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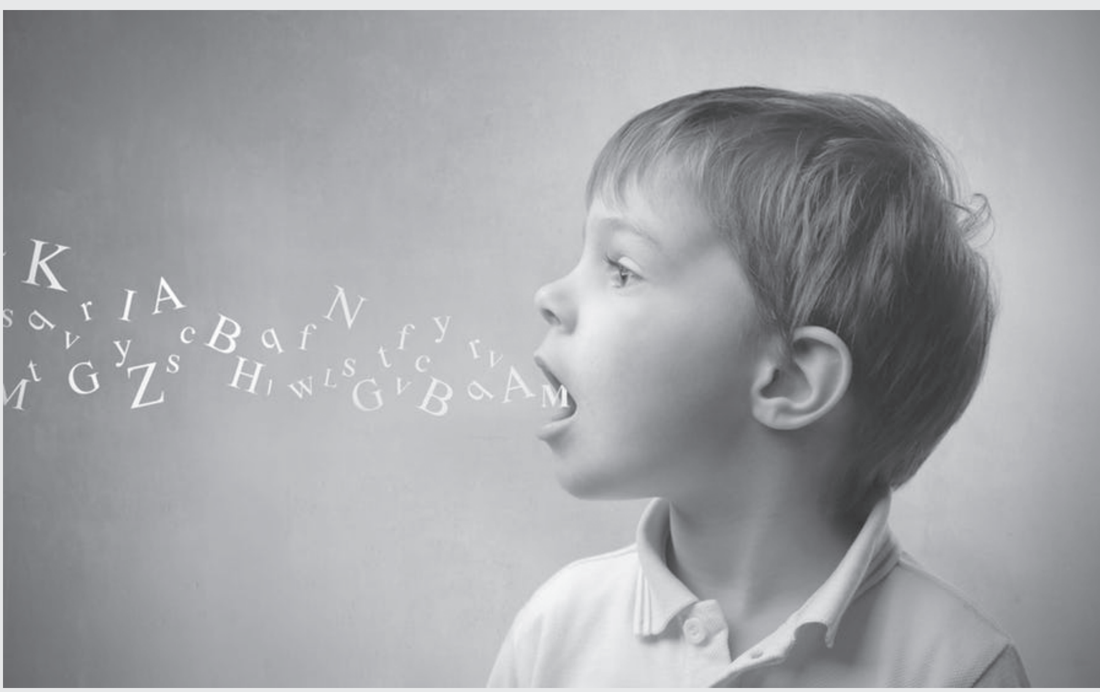

How a train goes around a bend

D. Indumathi,
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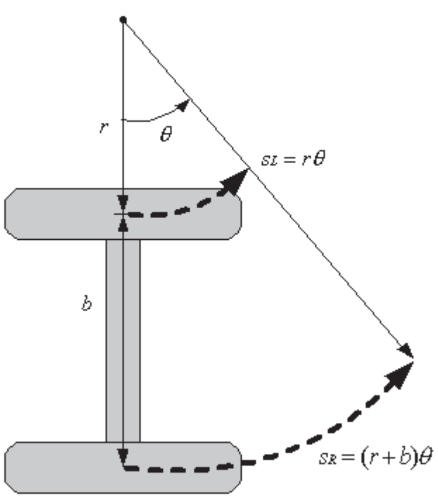
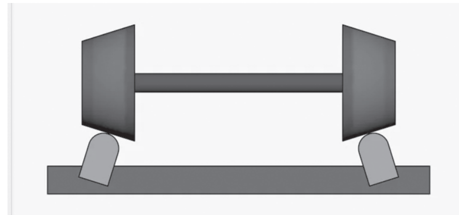
In the last issue of JM, we looked at how the differential in a car helps to provide different speeds to the wheels on the two sides, so that a car can turn. This is because, when it turns, the inside wheel moves slower than the outside wheel (see figure). The differential works by making available these different speeds on the two sides. *A reader of JM has now written in, asking if a train turns the same way.*

It is a very interesting question. Trains do not have differentials. Trains have wheels that are connected together by a fixed axle. This means that the wheels on both sides of the train always turn at the same speed. This can present problems when turning, because one wheel has to cover more distance than the other. How then can a train turn?

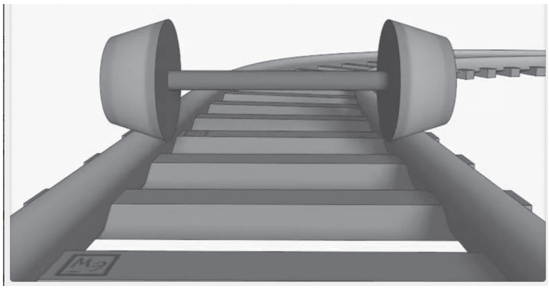




The wheels are specifically designed so that when the train goes around a corner it stays on the tracks. The part of the wheel that has to travel a greater distance has a greater diameter, and the end result is a train that stays on the tracks. Let us examine closely how this happens.

Train wheels aren't perfect cylinders. They're **beveled**, that is, the flat surface of the rim is sloped, to make them wider on the inside. This means that when the train moves left or right on the track, the diameter of the wheels can change. But because the wheels are connected by an axle, they still spin at the same rate. Because of this, the wheels will travel different distances per revolution.

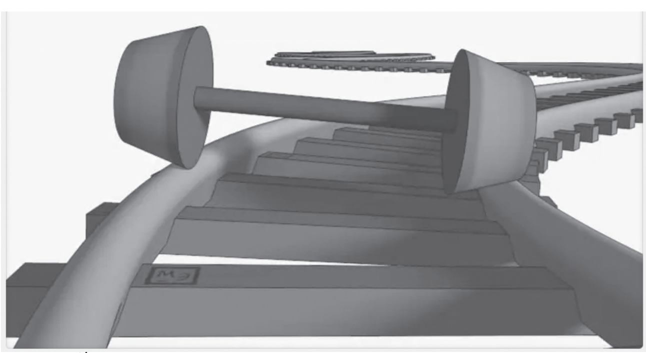
A simple way to understand this is to assume that train wheels are *conical* in shape; actually a cone that has its top chopped off. A cone has different diameters at different heights from the base. That allows the wheels to have a varying diameter at different points of contact. See the figure. By the way, did you notice that the track rails are also not flat?



The rails are embedded a little inclined inwards. This maintains the angle between the wheel and supporting track to be always 90 degrees.

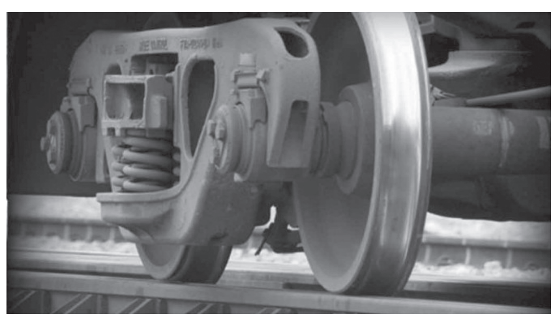
Coming back to the wheels, how does having a conical shape help? When the tracks are going straight, the wheels are symmetrically placed on the rails. So both of them rest on the track rail at a point where their diameters are the same. So as the train moves ahead, both wheels turn with the same speed (which they always do); in addition, they travel the same distance in equal times since their diameters are the same. See the figure.

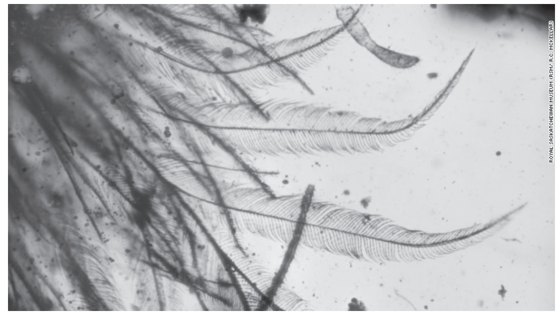
Now suppose the track turns right. The train's left wheels now have to travel more than the right wheels because at the turn the track on the left is longer. But the train has no differential, so both wheels are still turning at the same speed. Now, both the wheels move left, so that the portion of the left wheel touching the rails has a larger diameter (and so moves further in one rotation) while the wheel on the right moves less. The figure explains it very nicely. Now both the wheels move different distances in equal times so that the wheel which has to travel a larger distance smoothly moves around the curve and "catches" up with the inner wheel.

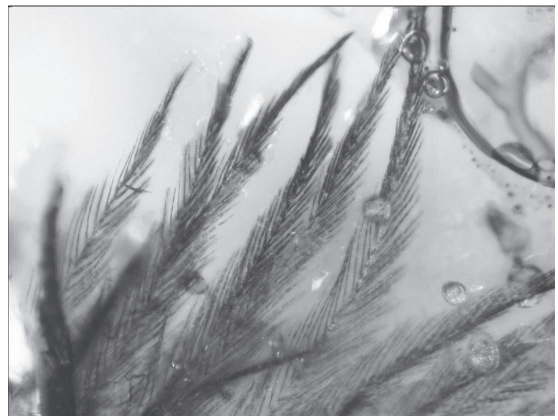


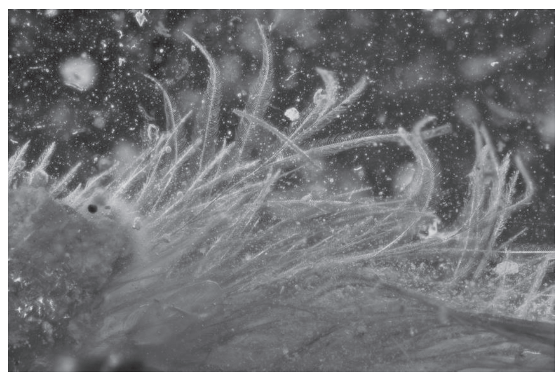
What happens if the curve is so sharp that the wheels are not able to adjust their diameters sufficiently? The observant reader may have noticed that train wheels have flanges: a kind of protruding part that doesn't allow the wheels to go off the rails. Flanges are a safety mechanism to keep the train on its track only if the main mechanism fails. This could happen if the train was going too fast around a bend. In fact, railway companies specify a "minimum railway curve radius" which states how sharp a bend can be if the train has a certain maximum speed.

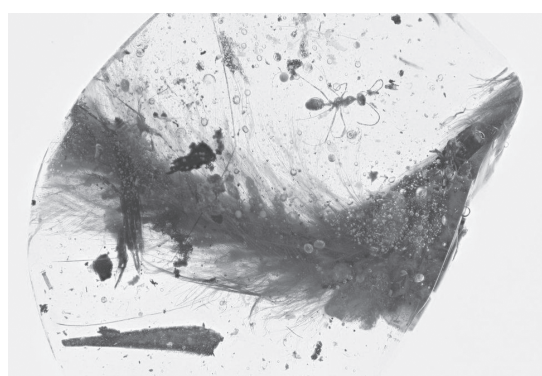
For a very clear video explanation of how the conical shape of train wheels helps it to turn, see the web-site, http://www.etudes.ru/en/etudes/train-wheelset/ from where these pictures are taken. As pointed out there, it's a very nice application of geometry, isn't it?











Did dinosaurs have feathers?

We know that dinosaurs evolved from reptiles, and they are the ancestors of today's birds. From films like *Jurassic Park*, one gets the impression of giant crocodiles. But perhaps some dinosaurs, at least, might have been closer to birds.

The picture by **Ryan McKellar** of the *Royal Saskatchewan Museum in Canada* shows the tail of a 100 crore year old dinosaur (a young **coelurosaur**), found preserved in amber (along with an ant and other material) in 2015. The amber comes from a mine in Kachin state in northern Myanmar (Burma). The expedition was led by **Lida Xing** of the China University of Geosciences. The second picture is a micro-CT scan of the feathers by Lida Xing. **Coelurosaurs** (Greek for "hollow-tailed lizards") are supposed to have evolved towards **maniraptors**, which includes birds.

Some feathers were found with the bones of a dino saur called **Archaeopteryx**, which has led to its being called an ancestor of birds. It was later shown that the feathers and the bones belonged to different animals.

Could it fly?

Many animals have feathers, but they do not all fly. The specimen shows eight tail vertebrae (bones). In modern birds like a hen or a turkey, the tail vertebrae are all fused together, with shafts, branches, sub-branches and hooks that latch. So the tail feathers can move as a single unit, which is important for the birds' flight.

The dinosaur feathers appear to keel to either side of the tail. Their open structure is similar to modern ornamental feathers than to flight

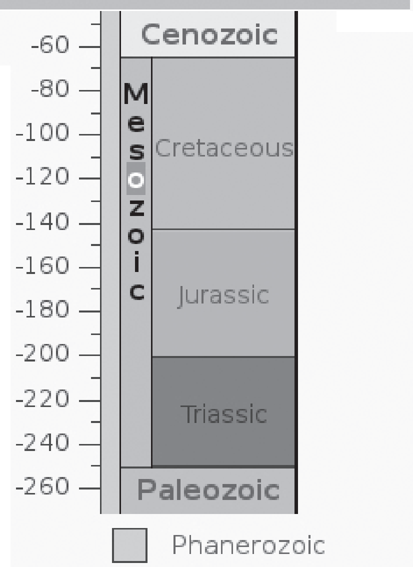
Ages

The **Triassic** period was from 25 crore years ago to 20 crore years ago. This is when we had the early dinosaurs. Then we had the **Jurassic** period, from 20 crore years ago to 15 crore years ago, when the giant dinosaurs started appearing. Finally we had the **Cretacious** period, from 15 crore years ago to 6 crore years ago, when we had dinosaurs in all parts of the world. These three periods form the **Mesozoic** era, also known as the age of reptiles, from 25 crore to 6 crore years ago. After that we have the **Cenozoic** era until today, known as the age of mammals. Although most of the dinosaurs died around 6 crore years ago, birds (which are modern dinosaurs) survived. In the Cenozoic era we had huge carnivorous flightless "terror birds" (1 to 3 metres tall) in the Americas, and Africa, until 20 lakh years ago. Three metre tall elephant birds (related to the New Zealand kiwi) seem to have been in Madagascar until thousands of years ago. Possibly humans were the ones who made them extinct. Some scholars think the *rukh* (or *roc*) in the story of Sindbad from the book *One thousand and one nights* may have been based on an elephant bird.

