloy where strongly magnetic bits, made from an iron-nickel-aluminum alloy, are embedded in an iron-cobalt alloy base. If you want something lighter that can generate a strong magnetic force, then one can try **ferrite** (or ceramic) magnets which are made from iron-oxide plus barium, strontium, or lead-oxide. Like other ceramic materials (such as toilet bowls), they are brittle, so a lot of care in handling is necessary.

The details of manufacturing permanent magnets are a trade secret. However, the general technique is to take a ferromagnetic material such as the ALNICO and expose it to a strong magnetic field, generated as very short but very powerful bursts from a nearby electromagnet. The magnetic "bits" in a ferromagnet are small collections of material (say, a millimeter or so) called domains that have a definite magnetic field with a north and south pole. Normally, these domains are oriented in random directions, thereby canceling each other out. When exposed to this powerful outside field, the domains start to orient themselves according to the direction of the strong outside field. The new alloy magnets have the added advantage that after the field is established, it tends to be more stable than other types of permanent magnets.

With electromagnets, another method to make them better is to construct a **superconducting** magnet. That is, the electrical coils are made of materials that will lose all electrical resistance when immersed in a tremendously cold substance, such as *liquid helium*. By reducing the electrical resistance, much higher amounts of electrical current can be put through the magnets,



thereby generating a much stronger magnetic force.

The magnets in the large particle accelerator, LHC, at CERN, Geneva, has superconducting magnets placed at a temperature of **1.9 K** (**-271.3°C**), colder than the **2.7 K** (**-270.5°C**) of outer space. The picture shows the ATLAS toroidal magnet, one of the largest superconducting magnets ever built. It is 25 m long, 5 m wide, and weighs 100 tons, all aligned to millimetre precision.

3. How many atoms are there in the world?

Answer: This is not an easy thing to count, but it is a great question, since it assumes that we can count the number of atoms on earth — which is what we will assume "in the world" to mean. (Now you may ask, what about atoms in the universe outside the earth? That is another great, but different, question.)

We can get an estimate of the number of atoms on earth by first knowing what its mass is. The mass of an object is a measure of how much material the object has. The mass of the earth is 5.98×10^{27} grams. That is the scientific notation to write a large number that has a lot of zeroes. We can write the mass of the earth with all the zeros like this: 5,980,000,000,000,000,000,000,000,000 grams. (But that doesn't mean very much to us, since it is hard to imagine beyond billions; the scientific notation is so much better.)

The composition of the Earth, by mass, is about 32% iron, 30% oxygen, 15%

magnesium, 13.9% sulphur, 3% nickel, 2% calcium, 1.4% aluminum by mass. There are dozens of other elements in the Earth's crust, but, since we are dealing with rough estimates, and they amount to less than 1% of the total mass, we can effectively discount them.

So that means that there is:
$1.9x10^{27}$ g of Iron
$1.8x10^{27}$ g of Oxygen
$9.0x10^{26}$ g of Magnesium
$8.3x10^{26}$ g of Sulphur
$1.8x10^{25}$ g of Nickel
$1.2x10^{25}$ g of Calcium
$8.4x10^{24}$ g of Aluminum

Because we know the atomic mass of each element, we can figure out how many atoms of each are contained in a sample of a given size. The atomic mass is the weight of $6.022x10^{23}$ atoms of that element in grams. The number $6.022x10^{23}$ is a quantity of material called a **mole**.

1 mole of:
Iron: weighs 55.8 grams
Oxygen: 16.0 grams
Magnesium: 24.3 grams
Sulphur: 32.1 grams
Nickel: 58.7 grams
Calcium: 40.1 grams
Aluminum: 27.0 grams.

So, we can divide to determine how many mols of each element there are:
Iron: $3.4x10^{25}$ moles
Oxygen: $1.1x10^{26}$ moles
Magnesium: $3.7x10^{25}$ moles
Suphur $2.6x10^{25}$ moles
Nickel: $3.1x10^{24}$ moles
Calcium: $3.0x10^{24}$ moles
Aluminium $3.1x10^{24}$ moles

Add all those moles up and you get a total of: $2.16x10^{26}$ moles.

Multiply that by $6.022x10^{23}$ and you get: $1.33x10^{50}$ atoms.

