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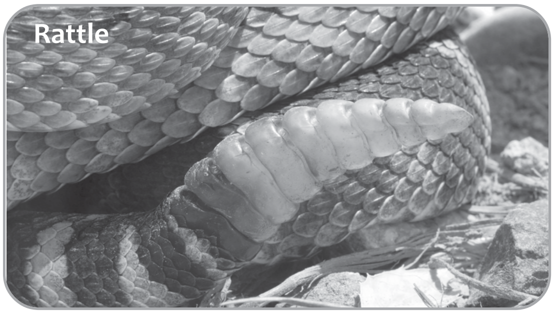
Animal tails

S.Narayani



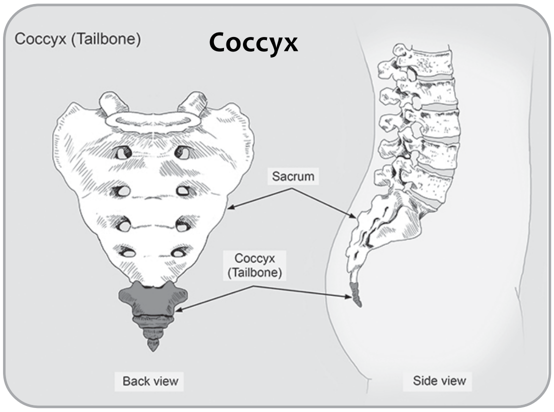
We are all familiar with how dogs use tails.... they wag them when they are happy, they tuck their tails in-between their legs when they are threatened and they always use their tails as communication tools. Tails evolved about 500 million years ago, and they serve a variety of purposes in animals.

What about humans?

Human beings belong to a group called great apes, which includes chimpanzees, gorillas and orangutans. Great apes do not have tails. The lesser apes like gibbons lack tails too.

It is commonly said that walking upright is the main reason human beings do not have tails. But what about these apes? They dwell in the trees, so it seems that having tails must be a necessity. Yet, these apes do not have tails.

Biologists say that for Gibbons, as they swing along from tree to tree, the trunk and legs hang below, giving them an upright posture. A tail will actually be a nuisance, they explain. Gibbons are also known to walk with two feet in an upright position, reducing the need for tails even further. The bone structures of the back and hip in the apes are more suited for walking in an upright position, so the tail becomes unnecessary.



Even humans do have tails, till about 35 days of the gestation period in the mother's womb, after which the tail becomes shorter and shorter and is represented by four fused vertebrae. This is called coccyx or "tail bone". We should be glad that we do not have tails... Imagine riding a motorbike or even a bicycle with a giant tail!

Tailing... sorry! Trailing back to the animal kingdom, a tail is used for a variety of purposes by various animal species.

Locomotion

A majority of animals use tails for

locomotion. Birds use their tail feathers for maneuverability. Fishes use their tail fins to steer themselves in the water. In fact, in marine research, a lot can be said about the type of fish, its preferred habitat and the speed of swimming by just looking at the tail fin and its proportions!

Social signaling

Dogs and cats use their tails for communicating their feelings. Cats wag their tails when they are unhappy, dogs wag their tails when they are happy. The rattlesnake, a type of venomous snake common in the American continents, is known to use the rattle at the end of its tail as a warning to predators. The "rattle" is made up of hollow, interlocked segments of keratin, which vibrate against each other to produce this chilling sound. Hippopotamuses and river otters use their tails to spread their wastes for marking territory. Many male birds, including peacocks, pheasants, ribbon tailed atrapia, racket tailed drongo and birds of paradise use their brilliantly coloured grand tail feathers during courtship rituals to attract females.


Bird of Paradise

Swatting

We have seen cows use their tails to ward of flies and other insects. A lot of mammals with long tails use their tails to swat the flies and insects that come near them.

Protection and Hunting

Scorpions have their stinger at the end of the tail, which is used to paralyze the prey. Animals living in extremely cold habitats use their furry tails as protection around the cold. They wrap themselves in their tails while sleeping. Thresher sharks have tail fins that are as long as their body. They use their tail fins to stun and startle prey fish, which are then hunted easily by the shark. Geckos or house lizards use the tail to escape from their predators. If the predator has caught the tail...they can cut off from their tails and escape, leaving a confused predator!