Mesozoic Era

251.902–66 million years ago

Key events in the Mesozoic



An approximate timescale of key Mesozoic events.
Axis scale: millions of years ago.

Bird Feathers

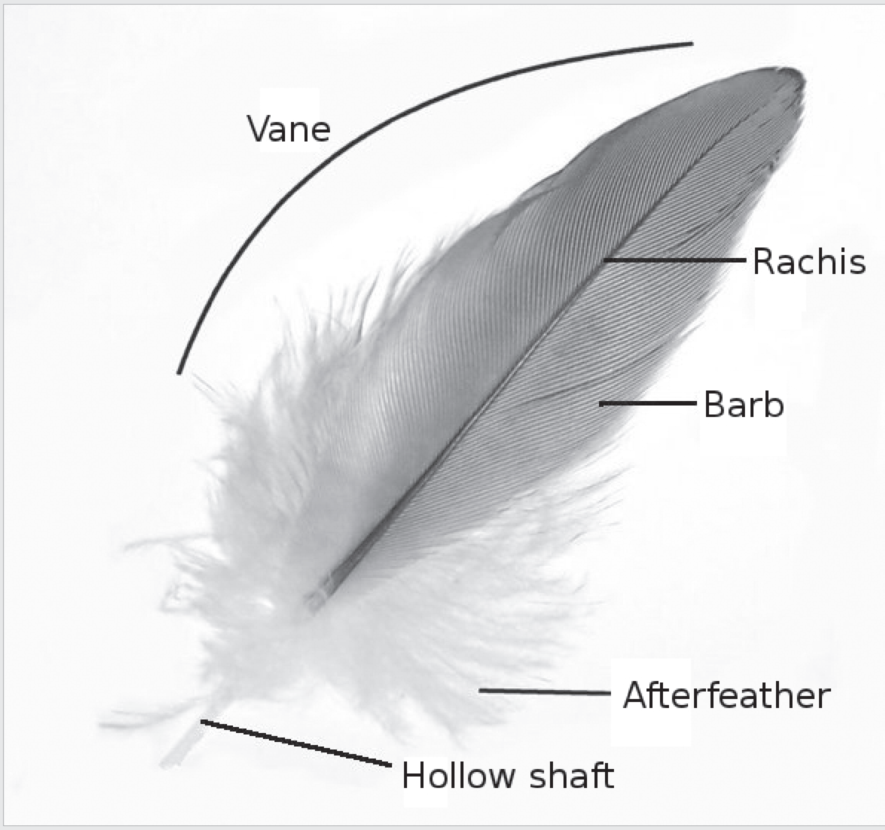
Feathers are complex structures found on the outside of the body of birds, and some dinosaurs as well. Not all feathers are used for flight. Feathers insulate birds from water and cold temperatures. They may also be plucked to line the nest and provide insulation to the eggs and young. The individual feathers in the wings and tail play important roles in controlling flight. Although feathers are light, a bird's plumage weighs two or three times more than its skeleton, since many bones are hollow and contain air sacs. Color patterns serve as camouflage against predators.

Striking differences in feather patterns and colors serve to differentiate the sexes.

Some birds have a supply of powder down feathers which grow continuously, with small particles regularly breaking off from the ends of the barbules. These particles produce a powder that goes through the feathers on the bird's body and acts as a waterproofing agent and a feather conditioner.

Waterproofing can be lost by exposure to emulsifying agents due to human pollution. Feathers can then become waterlogged, causing the bird to sink. It is also very difficult to clean and rescue birds whose feathers have been fouled by oil spills.

The colors of feathers are produced by pigments, by microscopic structures that can refract, reflect, or scatter selected wavelengths of light, or by a combination of both. Most feather pigments are melanins (brown and beige pheomelanins, black and grey eumelanins, and carotenoids (red, yellow, orange). Some birds show structural coloration or iridescence, with the blues and bright greens of



many parrots being produced by constructive interference of light reflecting from different layers of structures in feathers.

It was thought that feathers evolved as per the needs for insulation, flight and display. Discoveries of non-flying late Cretaceous feathered dinosaurs in China, however, suggest that flight could not have been the original primary function as the feathers simply would not have been capable of providing any form of lift. There have been suggestions that feathers may have had their original function in thermoregulation, waterproofing, or even as sinks for metabolic wastes such as sulphur.

Recent discoveries claim that feathers supported a thermoregulatory function, at least in smaller dinosaurs. The number of feathers per unit area of skin is higher in smaller birds than in larger birds, and this trend points to their important role in thermal insulation, since smaller birds lose more heat due to the relatively larger surface area in proportion to their body weight. The miniaturization of birds also played a role in the evolution of powered flight. The presence of a certain type of keratin (which is what feathers and scales are made of) in both birds and crocodilians indicates that it was inherited from a common ancestor. This may suggest that crocodilian scales, bird and dinosaur feathers, and pterosaur pycnofibres may have all come from the same primitive skin structures.

feathers. If the entire length of the dinosaur tail was covered in the type of feathers seen in the amber sample, the dinosaur would not have flown. The feathers could have been used for signalling, or have played a role in tempera ture regulation.

Fossils in amber

The researchers found the amber fashioned into jewelry at sale in a market in *Myitkyina*, a city in Myanmar. It had already been shaped into an oval. Because the dinosaur's tail had been cut in this reshaping, the scientists could do a chemical analysis. This revealed the presence of iron, which would have been produced from the haemoglobin which was present in the dinosaur's blood and was preserved in some of its tissue.

Amber is fossilized *tree resin*, a sticky plant secretion which protects them from pests. On occasion these pests, such as the ant in the first picture, get stuck in the resin and are frozen for crores of years. The third picture, also by Ryan McKellar, shows 8 crore year old dinosaur feathers, trapped in amber from Grassy Lake in Alberta in Canada.

McKellar said that soft tissue and decayed blood from the tail were found in the amber but no genetic material was preserved. Scientist Lida Xing is optimistic. "Maybe we can find a complete dinosaur," he speculates.

Do You Know?

1. Why do many of us like to sleep under blankets, even on warm nights?

2. What happens when we get flu? Why do we feel like lying in bed all the time?

3. I can imagine that melting glaciers cause sea levels to rise. but I read that they can also cause ocean floor to sink. How is this possible?

4. How does rain come down from the clouds?

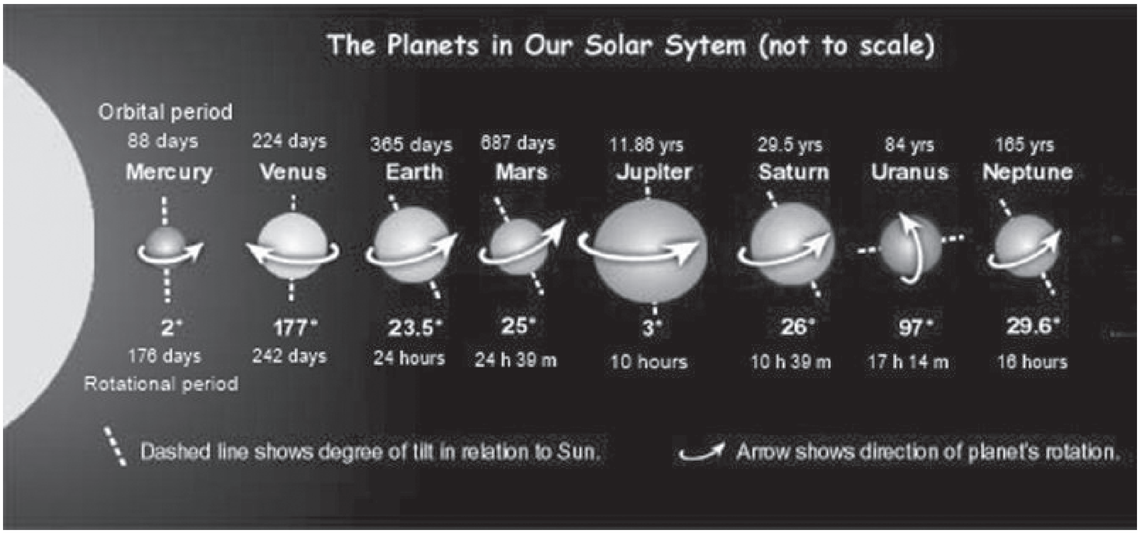
Answers to last issue's Do You Know?

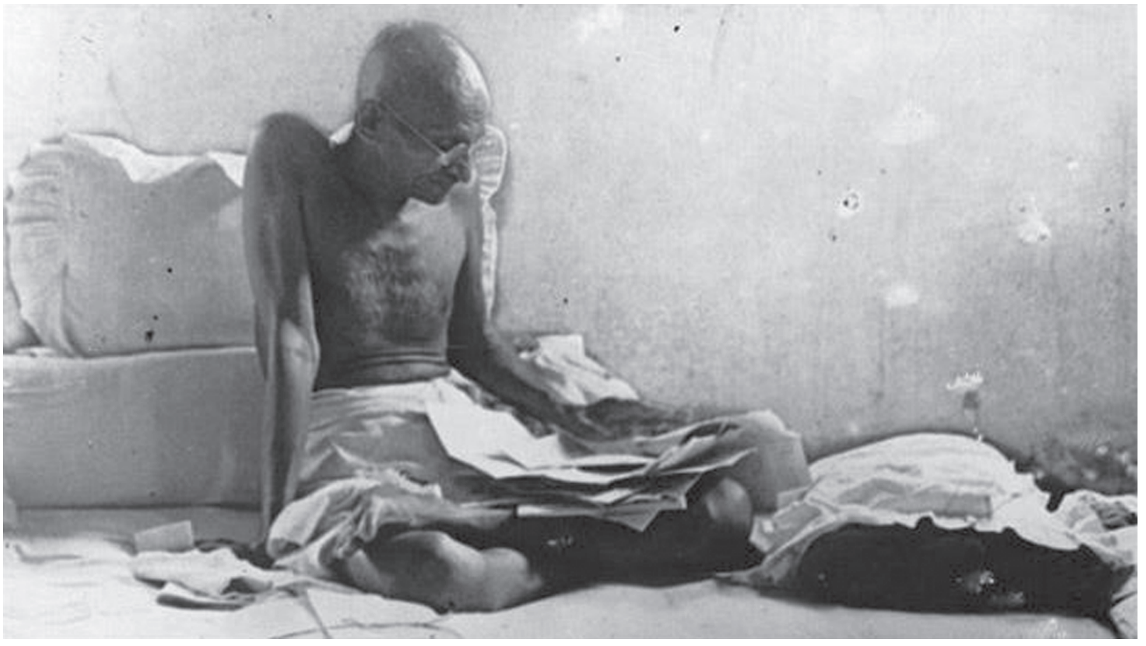
1. I know that planets rotate on their own axes. Why does this happen? Are there any special forces that cause this?

Answer: If you strike a billiards ball with the cue (stick), then, rather than sending it across the table, you will set it spinning. Most scientists believe that planets probably acquired their spin in much the same way, when clumps of matter collided during the planets' formation about 4.5 billion years ago.

When our solar system was nothing but a cloud of gas and dust, what was likely a shock wave from a nearby supernova bounced up against it and caused it to collapse. As it collapsed, its own gravitational forces pulled it into a flat, spinning disk. And since everything in our solar system was formed from that same disk, its momentum sent nearly everything spinning in the same direction. (Almost everything: Uranus and Venus are different. Venus travels around the sun once every 225 Earth days but it rotates clockwise once every 243 days. This is perhaps due to subsequent collisions with asteroids.)

Why have they continued spinning? This is because of **inertia**. In the vacuum of space, spinning objects maintain their momentum and direction — and hence their spin, because no external forces have been applied to stop them. So, the planets





in our solar system keep spinning.

The axis of rotation is different from the magnetic poles. This difference creates force for the earth to rotate on its axis. The same is the case with all planets in the solar system. Moon does not have a magnetic field; hence it does not rotate on its axis.

Thus we have the following picture. The sun itself rotates slowly, only once a month. The planets all revolve around the sun in the same direction and in virtually the same plane. In addition, they all rotate in the same general direction, with the exceptions of Venus and Uranus.

Fun fact: It takes 243 Earth days to complete its rotation, but it only takes 224.7 days to complete each orbit. Yes, that means that a day on Venus is longer than a year!