If you want to write it with all the zeros it would be:

133,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000.

4. How does baking soda help in cooking chickpeas (chana/kondaikadalai)?

Answer: We usually use baking soda when cooking chickpeas or rajma (mochakottai). This is to soften the beans faster and decrease cooking time. It makes the beans slightly alkaline, which increases the softening effect. In the case of some beans, baking soda is known to aid in breaking down gas-causing sugars as well. Higher concentrations of baking soda and/or pressure cooking may be needed to make this effect significant. In most cases, an increased soaking time will have a much greater impact on gas-causing sugars, so baking soda should perhaps be reserved for situations where preparation time is limited.

Baking soda uses its sodium ions to replace the magnesium in the cell walls of plants, resulting in faster softening. The softening of the cell walls allows faster breakdown in some of the sugars with cause gas.

But all this leads people to claim that adding baking soda "reduces gas", that it "lowers the temperature", etc. The former is true but the effect is too little to make a difference, the latter is false.

Baking soda added to water in fact raises the temperature, but only slightly. Chemical reactions are either "**endothermic**" or "**exothermic**". Endothermic means that you have to put in energy (heat) to make the

reaction go on while exothermic means that there is energy (heat) left over. The left over heat will raise the temperature. Baking soda and water is exothermic and so the water gets a little warmer. This is because the binding energy of the chemical bonds of the products has an excess over the binding energy of the components. Therefore, energy is released and the water warms up.

In 1974 scientists did an elaborate study using 5 types of beans and many kinds of preparation conditions: (6-hour soak vs. 12-hour soak, soaking alone vs. boiling vs. pressure cooking, sprouting for 1-4 days, etc.). In almost all preparations the sugar contents were only decreased by a few percent with baking soda. For almost all scenarios, it appears that soaking for an extra few hours, doing a 24-hour germination before cooking, or choosing to pressure cook beans will have far greater impact than adding baking soda.

In fact use of baking soda is known to destroy nutrients, so we should minimise its use.

—Compiled from several sources

A tribute to Rani Siromoney, 1929–2019

R. Ramanujam,
Chennai

One of the most inspiring researchers in formal language theory from India passed away recently, on September 28, 2019. **Rani Siromoney**, a mathematician and theoretical computer scientist, built up a life-long body of work on the mathematical study of **languages and grammars** that underlies the way computers work.

Working from *Madras Christian College*, Tambaram, she built up a strong group of students working in this area, placing Chennai early on the world map of computer science long before India became known as a centre for Information Technology.

Born on July 4, 1929, in Nazareth, Tamil Nadu, Rani Siromoney studied in Madras Christian College and became a teacher there too, getting her PhD in 1969. (In between she was a teacher at *Lady Doak College*, Madurai, for a year.)

Her first paper was on "**Grammar of Dravidian Number Names**", published in the journal "*Foundations of Language*". This was when she was doing her PhD work, under the guidance of her husband **Dr Gift Siromoney**, a statistician and another inspiring scholar from Madras Christian College.

Working with such an inspiring figure, Rani Siromoney entered the newly emerging field of *Automata Theory*. This is an exciting branch of computer science which is the study of abstract machines and automata. The approach is to find out what kind of computational problems can be solved using such abstract machines. It combines ideas in

Dr Gift Siromoney

Gift Siromoney was an extraordinary mathematician with wide-ranging interests. He applied statistical methods to a wide variety of themes from his everyday life, such as Karnatic music, Tamil poetry, Meteorology, distribution of trees on campus and Linguistics. He designed the first Tamil teleprinter keyboard based on statistical principles. In fact, his department in Madras Christian College was famous for writing joint research papers with members of the Departments of Economics, History, Philosophy, Mathematics and Botany. He was an equally inspiring figure as his wife, Rani Siromoney.

mathematics with problems in computing. She quickly made a name for herself in this field.