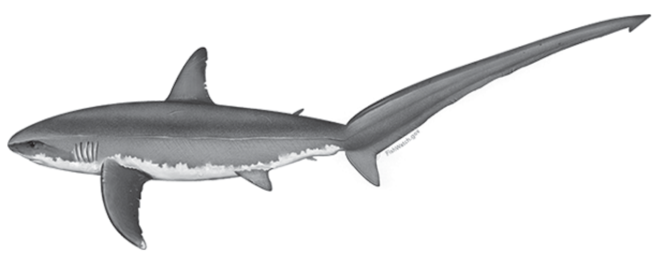
Balance

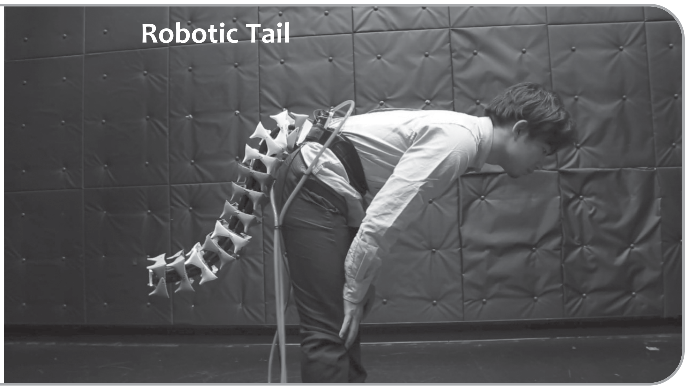
Animals like cats, kangaroos, dinosaurs and birds use the tail for balance. Keio University of Japan has developed a robotic tail for humans for the same purpose! This biomimetic tail based on the tail of a seahorse can be attached to the human body and can be used for balancing oneself!

Prehensile tails

A prehensile tail is adapted to grasp or hold objects. All monkey tails are

Thresher Shark

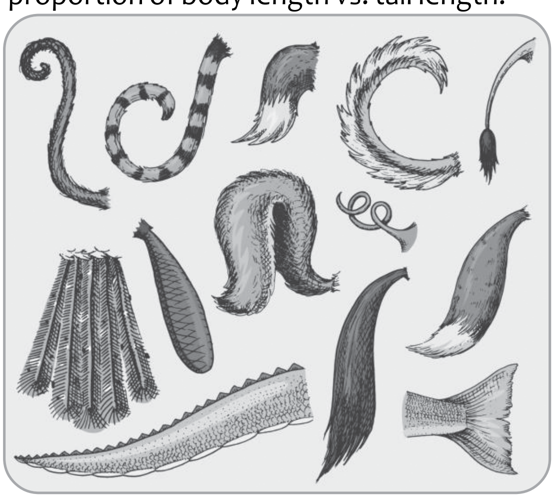




prehensile, and they are used to hold on to the branches of trees. Chameleons have prehensile tails, which are used for additional support. Many other animals like anteaters, opossums, pangolins and binturongs have prehensile tails. Seahorses and pipe fishes have prehensile tails, which they use to hold on to seaweeds or sea grasses. Snakes have prehensile tails too, which is not surprising since their whole body is prehensile!

Champions

We also have to talk about longest tails in the animal kingdom. Among mammals, giraffes have the longest tails, about 8 feet long! But we also have to think about the proportion of body length vs. tail length.



The Long tailed widowbird (male) has a tail which is almost four times the length of its body. But only the males have such long tails. The females have normal tails. The Asian Grass lizard with the 25 centimeter tail takes the world record! Its tail is almost three times as long as its body!

It is hard to imagine the animal kingdom without tails... even harder to imagine human beings having tails. The loss of a tail in a tadpole marks the beginning of its journey as a frog. A tailless lizard is a survivor, having escaped from a predator. Tails receive a lot of negativity in the English language...denoting the end of things, but for biologists, tails are where a lot of interesting tales begin!

Oxygen Cellular Sensing and Nobel 2019

Zareena, Mookayi and Mari

The three came rushing into the house excitedly: "Amma, you should have come! The talk was fantastic and you would have liked it". Usha sniffled, coughed and looked up to see her daughter Mari and her two friends Zareena and Mookayi. She was feeling a bit sick, dull and breathless but these three proved like a supply of fresh oxygen to her. She smiled and said "Alright. So what is all this about?"

The three said at the same time, "You were sleeping so we three went to the talk by Dr. Priya, a scientist working on Cancer research. She talked about the Nobel Prize in Medicine or Physiology for 2019". Usha asked them to sit down and speak one at a time.

Zar and Mooks sit and start telling what happened. "I will go to the kitchen and get something to eat and drink for all of us. Make sure you tell things correctly," said Mari.