2. *I heard somewhere: A human can survive 3 minutes without air, 3 days without water, and 3 weeks without food. How long can one really survive without food or water?*

Answer: Some years ago, a Canadian couple got stuck in the mud in a van in Nevada in the middle of nowhere. They waited for help for 3 days, then the husband went looking for help. He was never found, but the woman, **Rita Chretien**, was found by a group of hunters after she had been in the van for 48 days ! She was nearly dead, and had lost 15 kilos. But she had survived, eating only some candy and drinking water from a stream nearby.

At the age of 74 and frail in body, **Mahatma Gandhi** survived 21 days of total starvation while only allowing himself sips of water. Gandhiji did not have much energy reserve before the fast either. (Note that Gandhiji performed a total of 14 hunger strikes !)

As one may expect, there is not enough authentic medical data to know exactly how long human beings can survive in near-total starvation conditions with continued *hydration*. There have been many reported instances, but we do not have exact information on caloric intake, so prediction is difficult. But what is clear is that the body can moderate metabolism to conserve energy and that individual survival varies markedly. The body's ability to alter its metabolism is poorly understood, but it occurs at least in part through changes in thyroid function.

In fact, this is one reason scientists attribute to explain how genes causing diabetes have persisted in evolution, since these were perhaps helpful in the past to survive periods of starvation by enabling more economical use of energy.

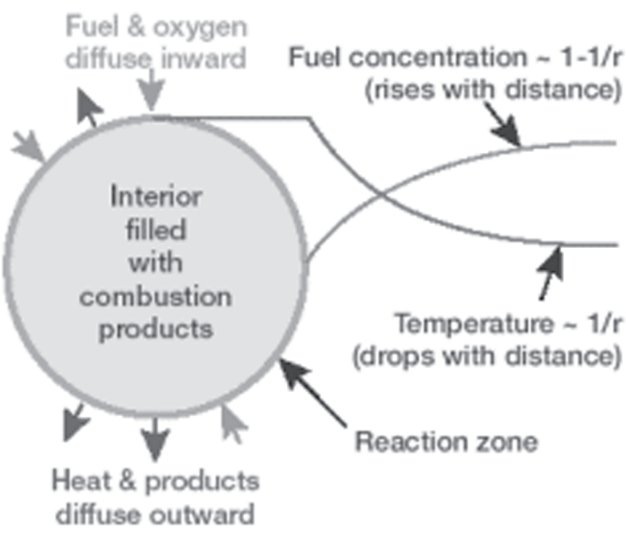
Most important factor of all, however, appears to be hydration. Even little sips of water matter. Rita Chretien survived her 48 day ordeal in large part due to the availability to some melted snow for drinking. Indeed, had no water been available, she may not have survived. In examples of hospitalized individuals who are in a persistent vegetative state, who become cut off from artificial sustenance, death occurs within 10-14 days. Note that these people are in a coma and completely immobile, thereby consuming the lowest amount of energy possible. So it is likely that the same conditions (no food or water) in a person who is at least somewhat active, and who may perspire, would only lead to a much swifter end.

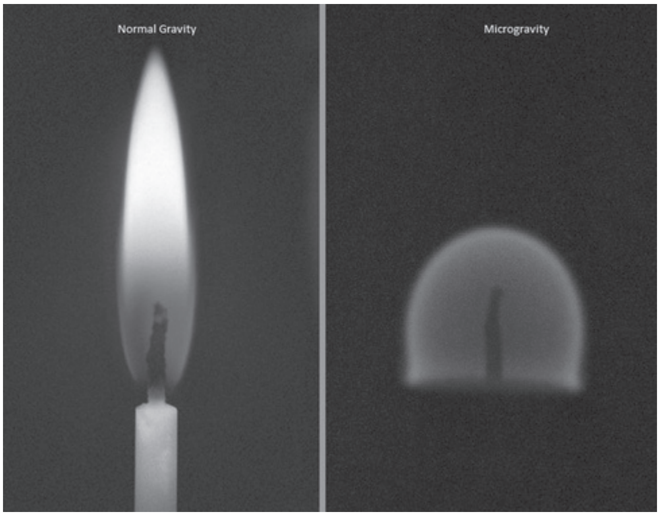
3. How does a flame look in zero gravity?

Answer: In space you cannot have fire since there is no oxygen to sustain combustion. Inside a spacecraft or in the **International Space Station**, you have the same air as on Earth, but because gravity is millions of times weaker, an open flame behaves very differently.

How does fire work, here on Earth? As fuel burns, it heats the air around it making it less dense. As gravity pulls down anything with a higher density, the hot air travels upwards and leaves the vicinity of the fire. With the hot air gone, fresh air is drawn into the gap providing a new source of oxygen-rich air. This is called *buoyancy* and it is what makes the flame shoot up and flicker. Thus, the cycle continues until all the fuel is used up.

In microgravity, there is no updraft and





oxygen is drawn into the flame through a completely different mechanism. The first such experiment was performed in 1997 aboard the *Columbia shuttle*. Scientists noticed that the flame was spherical, like a fireball. The flame is fed by **diffusion**, which is a much slower process. The flame occurs at a border between fuel and air; effectively the entire surface of the flame is the "bottom", reacting with fresh air close enough to the fuel source to combust, resulting in a rough sphere. Because exhaust gases like carbon dioxide cannot leave the combustion area, by the same principle, the outward diffusion of combustion gases can limit the inward diffusion of oxygen to such an extent that the zero gravity flame will die a short time after ignition.

Fire also has a different color in microgravity. When a candle burns, it is being consumed molecule by molecule. Sometimes, the fuel, long strings of carbon, gets pushed upwards where it burns like charcoal, glowing yellow. Without gravity, the carbon strings do not get burned, and the flame is blue, cooler, and much dimmer.

4. *Did travellers in the past actually depend on the North Star to guide them? How could they use its position?*

Answer: Imagine setting up a camera near the North Pole in winter, pointing it at the sky and then taking pictures over one (long, dark) day. Here is what you would see in the time-lapse video: Polaris, (or the North Star, or the Pole Star) almost directly overhead, like a beacon. Over 24 hours, the rest of the stars would appear to slowly circle it.

The stars' circling is really an illusion, of course. It is the Earth that is spinning under the stars, taking 24 hours to turn once around. While the Earth turns, Polaris appears to stand still only because of its position in the sky: lined up almost perfectly with our planet's axis.

How does this work? Earth's North (celestial) pole traces a small circle over 24 hours as the planet turns. Since the pole happens to be pointed at Polaris, the medium-bright star is always directly overhead there. That makes Polaris the Earth's North Star. (There is no corresponding South Star, simply because the South celestial pole is not pointing at any easily visible star.)

Since Polaris stands above the North Pole like a glowing directional beacon, it is the star to steer by in the Northern Hemisphere. Sailors, hikers, and even birds

have used it to find their way in the dark for many centuries.

While Polaris is directly overhead at the top of our planet, it sits on the horizon at the Earth's equator. Just south of the equator, Polaris disappears from view. Between the North Pole and the equator, Polaris is at an in-between position in the sky, corresponding to your latitude north of the equator. This can help you figure out where you are, even in the middle of the sea.

Sources: Discover, Space, Scientific American, ZMEScience

Shape Puzzle

Can you cut this Swiss Cross into four pieces of the same size and shape (called *congruent* pieces) with *JUST* two straight lines, so that the pieces then fit together to form a square?

From: https://www.mathsisfun.com

See page 18 for answer

Mahatma Gandhi, stargazing and astronomy

Based on an article and a lecture by

Dr Nandivada Rathnasree,

Director, Nehru Planetarium, New Delhi

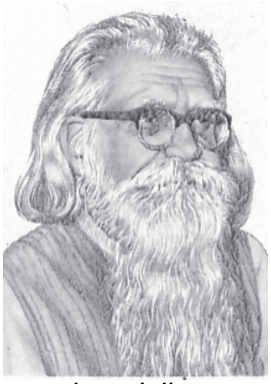
Mahatma Gandhi had a deep, though short-lived, interest in observing stars, a process he found to be a deeply spiritual experience. He pondered over mysteries of the universe while observing stars using sky maps, and read a number of books on astronomy, all during a few months spent in the *Yerawada Central Jail* in Pune, where he was imprisoned by the British Raj in 1932.

Gandhiji was in the Yerawada prison in 1932 in company with Sabarmati ashramite **D.B. Kalelkar** (known as **Kaka Kalelkar**) who had an interest in bringing out books on astronomy in Gujarati. Kaka Kalelkar wrote *Gujarati* in *Devanagari* script; he believed that even if India did not have a national language, it should have a national script, so that Indians could try to read each other's writings. It was during this period and after Kaka Kalelkar left prison, that Gandhiji got an opportunity to learn about astronomy. The pictures on page 19 show Gandhiji leaving Yerawada jail in 1933, and how the jail looks today.

In a letter to Kaka Kalelkar, dated July 23, 1932, Gandhiji wrote: "Looking at the sky, the impression we get of infinity, of purity, of order and of grandeur is one that purifies us. It may perhaps be that on being able to reach the planets and the stars one will get the same experience of good and evil that one gets here on earth. But truly divine is the peaceful influence of their beauty and coolness at this great distance. Also when once we are able to establish communion with the heavens it doesn't matter where we may happen to be. It then becomes like receiving the Ganga in one's own home. All these thoughts have made me a keen watcher of the infinite skies."

Gandhi's advice to Kalelkar

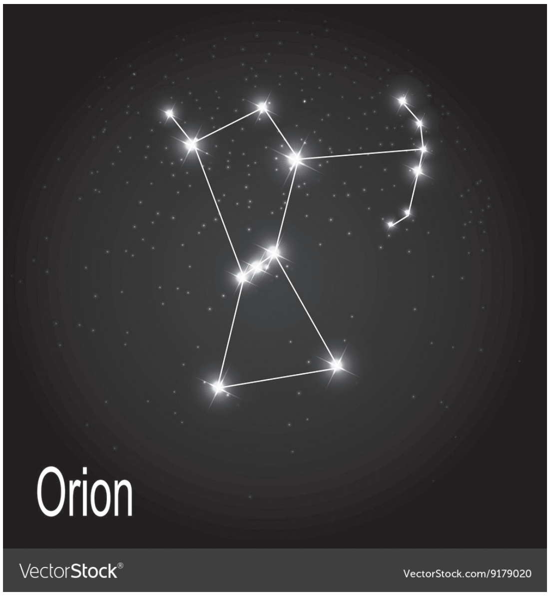
Gandhiji also seemed to have an educator's interest in understanding the science of the stars and making the content available in lucid textbooks on

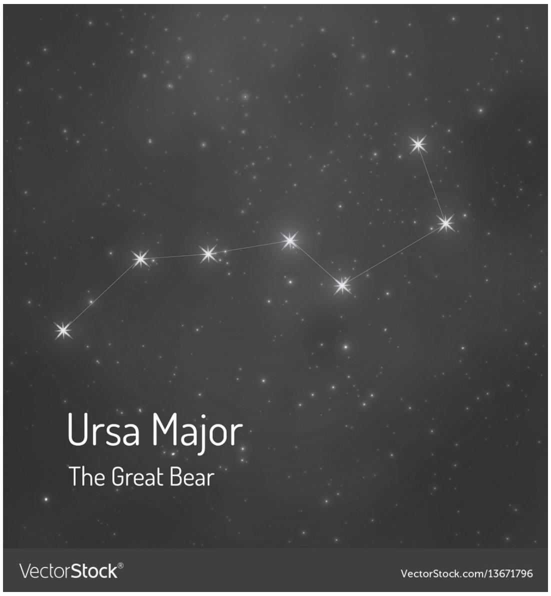


Kaka Kalelkar

astronomy for Indian students. In a letter written to Kalelkar in August 1932, he advised him that his book on astronomy "should give the names and short lives of Western astronomers, some of whom were men of great courage and spirit and of noble character". He also mentioned that the book should give some knowledge about physics. Thus he was well aware, not just about the positional astronomy aspects of watching the stars, but his reading had allowed him to realise that physics underlies an understanding of stars.

It was when aged 63, that Mahatma Gandhi set out to venture into this totally new area of learning. In a letter





to **Mathuradas Trikumji**, a young grandnephew, he wrote, "I myself have been watching the stars every night and enjoy the experience immensely." Though he had an appreciation of the science of stars, his own interest lay in the fact that looking at a star-studded sky gave him a very satisfying spiritual experience. What is more, using technology in this endeavour, seemed not to have interfered with the intensity of that spiritual experience.

Gandhi's advice to school children

In the articles "*Watching the Heavens: I and II*" which he sent to the ashram schoolchildren between February and April 1932, asking them to regularly observe the night sky, he combined his 'spiritual' view of the celestial objects with practical instructions for sky observations and even sketches of the **Orion** constellation (also called *Mriga* or *Vettaikkaran*). He advised ashram

inmates to make their own sketches, one reason being that the constellation as seen from different locations on earth would have differing orientations. He also advised beginner stargazers to observe from a fixed place at a fixed time, and sketch the constellations, and mentioned that once they are familiar with the constellations, they would be able to identify these even if their locations and the constellation orientations change. He also discussed the possibility of a measurement of time by looking at the changing positions of the '*Saptarshi*' (**Great Bear**) constellation.

He immediately clarified that these constellation names are "beautiful fancies", and that there are no such real figures in the sky. Gandhiji wrote: "Both children and grown-ups love dramas and the spectacular scenes which they present. But no drama composed or acted by human beings can even equal the great spectacle which Nature has arranged for us on the stage of the sky".