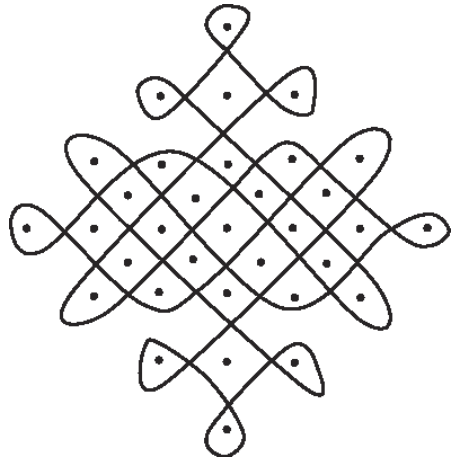
Until Gift Siromoney's untimely death in 1988, the couple collaborated on a range of topics in formal languages and automata theory, including the analysis of *kolams* (*rangolis*) by mathematical means.

She was always willing to learn new areas, new techniques and seek new applications. When she was in her 60's she embarked on the study of *cryptography*. This is the study of designing secure communications so that third-party outsiders cannot intercept and read your message. It is a very important aspect of modern computer communications. For example, how can you ensure that your e-mail or whatsapp message is not being read by someone else? The message is encrypted so that only the genuine receiver can decode and read it.

Rani Siromoney designed perhaps the first **cryptosystem** for the Tamil language. She also linked *cryptology* (which is the study of codes) with *formal language theory* (which studies how humans learn langauge).

Over the last half-century, Rani Siromoney contributed to many sub-areas of formal language theory: the study of grammars, L-Systems, Thue systems, picture languages, languages of infinite words, puzzle grammars, and so on.

In her 70's, she worked on a wide range of problems relating to the newly emerging area of *DNA computing*. Here, instead of relying on normal machines (like the one I am typing this article on), DNA computing uses



"living" DNA from cells, and knowledge of biochemistry, and molecular biology hardware for mathematical computations. She also related membranes and biomolecules to formal language theory.

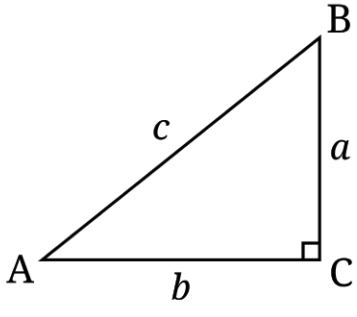
In 2017, when she was 88 years old, she published two papers in an area called *contextual array grammars*, both part of an international collaboration (with two European researchers and one of her former students). This attests to her indomitable spirit and commitment to research.

Rani Siromoney was an Editor of the prestigious journal "*Theoretical Computer Science*" and achieved international recognition in many professional ways. But perhaps her best achievement lies in inspiring a generation of researchers, in refusing to accept any limitations imposed by her surroundings.

How Polya found sums of square roots

Kamal Lodaya,
Bangalore

In geometry we first come across *square roots*. We learn that for a right-angled triangle ABC with sides BC, CA, AB of length a, b, c, AB of length c being the *hypotenuse*, the longest side which faces the right angle at C, we have Pythagoras's equation, $a^2 + b^2 = c^2$.



So, if length a is 3 and length b is 4, length c can be calculated. $a^2 + b^2$ is $3^2 + 4^2$, which is $9 + 16$, that is, 25. Since we know c^2 is 25, c must be its square root $\sqrt{25}$, which is 5.

Things may not be that simple. If for the same kind of triangle, we have a is 1 and b is 2, what is c? This time $a^2 + b^2$ is $1^2 + 2^2$, which is $1 + 4$, that is, 5. So c must be its square root $\sqrt{5}$. We cannot simplify further. Of course a calculator can show you what this number is—somewhere between 2 and 3.

Why? Because $2^2 = 4$ and $3^2 = 9$. If $c^2 = 5$ then c must be somewhere between 2 and 3, and perhaps a little closer to 2.

So $5 = c^2 = c \times c > 4 = 2 \times 2$. Geometrically, a square with sides of length 2 has area 4, so a square with area 5 must have sides little longer than 2.

So we have a geometrical demonstration of a property, not as famous as Pythagoras's equation: For two positive numbers, call them c and d, if $c^2 > d^2$, then $c > d$. Notice that there is nothing here about geometry, this is just a property of numbers. We will name this the **Square Root Property** (SRP in short).

For example, consider two positive whole numbers; call them a and b. If $a > b$, then $\sqrt{a} > \sqrt{b}$. A mathematician would say that $a > b$ is *sufficient* to show $\sqrt{a} > \sqrt{b}$. Since $5 > 4$ and $9 > 5$, these two conditions are sufficient to show $\sqrt{5} > 2$ and $3 > \sqrt{5}$, that is, $\sqrt{5}$ is between 2 and 3.