An educationist in Pune, **Lady Premlila Thackersey**, lent him two telescopes. Lady Premlila dedicated herself to women's education, and after India's independence became the first Vice Chancellor of the *SNDT Women's University* in Mumbai. The correspondence between Gandhiji and the British jailers is very funny to read today. The poor jailers could not decide whether this facility should be allowed for a prisoner. Gandhiji argued that the telescopes were only for his education. Finally the secretary to the Viceroy of India decided that it was *not* dangerous to allow Gandhiji this opportunity.

Passion for observation

Gandhiji told a visiting journalist that astronomy "has become a passion with me. Every free minute I get I devote myself to it." He said that he could easily understand the use of the telescopes "as their adjustments, though delicate, are simple". Gandhiji was indeed very hands-on with all his experiments. He also mentioned that he had been keen to observe '*Parijata*' (the star called **Antares**), *Jyeshtha* or *Kettai*, in the **Scorpio**/*Vrischika* constellation, which

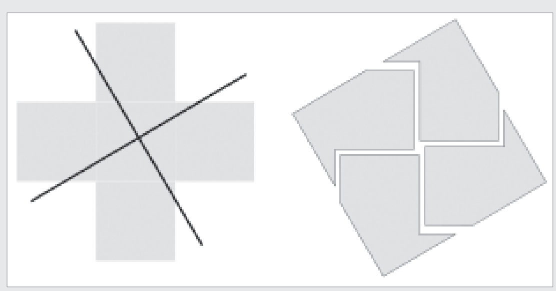
he had been unable to do. Apparently Kaka Kalelkar had told him that it is a *red giant star*. There is a sense of loss expressed by him for not having the time to observe the magnificence of the heavens as much as he could have had done.

In April 1933, Gandhiji's ashram fellow **Madeleine Slade**, the daughter of a British admiral whom he gave the name **Mira**, wrote from *Sabarmati Jail* in Ahmedabad, where she was imprisoned, to Bapu (as she called him) at Pune, where he was imprisoned. "I hear you have got a telescope now-a-days! I once looked at the stars and planets through a very small one of my uncle's and even that was a wonderful sight. Every night as I look at the stars I think how you, too, must be looking at them from Yervada." The picture shows Mirabehn with Gandhi (to his left) at Darwen, Lancashire, England, on Sep 26, 1931.

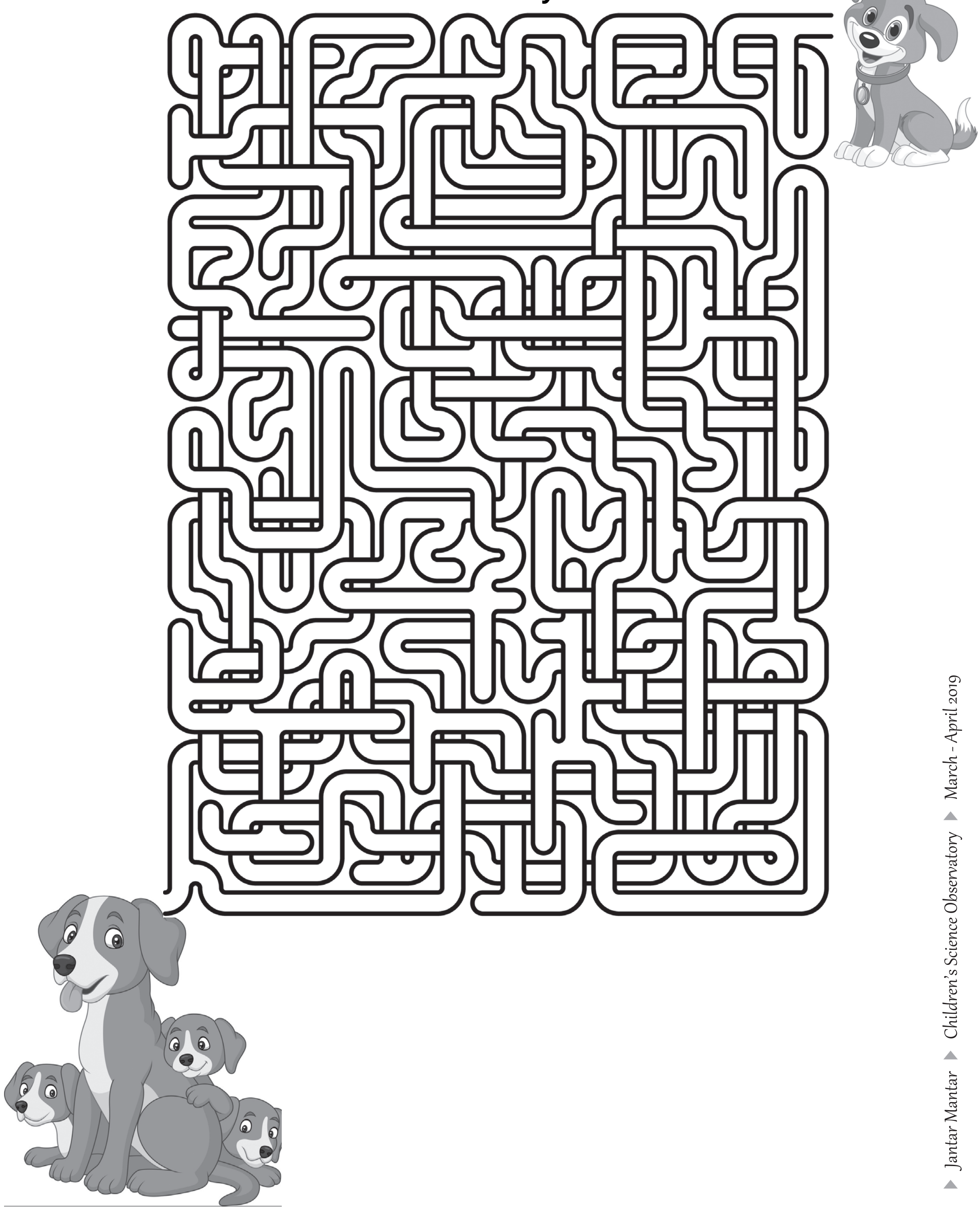
This inspiration towards a pure and spiritual experience of seeing the beauty of the starlit night sky is denied to today's city children, due to the rampant light pollution in all Indian cities. However, some of the excitements of the night skies, consisting of the moon, planets and brighter stars and celestial objects are yet available to be appreciated from city skies, with just a little guidance needed for anyone to locate and view these. That is what is being done during a year-long **Bapu Khagol Mela** being celebrated from October 2018 to October 2019.

Solution to Shape Puzzle on Page 14

The simplest solution is to cut apart the four "arms" and piece them together to form a square, but this needs four cuts, not two. The answer is given below and really challenges your imagination.



Find the way!



Space diary

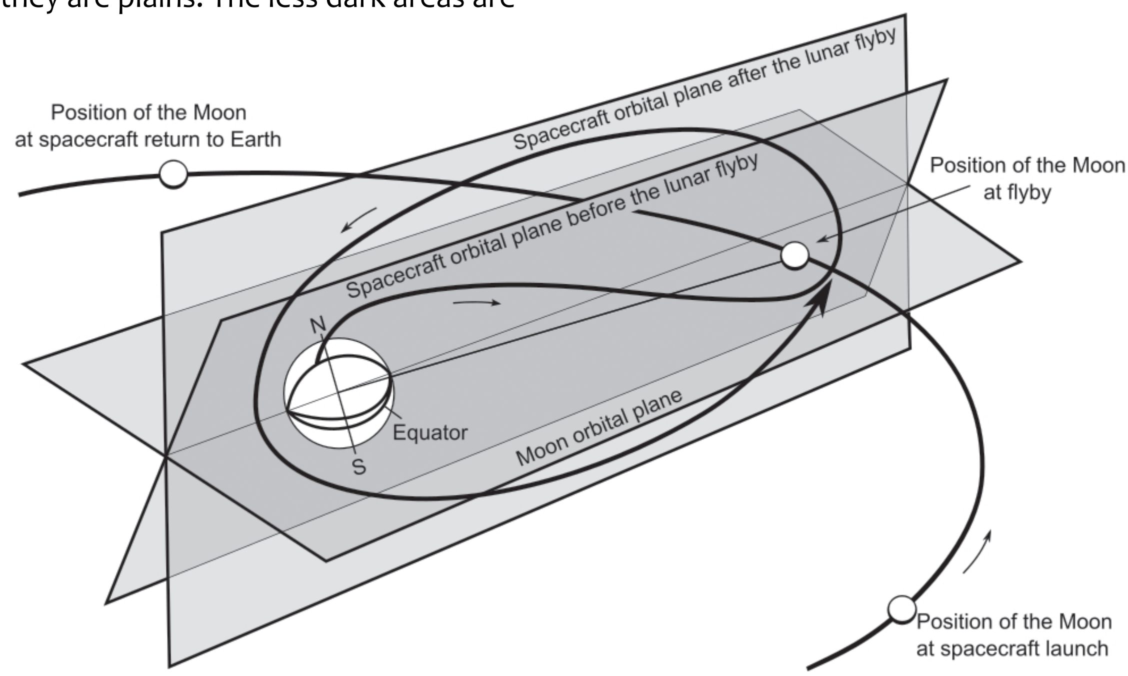
FAR SIDE

Kamal Lodaya

The Moon goes around the Earth in about a month (the words "moon" and "month" are related), 29 and a half days from new moon to new moon. It has *phases*, from **new moon** to **crescent** to **half moon** to **gibbous** and back the same way to new moon. As it goes through the phases, more and more of its face gets uncovered, and on full moon we can see the "rabbit" formed by the dark areas on its surface. The Italian scientist *Galileo Galilei* thought these were "seas". Today we know that they are plains. The less dark areas are rougher, reflecting more sunlight.

The fact that some parts of the Earth are closer to the Moon than others, because they are directly under it, gives rise to *tides*. The water in the oceans rises higher as it is pulled towards the Moon in some places. In other places the water that is pulled away elsewhere makes it a low tide at the same time.

If the Moon's gravity has so much effect on our oceans, imagine what the effect of the Earth's gravity on the Moon would be. The Earth is four times the diameter of the Moon, and weighs a lot more. How come we do not see the effects of the earthly tides on the Moon? The answer is, yes we can. The effects lie in the simple fact that from new moon to full moon, *we always see the same face of the Moon, the one with the rabbit*. The Moon's rotation also



takes one month, because the earthly tides are so powerful that they have **locked** its rotation period.

The dark side of the Moon

The Moon is a sphere, so it does have another side, but it is always away from us, It was first seen by the Russian spacecraft **Luna 3** in 1959, which went all the way around the Moon six decades ago. **Luna 3** found that the far side of the Moon is more rocky than the one we see, it has fewer plains and more mountains. Although it flew over the Moon's south pole to reach the far side, **Luna 3** used the gravity of the Moon to change its path and arrive back over the northern hemisphere of the Earth (where Russia is). This calculation using the equations of Isaac Newton was done by **Mstislav Keldysh** at the Steklov Institute of Mathematics. He was known as the "chief theoretician" of the Russian space programme in those days. Unfortunately the spacecraft did not survive our own atmosphere. Contact was lost and **Luna 3** is believed to have burned up in the atmosphere.

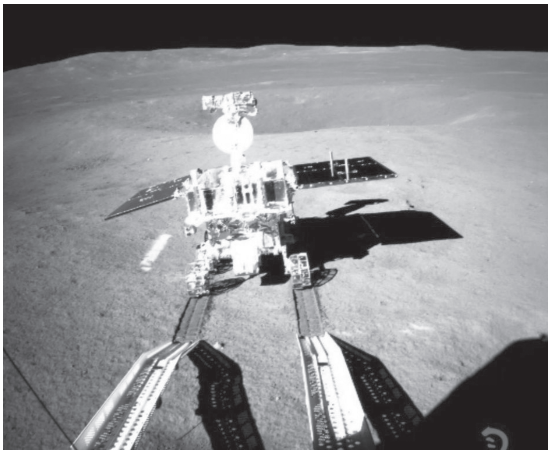
Ever since Luna 3, people have thought of using the far side of the Moon. Since the bright Earth is never visible from that side, and there is no atmosphere to speak of on the Moon, even a moderate-sized telescope could yield a spectacular view of the stars.

The difficulty is, even if we set up such a telescope, who could use it? Having humans living on the airless Moon would be hugely expensive. India has a telescope at **Hanle** in Ladakh, used by astronomers from all over India, operated largely using computers. Couldn't we have such an automated telescope on the Moon?

How would we operate it? Even if we pre-programmed all that it had to do, how would we get back the pictures it took? The data cannot be sent because the far side is the far side, we cannot ever see it! This is why no humans have landed on the far side of the Moon. It would be too risky for them to be out of contact with the Earth for a large amount of time.

Chang'e-4

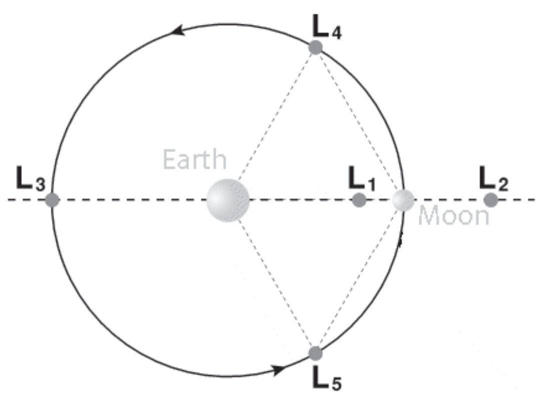
The solution to this problem was found by China. On 3rd January this year, they landed an automated spacecraft **Chang'e-4** on the far side of the Moon.



(Chang'e is a moon goddess in China.) After landing it unrolled a ramp and an automated rover **Yutu-2** rolled down the ramp to the surface of the Moon. The name stands for "jade rabbit". Now the rover is going to go around taking pictures and sending them back to us.

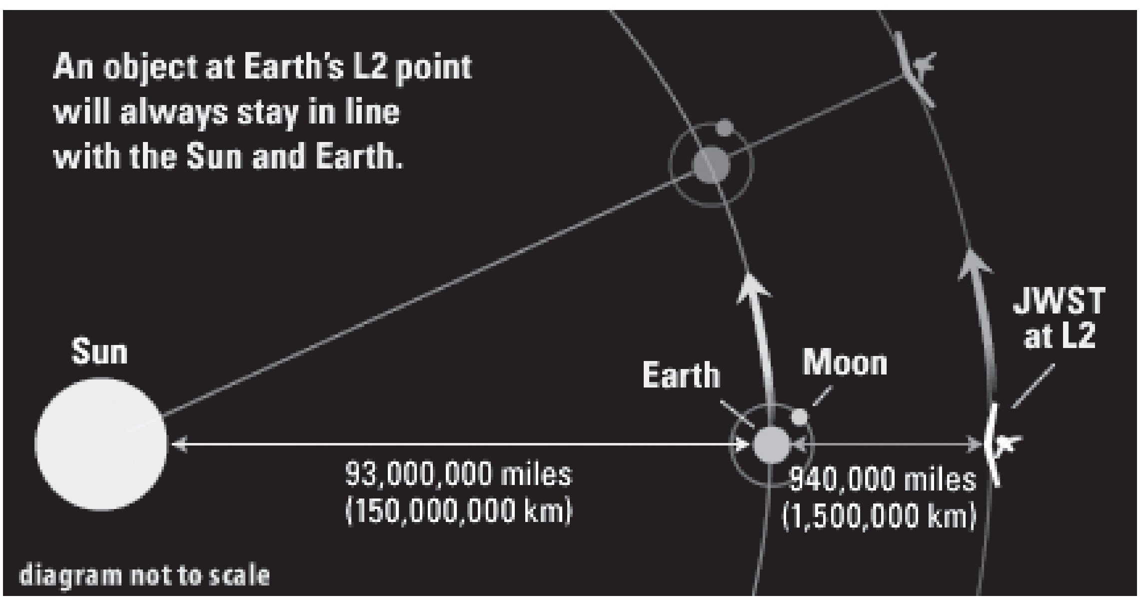
Lagrange point L2

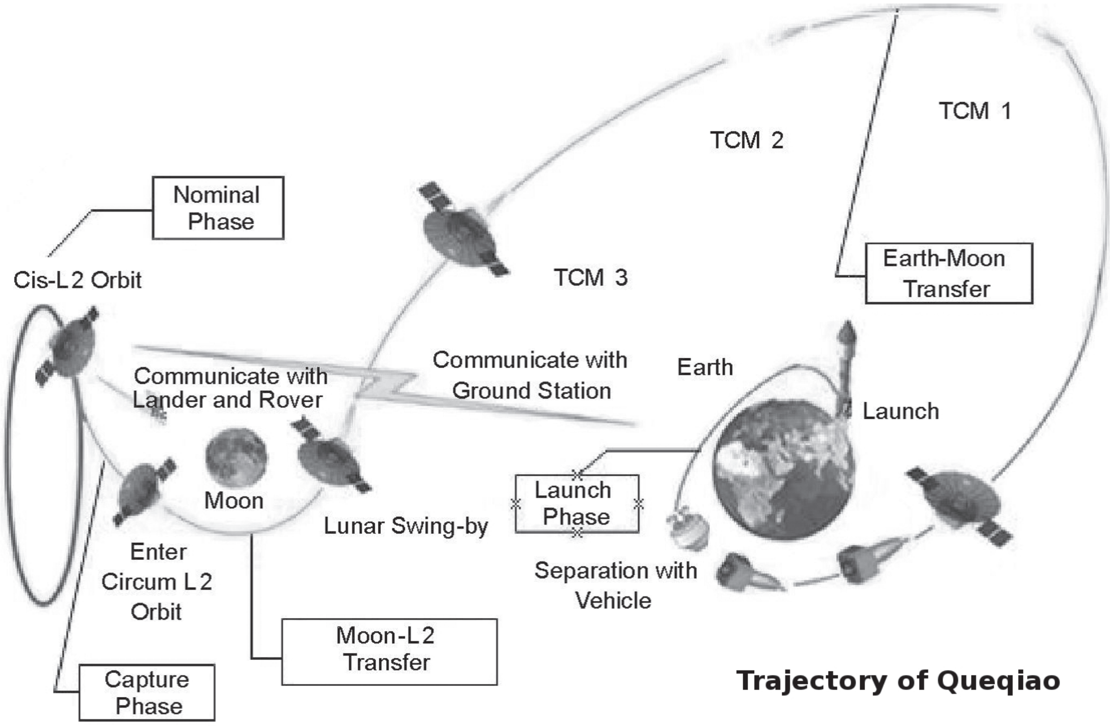
But how can it beam these pictures back to us? China had first sent its **Yutu 1** rover to the side of the Moon that we can see, so that it could try out the rover technology and send us pictures. But how to send pictures from the far side? This required some preparation and we have to take a flashback to May 2018.



On the Moon we have the Moon's gravity. It is one-sixth of what we find on the Earth but it is the Moon's gravity which holds **Yutu** there, it does not fly off into space. As we rise from the Moon's surface and fly out, its gravity becomes less and less, until we reach a point 65,000 km from the Moon (remember the Moon is already about 4 lakh km from the Earth). This point has a name, it is called the *Lagrange point L2*. Here the Moon's gravitational attraction is the same as the Earth's gravitational attraction, even though the Earth is farther, because Earth has more mass. If we put a spacecraft there, it would stay there, neither would it fall on the Moon, nor on the Earth. And from there you can see both the far side of the Moon and the Earth.

To go off on a tangent, this should





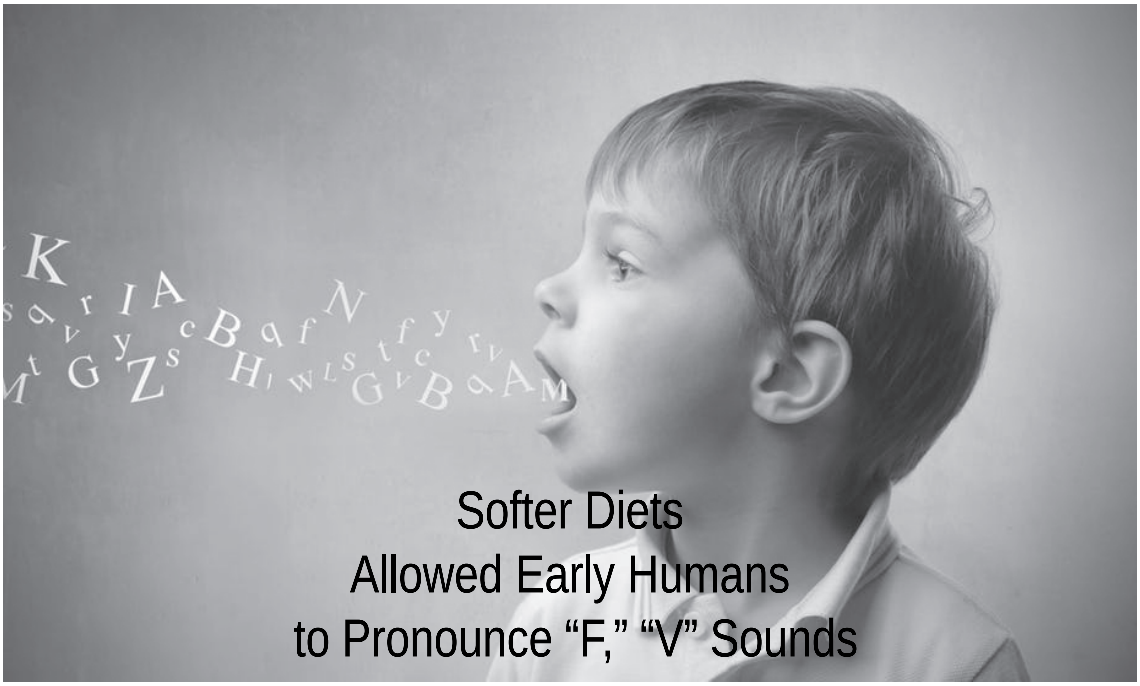
Trajectory of Queqiao

suggest to you that there is another such point, the Lagrange point L1. Can you think of where this might be? The European mathematicians Leonhard Euler and Joseph-Louis Lagrange studied these kinds of points in the 18th century.)

Pictures from the L2 point was taken by the **Queqiao s**pacecraft, which reached **t**he L2 point in June 2018. The picture of Earthrise over the Moon is by the **Longjiang 2** satellite. It shows a crater on the far side. The name "Longjiang" name means Dragon river. This satellite was put into lunar orbit by the Queqiao spacecraft; the name means "Magpie bridge". Getting a spacecraft to L2 was difficult. The picture shows the complicated path taken by it.

To get back to our problem, Yutu talks to Chang'e. Chang'e talks to Longjiang. Longjiang talks to Queqiao. (Actually both Yutu and Chang'e can directly talk to Queqiao.) Queqiao talks to Earth. Just as we in India can talk to people, elsewhere in India or in China or in America, using a communications network which includes satellites in space above the Earth, the Chinese have their communications network set up for the far side of the Moon.

Meanwhile Chang'e is not sitting idle. There are many interesting experiments on it. One designed by Chinese universities is to try and grow potatoes, tomatoes, a flowering plant and silkworms, by providing in a box a small Earth-like atmosphere. But of course this life has to live in lunar gravity, not Earth's gravity.



Softer Diets Allowed Early Humans to Pronounce “F,” “V” Sounds

In 1985, the American linguist **Charles Hockett** proposed a radical idea during a lecture at the annual meeting of the American Anthropological Association: “f” and “v” sounds only became part of spoken language after the dawn of agriculture, and as such, were a “relatively recent innovation in human history.”

Hockett reasoned that softer, processed foods would lead to changes in the arrangement of the human bite, making the pronunciation of these sounds possible. This would explain why many hunter societies don’t tend to use “f” and “v” sounds in their languages. But the idea was sharply criticized, and Hockett himself soon gave up on it.

A new look at old ideas

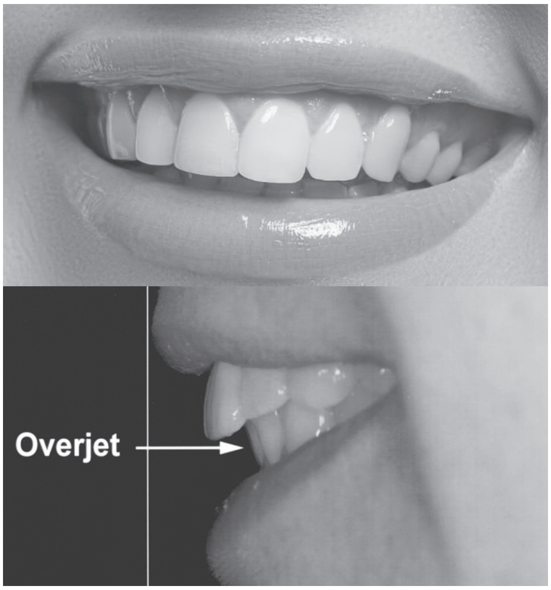
Now, more than 30 years later, an international team of researchers has taken another look at Hockett’s hypothesis. This time they used information from historical linguistics and paleoanthropology data and combined it with biomechanical simulations of sound production.

In particular, they studied labio-dental sounds: these require the require the involvement of the bottom lip and the upper teeth. They concluded that such sounds only emerged recently (last few thousand years) because the human diet changed, and with that, the human bite as well. The research was published in the Journal Science.

“Hockett’s paper was always just a curiosity to me, but now this is something I’ll talk about in class,” remarks **Joe Salmons**, a professor of language sciences at the University of Wisconsin who wasn’t involved in the study. “Whether they’re ultimately right or not, we can’t say for sure. But it’s a much more powerful case.”

Bite-sizes

Modern-day humans start out as children with the same bite configuration as young



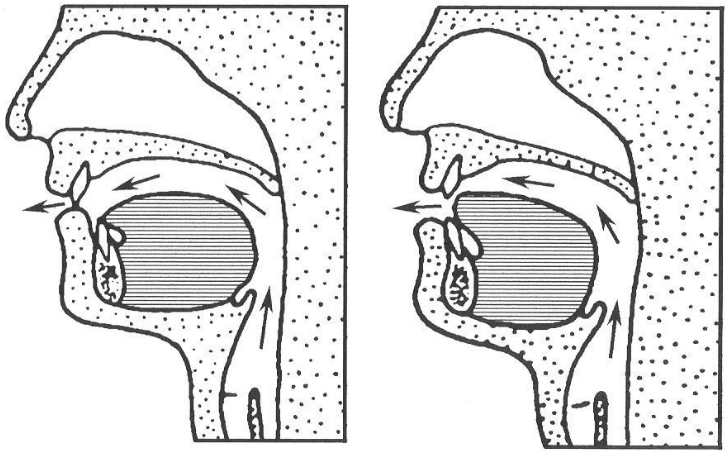
hunter-gatherers did thousands of years ago. They have an "overbite," in which the upper jaw overlaps the lower one, and an "overjet," where the top front teeth protrude over the bottom ones. In previous studies, this bite configuration has been shown to change depending on the diet.