Mathematicians always like to extend what they know. So it was not long before a mathematician asked this question: if you have *four* positive whole numbers a, b, c, and d,

what are the conditions sufficient to show that $\sqrt{a}+\sqrt{b}>\sqrt{c}+\sqrt{d}$?

A little thought will tell you that if $a > c$ and $b > d$, then this is sufficient. If you like, think about this geometrically, but like before, we are only talking about properties of numbers. So $a > d$ and $b > c$, this is also sufficient. You can try coming up with more sufficient conditions, or turning the question around a little bit.

But there are hard questions here. What if $a < c$ and $b > d$? For example, is $\sqrt{2}+\sqrt{7}>\sqrt{3}+\sqrt{5}$? That is hard to tell without a calculator.

Here is a demonstration that this is really so. The proof was given by the great Hungarian mathematician George Polya in one of his books. It uses another property of numbers, which we will call the **Square Equation**:

$$(a+b)^2 = a^2 + b^2 + 2 \times a \times b \ .$$

If you want to see this geometrically, take a square of side $a + b$, and inside it mark out squares of side a and side b at two opposite corners, and show that the remaining two rectangles both have area $a \times b$.

Let us get back to numbers and Polya's problem. You agree, he says, that $224 > 9$? Then you must also agree that $\sqrt{224} > \sqrt{9}$. That is because of our Square Root Property, SRP.

Now he does some simplification. The left hand side is $4\times\sqrt{14}$ because $224 = 16 \times 14$. So you agree that

$$4 \times \sqrt{14} > 3 \ .$$

(Is it easy to see this directly, without using any sufficient condition?)

Now Polya does another trick. He adds a number on both sides, to get

$$57 + \left(4 \times \sqrt{14}\right) > 57 + (3) \ ,$$

or written another way,

$$1 + 56 + 4 \times \sqrt{14} > 60 \ .$$

Do you agree?

Now he uses this as a sufficient condition for SRP, to convince us that

$$\sqrt{1 + 56 + 4 \times \sqrt{14}} > \sqrt{60} \ .$$

Here is where the Square Equation comes in, because

$$1 + 56 + 4 \times \sqrt{14} = (1 + 2 \times \sqrt{14})^2 \ .$$

Do you see this? So

$$1 + 2 \times \sqrt{14} > 2 \times \sqrt{15}\,,$$

where the right hand side is simplified a little bit.

George Pólya, 1887–1985

Polya was a Hungarian mathematician who worked for some time in Switzerland before moving to the United States, where he lived for 40 years till his death at the age of 97.

He worked on a number of areas of mathematics, but he is best known for his series of books on *"How to solve it, Mathematics and Plausible Reasoning"*. In these books, Polya discussed problem solving for both mathematical and non-mathematical problems. He also included advice for students on how to learn and teach mathematics.

The book has been translated into over 17 languages. Apart from telling the student how to make a plan to solve a problem (and carry it out), Polya stated a very important principle:

"Much can be gained by taking the time to reflect and look back at what you have done, what worked, and what didn't. Doing this will enable you to predict what strategy to use to solve future problems."

Okay so far? Now just look at what you have shown. Since the values of $\sqrt{14}$ and $\sqrt{15}$ are difficult to get without a calculator, it would be hard for you to believe this. Polya has shown you how to convince yourself. He will now do this magic one more time. First he adds 8 on both sides to get,

$$8 + 1 + 2 \times \sqrt{14} > 8 + 2 \times \sqrt{15}\,,$$

which can be rewritten as

$$2 + 7 + 2 \times \sqrt{14} > 3 + 5 + 2 \times \sqrt{15}\,.$$

Agreed? So using the SRP, we have,

$$\sqrt{2 + 7 + 2 \times \sqrt{14}} > \sqrt{3 + 5 + 2 \times \sqrt{15}}\,.$$

Now look closely at this equation. You can see that the Square Equation can be used both on the left hand side and the right hand side. Doing this, we see that the two sides can be rewritten as

$$\sqrt{2} + \sqrt{7} > \sqrt{3} + \sqrt{5}\,.$$

If you find this sort of problem solving amusing and interesting, you can try to take this a little further. What Polya has done is actually shown you a *method* to answer the four-number question. But this method will not work always.