To investigate if this were true, the researchers simulated the production of a labio-dental sound using computers. Since they modelled the mechanical working of the oral cavity and the facial muscles, it is called orofacial mechanics. Energetically speaking, making "f" and "v" sounds with an overjet and overbite is nearly 30 percent more efficient than with an edge-to-edge bite.

Through statistical techniques, they examined the relationship between the distribution of labio-dental sounds across nearly 2,000 languages worldwide and their speakers' sources of food. The biggest contrast is expected to be in hunter-gatherer societies where the food is mostly in raw or un-processed state, and in food-producing societies where sophisticated processing methods are used. For instance, the meat eaten by hunter-gatherers is more rough on the teeth while the processed soft foods that we eat in cities hardly requires chewing. They found that, on average, hunter-gatherer societies have only 27 percent as many labio-dental sounds in their vocabulary as do food-producing societies.

Hunter gatherers and sounds

The researchers also looked specifically at several regions with a history of hunting and gathering until very recently: Greenland, southern Africa, and Australia. Many native societies in these areas don't express labio-dentals (that is, do not have such sounds), but some have picked up these sounds through contact with groups who do use labio-dentals. For instance, the language of West Greenlandic has acquired one labio-



f and v (as in very) th

dental sound. This was probably due to long contact with Europeans since the 18th century.

"The diet came with these people that [also] provided them with the words," says **Damián Blasi**, a postdoc at the University of Zurich's Psycholinguistics Laboratory and first author on the study.

Phylogenetic Analysis

Phylogenetics is the study of evolutionary relationships among biological entities - species, individuals or genes. Researchers reconstructed the evolution of labio-dental sounds through a phylogenetic analysis of the Indo-European language family. According to the model, labio-dental sounds most likely emerged between 3,500 and 6,000 years ago across different languages, coinciding broadly with archaeological evidence of bite configurations. For instance, human skulls from Pakistan show evidence of an overbite and overjet around 4,300 years ago. The model suggests a particularly steep rise in the use of labio-dentals some 2,500 years ago, around the time when industrial milling of food became widespread in western Europe.

Blasi says he and his colleagues were initially surprised at how well the different lines of evidence supported Hockett's theory. However, he cautions that maintaining an overbite and overjet doesn't necessarily guarantee that a particular community will start using labio-dentals in speech, it just means there's a higher probability they will. There are plenty of exceptions to the rule: Spanish, for instance, has an "f," but no spoken "v" he notes: Most varieties of Spanish pronounce the letter "v" as a "b," a sound which is produced through both lips. Plus, there are many other factors that determine whether a sound will be acquired in a given language. Perhaps some sounds carry a negative social connotation, or others aren't easily audible. "There's so many things we don't know about the dynamics of language."

Pedro Tiago Martins is a graduate student at the University of Barcelona. He studies the evolution of speech. People used to believe that humans can make a range of sounds that has remained the same over ages. Now he has shown that "the sound system we have is not fixed," and can be shaped by the environment and culture.

Cultural changes, such as the agricul tural revolution, can affect biology and vice versa, points out **Timothy Weaver**, a biological anthropologist at University of California, Davis. The new findings provide a good example: "You have these cultural changes that lead to dietary changes and those dietary changes influence the anatomy, and the anatomy then influences an aspect of culture, that is, language."

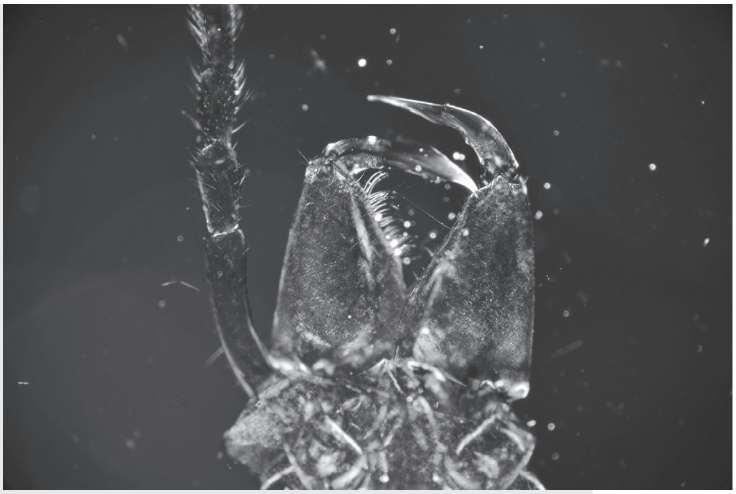
Salmons is particularly impressed by the variety of evidence the researchers provided, and says he hopes the study will raise the bar for future work on the effect of the environment on language evolution. "I really like that they used such a multi-faceted approach for this kind of question," he says. "No single strand of evidence alone would have made the story the way that the whole set does."

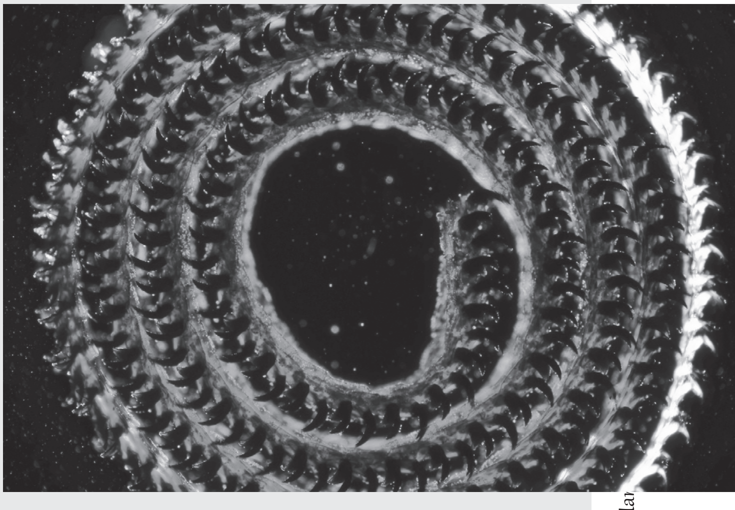
Image of the Day: Under the Microscope

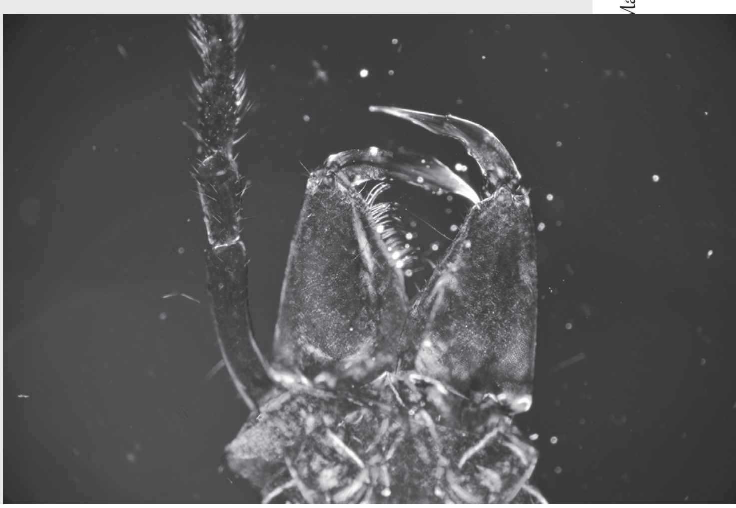
A virtual exhibition of C.R. Percival's slides reveals the natural world up close.

CAROLYN WILKE

In the late 1800s to mid 1900s, microscopist C.R. Percival collected and prepared microscope slides that let scientists zoom in on the natural world. His slides capture the colors and textures of life from miniscule ocean creatures to insect legs to sections of teeth. A collection of photographs taken of his slides is on display virtually at Ingenium, an organization that runs science museums in Canada.







Spider fangs (Dysdera crocata) at 40x magnification

Sea snail (Patella vulgate) at 40x magnification

Polar bear hair at 40x magnification

Climate Change

Climate change is increasing fire activity in the western United States. This can speed up climate-induced shifts in vegetation communities. Wildfires can induce vegetation change by killing adult trees that could grow in the changed climate conditions. However, the seeds may not be able to survive in a similar climate.

A study of the effect of climate change in conifer trees was carried out in the western United States. The study showed that climate change combined with high severity fire is leading to increasingly fewer opportunities for seedlings to establish after wildfires and may lead to drastic changes in the local ecosystem.

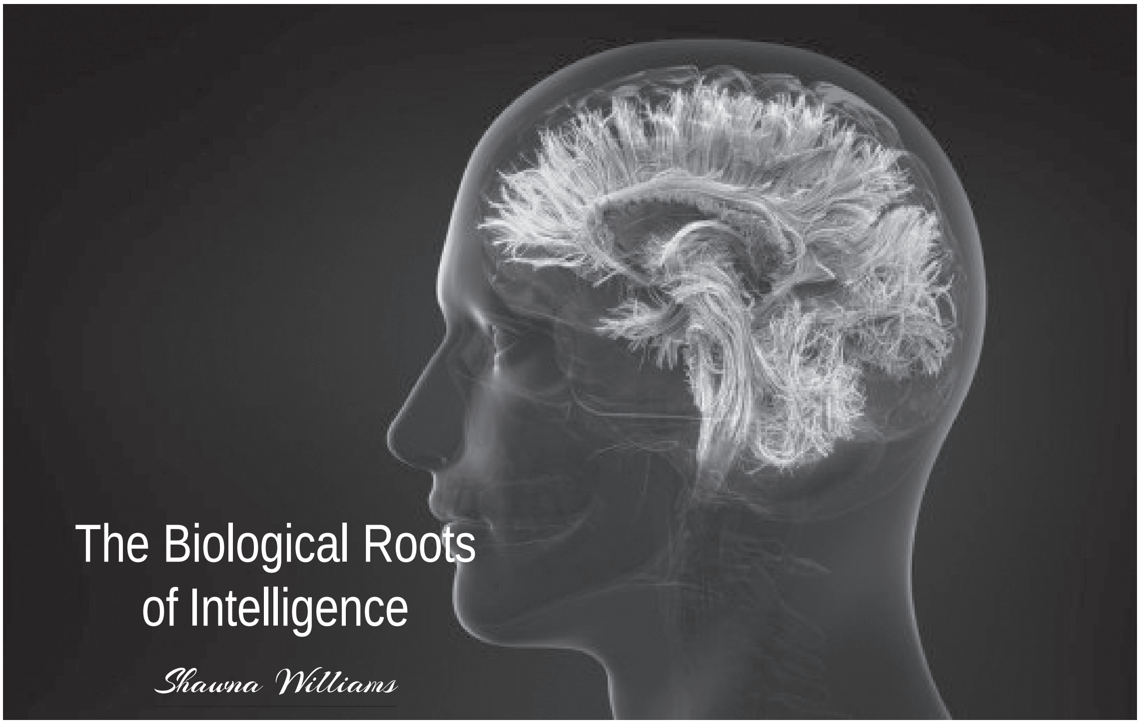
The picture shows a Ponderosa pine and Douglas-fir forest in the Boise National Forest, Idaho, 22 years after it burned in the 1994 Idaho City Complex Fire.

Soil, temperature, and humidity conditions driven by climate change have

made it more difficult for Douglas fire and ponderosa pine seedlings to establish themselves after a forest fire, researchers reported yesterday (March 11) in PNAS. At some locations in the western US, a "critical climate threshold" has already been surpassed over the past 20 years, meaning forests may not return after wildfires.

"Maybe in areas where there are really abundant seed sources, there could be some trees, but it is becoming really hard to get these trees back due to climate change," coauthor Kim Davis, a postdoc at the University of Montana, tells CNN. Davis and her colleagues analyzed tree rings sampled from nearly 3,000 trees in the Rockies and California from 1988–2015 to figure out when the trees had established themselves. When comparing regeneration after wildfires to annual climate conditions at their study sites, they found certain thresholds for summer humidity and temperature (too high) and soil moisture (too low) beyond which it became difficult for new trees to grow after a fire.

"Across the study region, seasonal to annual climate conditions from the early 1990s through 2015 have crossed these climate thresholds at the majority of sites, indicating conditions that are increasingly unsuitable for tree regeneration, particularly for ponderosa pine," the authors write in their report. The consequence is that when adult trees die in forest fires, seedlings struggle to replace them, and forests could rapidly give way to other types of vegetation. The effects are both ecological and economic, as both species of tree are important to the timber industry.



The Biological Roots of Intelligence

Shauna Williams

In 1987, political scientist **James Flynn** of the University of Otago in New Zealand found out something curious : intelligence had broadly increased in multiple human populations over time. The data was collected across 14 countries where many decades of average IQ scores of large fractions of the population were available. He found that all of them showed upward swings—some of them dramatic.

Children in Japan, for example, gained an average of 20 points between 1951 and 1975 on a test known as the *Wechsler Intelligence Scale for Children*. In France, the average 18-year-old man performed 25 points better on a reasoning test in 1974 than did his 1949 counterpart. Flynn initially suspected the trend reflected faulty tests. Yet in the ensuing years, more data and analyses supported the idea that human intelligence was increasing over time.

Proposed explanations for the phenomenon, now known as the **Flynn effect**, include increasing education, better nutrition, greater use of technology, and reduced lead exposure, to name but four. Beginning with people born in the 1970s, the trend has reversed in some Western European countries, deepening the mystery of what's behind the generational fluctuations. But no consensus has emerged on the underlying cause of these trends.

What is intelligence?

A fundamental challenge in understanding the Flynn effect is defining intelligence. At the dawn of the 20th century, English psychologist **Charles Spearman** first observed that people's average performance on a variety of seemingly unrelated mental tasks—judging whether one weight is heavier than another, for example, or pushing a button quickly after a light comes on—predicts our average performance on a completely different set of tasks. Spearman proposed that a single measure of **general intelligence**, called **g**, was responsible for that commonality.

What causes variations in g?

Scientists have proposed several biological mechanisms for variations among individuals' **g** levels, such as brain size and density, and overall connectivity within the brain cortex. But the precise physiological origin of **g** still unknown. The study also becomes controversial because of eugenics, which attempts to label genetic groups as "superior" or "inferior" based on unethical practises.

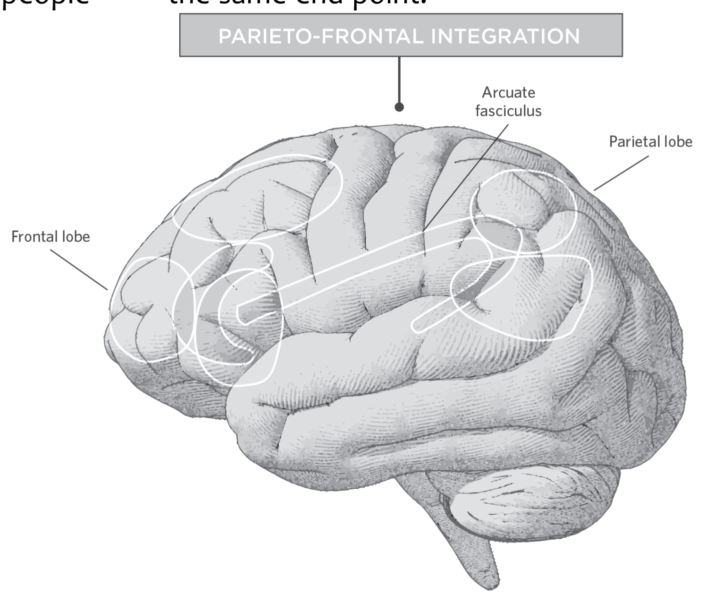
Early studies of people with brain injuries indicated that the *frontal lobes* of the brain were vital to problem solving. In the late 1980s, Richard Haier of the University of California, Irvine, and colleagues imaged the brains of people as they solved abstract reasoning puzzles. As their brains were working, specific areas in the *frontal, parietal*, and *occipital lobes* of the brain, as well as *communication between them*, showed increased activity. The frontal lobes are associated with planning and attention; the parietal lobes interpret sensory information; and the occipital lobe processes visual information—all abilities useful in puzzle solving.

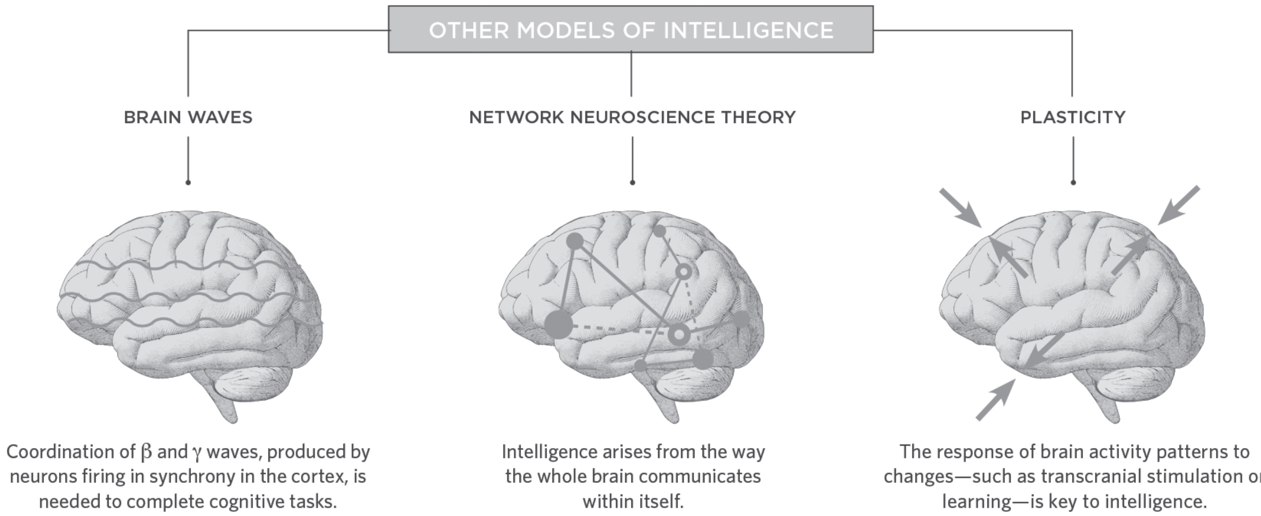
But more brain activity doesn't mean better ability to understand and acquire knowledge: these are called **cognitive prowess**. The people with the highest test scores actually showed the lowest brain activity, suggesting that it wasn't how hard your brain was working that made you smart, but how efficiently your brain was working!

The parieto-frontal integration theory

In 2007, based on this and other neuroimaging studies, Haier and the University of New Mexico's **Rex Jung** proposed the parieto-frontal integration theory. This states that the brain areas identified in Haier's and others' studies are central to intelligence.

But patterns of activation vary, even between people of similar intelligence, when performing the same mental tasks. This can mean that there are different pathways that the brain can use to reach the same end point.





Models of intelligence

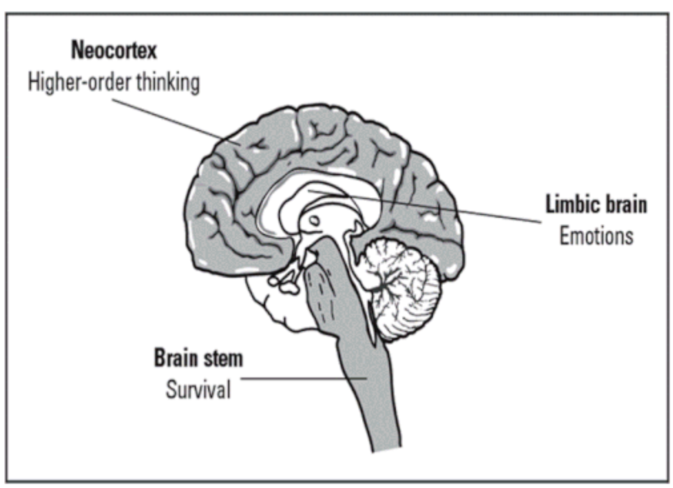
However, tools to study the brain are still limited. In addition, is intelligence only tied to the anatomical features of the brain? It's become clear over the past 10 to 15 years that this view is too simplistic.

Researchers have begun to propose alternative properties of the brain that might determine intelligence. Miller, for example, has been tracking the behavior of brain waves, which arise when multiple neurons fire in synchrony or together, for clues about IQ.

In one recent study, he and colleagues hooked up EEG electrodes to the heads of monkeys that had been taught to release a bar if they saw the same sequence of objects they'd seen a moment before. The task relied on working memory, that is, the ability to access and store bits of relevant information, and it caused bursts of different kinds of waves, some at high frequency and others at lower frequency. More importantly, when the bursts weren't synchronized at the usual points during the task, the animals made errors. So not only are the frontal and parietal parts of the brain important, but the connections between them also determine your cognitive skills.

Network Neuroscience Theory

The overall pattern of brain communications is another candidate to explain intelligence. Earlier this year, **Aron Barbey**, a psychology researcher at the



University of Illinois at Urbana-Champaign, proposed this idea, which he calls the network neuroscience theory.

Putting the g in genes

Is intelligence genetic? Can it be inherited from parents? It seems unlikely, since we know of lots of scientists whose brothers and sisters did not become famous! (Of course there are some such cases as well). Some estimates state that about 25 percent of individual variation in intelligence will turn out to be genetic. While the correlation between education and intelligence is imperfect, “intelligence and school achievement are highly correlated, and genetically very highly correlated,” says von Stumm.

Despite the hints uncovered about how intelligence comes about, Santarnecchi finds himself frustrated that research has not yielded more-concrete answers about what he considers one of neuroscience’s central problems. To address that shortcoming, he’s now spearheading a consortium of cognitive neuroscientists, engineers, evolutionary biologists, and researchers from other disciplines to discuss approaches for getting at the biological basis of intelligence.

As researchers struggle with the phenomenon of intelligence, a philosophical question arises: Is our species smart enough to understand the basis of our own intelligence? While those in the field generally agree that science has a long way to go to make sense of how we think, most express cautious optimism that the coming decades will yield major insights.

Brain and its functions

Frontal Lobes: Initiation; problem solving; judgment; inhibition of behavior; planning; nticipation; self monitoring; motor integration; personalities; emotions; motivation; awareness of abilities; attention; concentration; mental flexibility; speaking.

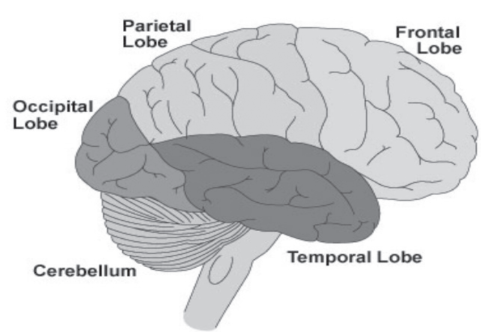
Parietal Lobes: Sense of touch; seeing differences in size, shape, color; spatial perception; visual perception.

Temporal Lobes: Memory; hearing; understanding language; organization; sequencing; music awareness.

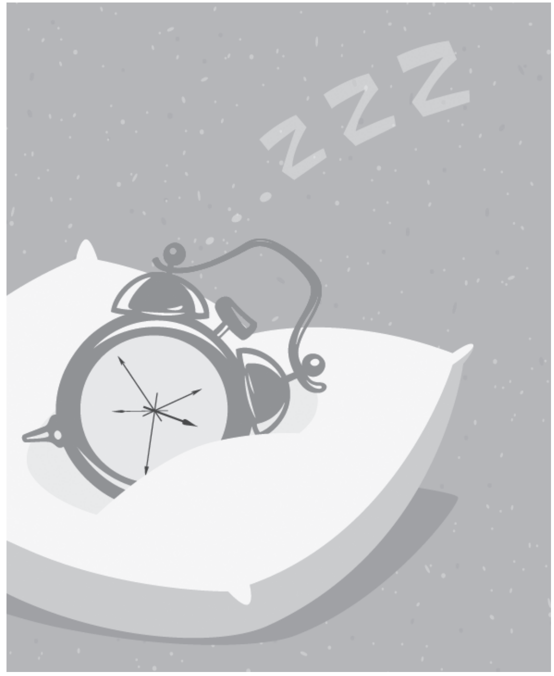
Occipital Lobes: Vision; Cerebellum: Balance; coordination; skilled motor activity.

Brain Stem: Relay station; consciousness; alertness; breathing; heart rate; basic body functions.

The Human Brain



Muscle Clocks Play a Role in Regulating Metabolism



Just 20 years ago, scientists didn't even realize muscles had their own circadian clocks. This means that they have a natural twenty-four hour cycle, matching with an Earth day.

In the early 2000s, **Stefano Schiaffino**, a muscle physiologist at the University of Padova in Italy, was faced with puzzling results: two seemingly identical experiments involving hind leg muscles in rats had yielded different findings.

Schiaffino and his team were investigating the nuclear factor of activated T cells (NFAT), a *transcription factor* that responds to the level of muscle activity. Despite using similar procedures, the researchers found that in the tissues from one set of animals, NFAT had moved from the cytoplasm into the nucleus in a large proportion of cells, while in tissues from another experiment, this change had not occurred.

The explanation for this difference turned out to be simple: **timing**. The researcher responsible for one trial had experimented on the nocturnal animals in the evening, while another had conducted the same procedure for the second trial in the morning. This meant that the first group of animals was more active at the time of measurement than the second. When the scientists repeated the second experiment late in the day, when the animals were more likely to be awake, they observed high levels of NFAT in the nuclei of the muscle cells, essentially replicating the first experiment. "At that time, I'd been working for many years on muscle, but had never thought about the circadian rhythms," recalls Schiaffino, whose research now focuses on this aspect of muscle biology.

Around the same time, on other side of the globe, muscle physiologist **Karyn Esser**, then at the University of Illinois at Chicago, also stumbled upon a surprising discovery: that genes encoded essential elements of biological clocks which were being expressed in rat muscle tissue.