Try to find four whole numbers a, b, c, d, with $a < c$ and $b > d$ where the method breaks down.

–Compiled from several sources

Why is gold golden in colour?

D. Indumathi,

The Institute of Mathematical Sciences, Chennai

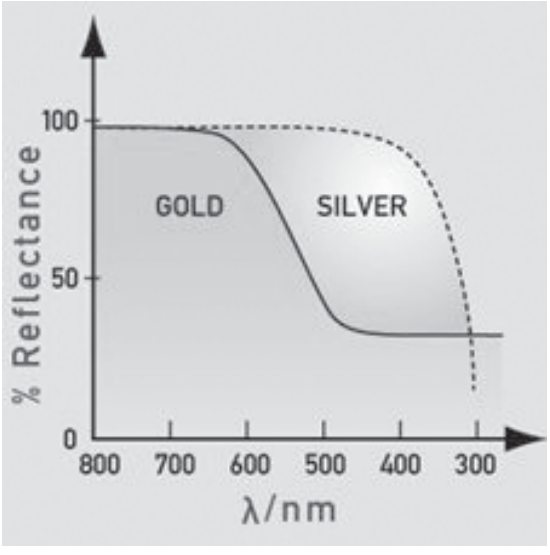
Gold has fascinated human beings since time immemorial. Most metals are shining and silvery—silver, iron, platinum, even reactive metals such as sodium, magnesium, aluminium, and exotic ones such as uranium, plutonium, polonium, etc. But gold is coloured, and coloured with such a lovely gleam of yellow. Why is it coloured?

Periodic Table

You might have seen the elements lined up in rows and columns in the periodic table. Gold is in the last row of the periodic table that contains stable elements. You may know that the rows in the periodic table tell us how many **shells** or **orbitals** of electrons are there around the nucleus. You may have also learnt that the electrons in different shells have different energies and so these are sometimes also called **energy levels**. Gold is in the sixth row of the periodic table and so has upto six shells of electrons orbiting the nucleus. Just like hydrogen, gold has just

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H Hydrogen 1.008																	2 He Helium 4.002602
3 Li Lithium 6.94	4 Be Beryllium 9.012831											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998403163	10 Ne Neon 20.1797
11 Na Sodium 22.98976928	12 Mg Magnesium 24.305											13 Al Aluminium 26.9815385	14 Si Silicon 28.085	15 P Phosphorus 30.973761998	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955908	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938044	26 Fe Iron 55.845	27 Co Cobalt 58.933194	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.921595	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90584	40 Zr Zirconium 91.224	41 Nb Niobium 92.90637	42 Mo Molybdenum 95.95	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
55 Cs Caesium 132.90545196	56 Ba Barium 137.327	57 - 71 Lanthanoids	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.592	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 - 103 Actinoids	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (269)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (282)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (289)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93033	68 Er Erbium 167.259	69 Tm Thulium 168.93422	70 Yb Ytterbium 173.045	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.0377	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (266)



one electron in the 6s shell (outermost shell). Then this should have been as reactive as hydrogen.

Because of the large number of protons (79) in its nucleus, the electrons of the gold atom are subjected to an intense electrostatic attraction. In addition, the velocity of the electrons in the orbits are nearly half the speed of light, which is very high. Due to these effects, some of the outermost electrons get pulled closer towards the nucleus.

Metal gold

All this is true for a single gold atom, but also is true when many many gold atoms together form the solid metal. What happens in that case is that the overlapping of the energy levels of single atoms causes **bands** of energy levels to be formed. Because of the large numbers of electrons, some energy bands start to overlap.

Electron levels and colour

Now, what does this have to do with colour? We know that light is an electromagnetic wave that is visible to us. If the wavelength of light beomes larger than visible light, it becomes an infra-red or radio wave, and if its wavelength becomes smaller than visible light, it becomes ultraviolet light. Only the colours from violet to red can be seen by humans.