A growing body of evidence now points to these cyclical dynamics as mediators of metabolism. Disrupting them may have consequences for health, predisposing individuals to conditions such as diabetes. Research also indicates that these clocks cycles that regulate tissue and cell function, may influence muscle strength and structure, and may even regulate neurological processes such as sleep.

Managing metabolism

One of the most clearly defined roles of a muscle's clock is maintaining the tissue's ability to take up glucose, a process that occurs in response to insulin levels and muscle contractions. During an animal's waking hours, feeding releases insulin from the pancreas and physical activity induces the movement of the glucose transporter called *GLUT4* to the cell membrane.

Studies show that disrupting clock genes in the muscle impairs the transcription of GLUT4 and other key genes involved in this process. Proteins required to metabolize sugars and lipids are also produced in a circadian manner. Researchers have found that genes that regulate the storage of these fuels reach peak expression levels when animals are preparing for rest, while those involved in breaking them down for energy production peak just before the active phase begins.

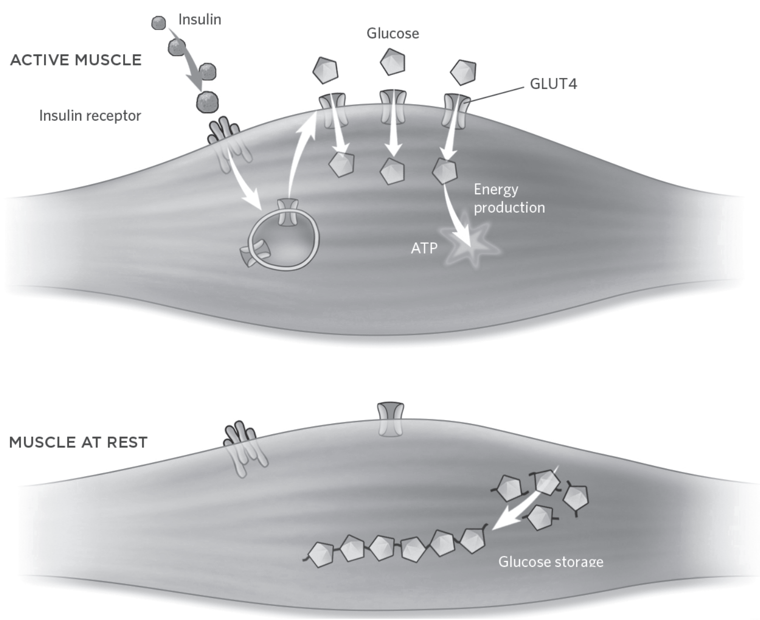
These findings implied that "the intrinsic muscle clock is an important controller of glucose metabolism," Schiaffino says. This makes sense, he adds, because a muscle can become a "sponge for glucose" when insulin is released in a healthy animal—after a meal, for example. In fact, skeletal muscle is the body's major glucose storage unit, responsible for around 70 percent of the body's uptake of the sugar.

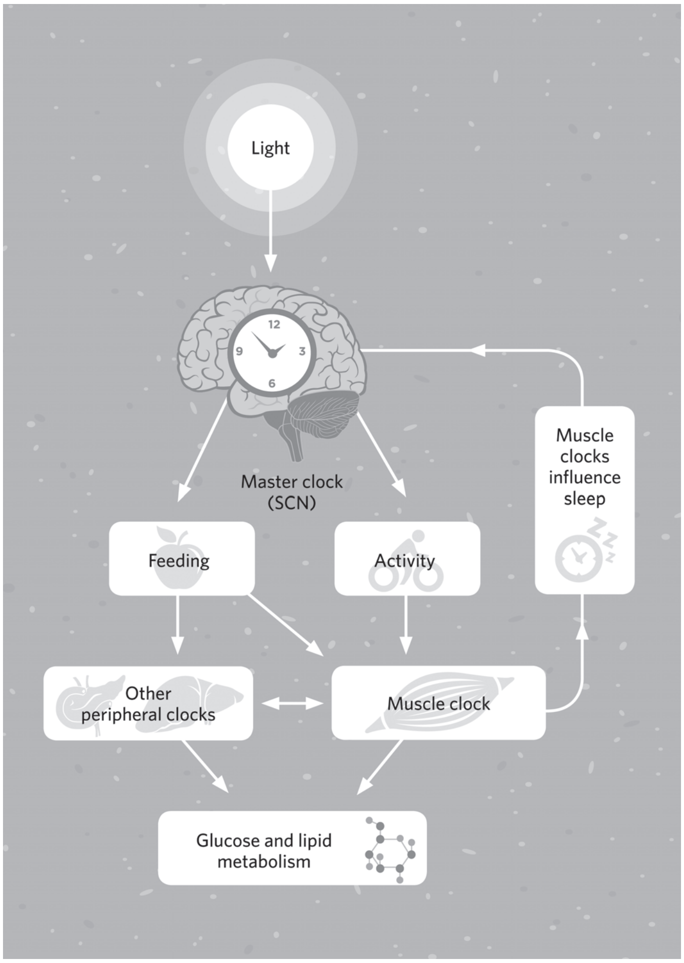
This daily cycle helps muscles prepare to transition from rest (and fasting), when the cells tend to store fuels, to a wakeful period, when the animal is eating and its cells burn fuels to generate energy for activity.

Earlier this year, **Charna Dibner** of the University of Geneva and her colleagues reported similar outcomes in human muscle cells: disrupting the clock in vitro altered the expression of a number of genes, including those encoding proteins involved in glucose transport and lipid metabolism, and impaired the muscle cells' ability to take up glucose in response to insulin.5

The muscle clock also appears to regulate the type of fuel that the cell burns. Although active tissues require more energy, cells still need some fuel during sleep, but rather than rely predominately on glucose, which powers contractile activity during waking hours, they burn lipids and amino acids while at rest.

Those who have flown overseas or large distances by air will understand what it feels like when the body's rhythms are out of sync. Traveling long distances across multiple time zones throws off the usual clock-setting cues, or zeitgebers, such as the daily light-dark cycle. Jet lag can cause a variety of temporary symptoms, including dizziness, irritability, and





indigestion.

Longer-term perturbations of these rhythms can have lasting effects on the body. Researchers have also found that, in rodents, mutations in circadian clock genes can cause obesity, metabolic syndrome (a cluster of conditions that includes high sugar and low insulin levels in the blood), and diabetes. A number of epidemiological studies have shown that people who work night shifts are at a higher risk for these conditions as well.

Muscle clocks may affect aspects of health other than metabolism as well. Esser and her colleagues have found that knocking out tissue-specific timekeepers leads to weaker muscles in mice.

Many questions remain about the way muscle keeps time, such as how external signals are incorporated. Studies, primarily in rodents, suggest that feeding and exercise may serve as primary triggers. Oxygen levels may also play a role. And when it comes to uncovering the molecular pathways that keep time in muscles and control that clock's effects on the body, Esser says, researchers have only just begun. "There's a lot still to learn."

Adapted
from the article by
Diana Kwon
in The Scientist:
https://www.the-scientist.com

Form - IV Rule - 8

Jantar Mantar

Children's Science Observatory

1. Place of Publication	:	130/3, Avvai shanmugam Salai, Gopalapuram, Chennai - 600 086
2. Periodicity of Publication	:	Bi-Monthly
3. Printer's Name	:	S.Vaidyanathan
Whether citizen of India (If Foreigner state the country of Origin)	:	Indian
Address	:	Print Specialities, 186, VM Street, Royapettah, Chennai - 600 014
4. Publisher's Name	:	C.S.Venkateswaran
Whether citizen of India (If Foreigner state the country of Origin)	:	Indian
Address	:	130/3, Avvai shanmugam Salai, Gopalapuram, Chennai - 600 086
5. Editor's Name	:	D.Indumathi
Whether Citizen of India (If foreigner state the country of origin)	:	Indian
Address	:	IMSC, Tharamani, Chennai - 600 036
6. Name & Address of Individuals who own the news paper & partners shareholders holding more than one percent of the total capital	:	Tamilnadu Science Forum 130/3, Avvai Shanmugam Salai, Gopalapuram, Chennai - 600 086

I, C.S.Venkateswaran, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Chennai

Signature of Publisher

The great wall of China

China has a great wall. At Badaling near Beijing, an inscription says that many dynasties rebuilt the Wall. The present Great Wall was rebuilt during the Ming dynasty on ancient foundations.

But there are myths about the wall. For example, when US president Nixon visited China in 1972, the ***New York Times*** said that its construction began in 221 BCE, took 15 years and employed 10 lakh people. Others said that the wall is the only manmade structure visible from space. The traditional Chinese perception has been that the Great Wall was the border between the Chinese civilization and the barbarian Huns, Turks and Mongols who invaded it.

Unfortunately evidence is lacking for these statements. When Nixon visited, the ***New York Times*** said the length of the wall was 4000 kilometres. ***Time*** magazine said it was 2500 km. In 1979 the Chinese news agency said there were 40000 kilometres of wall.

The first myth is that there is **one** Great Wall. Walls were built by the Ch'in dynasty around 220 BCE, the Han dynasty (200 BCE to 200 CE), the Ch'i dynasty about 550 CE, the Sui dynasty around 600 CE and the Ming dynasty (1400 to 1600 CE). So the question is, why did they all build walls?

It does seem to have been "national security policy" of the agricultural Chinese civilization against nomadic people coming from the steppes to the North and Northwest, to build walls. This policy was followed by the dynasties above, but was not followed by other dynasties. The simplest statement which can be made is that the earlier dynasties did build and rebuild walls, and most of these walls no longer exist. What we have now are the walls built by the Ming dynasty (and later) which have survived until today.

When the Ming defeated the Mongol Yuans, the problem was not to throw them out of the Wall, because the Wall did not exist. The problem was for the Ming to decide where their rule would end. As a concrete formulation of their decision they built walls.

The national security policy of the Ming centred around the dustlands of the Ordos, which they repeatedly considered occupying, but never did. The Ordos desert is where the Yellow river (Hwang Ho) makes a great bend, turning from going Northeast to going Southeast. It then turns again from going Southeast to going Southwest. This region has very little rainfall and is a desert. Yet, because of the river, irrigation is possible and there were Chinese settlements there.

These settlements could not be sustained. All through its existence the Ming dynasty fought battles with the Mongols. At times they had control over the Ordos, at times it was the Mongols. Unfortunately the Ming did not have an army which they could afford to be stationed there all the time.

But these settlements had strategic importance for the Chinese empire. So the question was, how to take over this region, and prevent the Mongols from reclaiming it if there were not many Chinese troops there. The solution was not to fight the Mongols, but to try and exclude them by more and more ambitious wall-building. Of course this was costly, and in the end it proved futile. But this is true of many policies of "national security", which turn out to be only about politics.

It was when the Europeans came to China in the 16th and 17th centuries that the reputation of the Wall began to build up. For example, the Jesuit priest Martino Martini published an atlas of China in 1665.

He described the Wall as built entirely of stone and continuous over mountains, with a few breaks for rivers. Father Athanasius Kircher also wrote about China. He had pictures of the Wall as well. Thus they generalized from what they had seen to something running over thousands of kilometres. Ferdinand Verbiest said, "The seven wonders of the world are not comparable to this work... [as] I myself have seen." The French writer Voltaire never visited China, but described the Wall as a "great feat of engineering superior to the pyramids of Egypt ... by its immensity." Paintings such as the one you see by W. Alexander from a sketch by H.W. Parish gave an impression justifying these words.

It was much later that the Chinese themselves started using the wall for mythmaking. The 20th century premiers Sun Yat Sen and Mao Tse Tung both extolled the Wall as a symbol of the Chinese people. Meanwhile hundreds of kilometres of the real walls were being destroyed, with the material being used for constructing roads, reservoirs and buildings.

In 1971 China replaced Taiwan as a member of the Security Council of the United Nations, largely because it conducted tests of atomic weapons, which made it a nuclear power. In 1972 US president Nixon visited the country. Now China was keen to project 5000 years of unified Chinese culture, and the Wall became a symbol which could be shown to visitors. The Forbidden City (the palaces of the Ming emperors) were thrown open as tourist attractions, both for the Chinese themselves and for outsiders. In 1984 premier Deng Xiao Ping started arguing for restoration and rebuilding of the Wall. Today it is a major tourist attraction of China. The picture shows a section of the wall in Mutianyu near Beijing.

Based on *The great wall of China* by
Arthur Waldron

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Publisher
C.S.Venkateswaran
TNSF, Chennai 600 086

Typeset at
Fineline

Design, Illustrations and Layout
Basheer
Rajeswari

Printed at
Print Specialities,
186, V.M.St, Royapettah,
Chennai - 600 014.

Bank Details

Jantar Mantar, Indian Overseas Bank, Dr. RK Salai Branch, Chennai - 600004
AC No: 029101000031081 IFSC Code: IOBA0000291

"No, I said my name is Dr. Gofman. G as in glucose, O as in ornithine, F as in Ferritin, M as in Methionine, A as in acetlycholinesterase, N as in nitrogen."

Jantar Mantar Children's Science Observatory, Bimonthly, published by C.S.Venkateswaran on behalf of Tamilnadu Science Forum, and Printed by S.Vaidyanathan at Print Specialities, 186, VM street, Royapettah, Chennai 600 014.
Published from 130/3, Avvai Shanmugam Salai, Gopalapuram, Chennai - 600 086

Editor: D.Indumathi