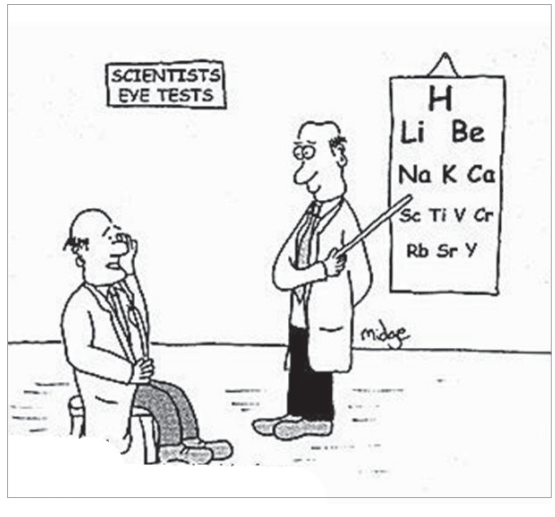
Now, when light falls on a surface, it gets reflected back into our eye. Hence we are able to see the object. When the light falling on gold has an energy equal to the *difference* between two energy levels in the metal, it is *absorbed* and the electron uses that energy to *jump* to a higher energy orbital. After some time, the light is emitted back, with the electron "falling back" into the lower energy state. Since given colours of light have fixed energies, this means that atoms in metals typically *absorb and emit* **fixed colours** of light. In fact, for metals, most of the light does not penetrate the surface (it is opaque) and so most metals are highly *reflective* and look white or silver.

Sometimes, the atoms absorb the light, but are not equally efficient in re-emitting it. This is called *reduced reflectivity*. While most metals have excellent reflectivity over all the visible spectrum, gold has reduced reflectivity at lower wavelengths, as can be seen from the figure (Note that the x-axis goes from higher to lower values of wavelength).

In contrast, the figure shows that **silver** loses reflectivity (that is, has increased absorption) at much lower values of wavelength, about 300 nm. This corresponds to wave lengths in the **ultraviolet** region,

Back Cover: "Starry Night", Painting by Vincent van Gogh, showing use of complementary colours. See the article for more details.

Colour Wheel showing the three complementary colours cyan (C), magenta (M) and yellow (Y). The three primary colours blue, green and red are complementary to yellow, magenta and cyan respectively. All overlayed together gives black for paint or white for light.



which is anyway not visible. Hence silver, like most other metals, shines silver since it reflects all visible colours equally.

What about gold? It absorbs most of the light about 500 nm or less, which corresponds to the **blue** region of the visible spectrum. Why does this make gold look *yellow*? To answer this question, we need to understand something more about colour and how we perceive it.

Colour theory

Modern color theory uses either the red-blue-greeen (RGB) additive color model or the cyan-magenta-yellow (CMY) subtractive color model. This just means that all colours can be generated by suitable combinations of these three primary colours. For instance, equal amounts of red and green make yellow, equal amounts of blue and green make cyan, and equal amounts of blue and red make magenta. Conversely, we can start with cyan, magenta and yellow, and get red-green-blue. See the picture on the back cover of this issue.

Complementary or "opposite colors"

The complementary pairs are those with greatest contrast: combining them gives white light. So complementary colours are magenta–green, yellow–blue, and cyan–red.

In other words, if blue is absorbed out of white light, its complementary colour, yellow, is left behind. How do we understand this? Looking at the colour wheel on the back cover, it is clear that if we remove blue from white light, red and green are left behind. The combination of red and green makes yellow. In other words, when red and green light fall on our eye, it combines them and the light appears as a single colour, which is yellow. So our brain interprets what the eye sees.

We saw that blue light was strongly absorbed by gold. So when white light shines on this metal, the blue is absorbed, while more red and green are emitted/ reflected. So the gold looks golden in colour. A simple accident of nature makes gold so different and so enticing, over which many wars have been fought.

Can you figure out why copper is orange-red? It has less protons and so the effect is smaller so that the colour that has smaller reflectance is not blue but blue-green. Hence it shines a darker orange-red, which is the complementary colour to blue-green.

Complementary colours and art

Vincent van Gogh was especially known for his striking use of *complementary colors.* He created his own oranges with mixtures of yellow, ochre and red, and placed them next to slashes of sienna red and bottle green, and below a sky of turbulent blue and violet. He also put an orange moon and stars in a cobalt blue sky. The resulting masterpiece, *Starry Night*, is on the magazine's front cover.

—Compiled from several sources. Figures from http://www.webexhibits.org

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