Zar and Mooks looked at each other and sat down to tell Usha about what they learnt at the talk arranged by Tamil Nadu Science Forum as part of their popular science lecture series.

Zar: "Amma, you know the 2019 Nobel Prize in Medicine was awarded jointly to … what are their names, I don't remember now."

Mari shouted from the kitchen: "**William G. Kaelin, Jr., Sir Peter J. Ratcliffe** and **Gregg L. Semenza**."

Zar pouted and mumbled, "I was just going to say that, Miss Know It All."

"Now don't start fighting. Each of you tell me what you followed and remember," said Usha firmly.

Mooks immediately said: "They got the award for their discoveries of how cells sense and adapt to oxygen availability."

Zar went on: "They identified **molecular machinery** that regulates the activity of genes in response to varying levels of oxygen."

Mooks carried on: "Animals need oxygen for the conversion of food into useful energy. The fundamental importance of oxygen was understood for centuries. However, how cells adapt to changes in levels of oxygen came to be known because of the work of these three."

Mari came in carrying a tray with snacks and hot cups of tea. She added, "In 1931, **Otto Warburg** got the Nobel Prize in the same category for his work on sea urchins and other organisms at an early stage of development – he showed that the process of how cells utilise oxygen involves chemical reactions using enzymes."

Zar quickly added, "During evolution, mechanisms developed to ensure a sufficient supply of oxygen to tissues and cells."

Mari smugly put in, "The 1938 Nobel Prize was given to **Corneille Heymans** for discoveries showing how blood oxygen is sensed by something called the *carotid body*. This controls our respiratory rate by communicating directly with the brain."

Mooks said, "Yes. Dr. Priya mentioned that the carotid body is adjacent to large blood vessels on both sides of the neck. It contains specialized cells that sense the blood's oxygen levels and provide signals that increase or decrease our breathing rate."

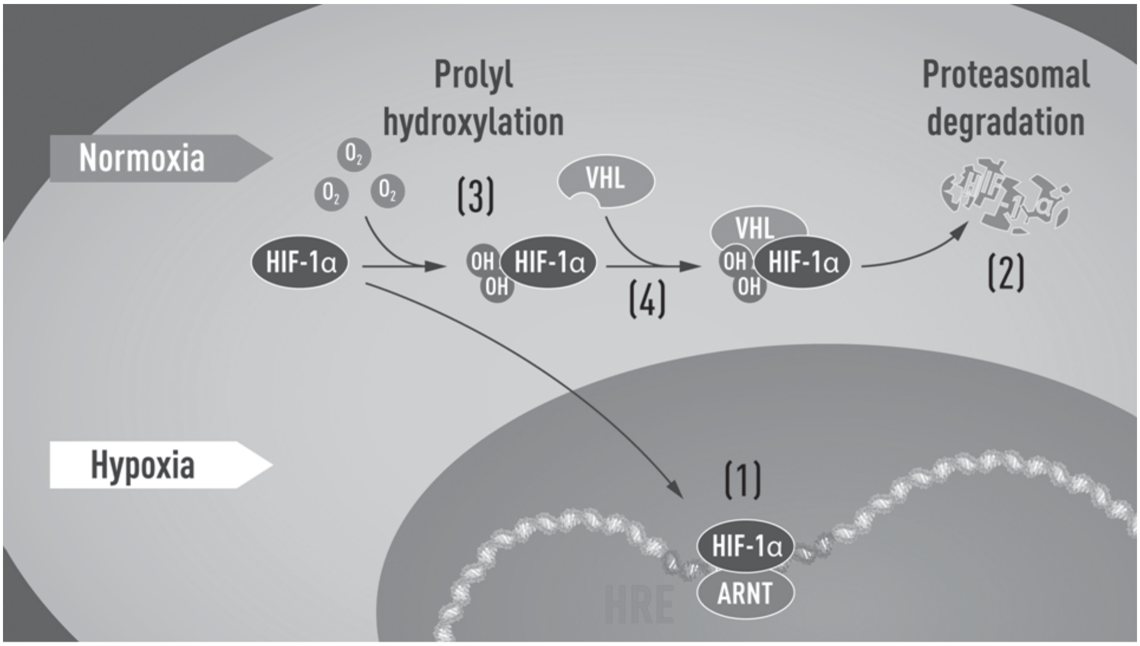
Mari added, "She said that the controlled rapid adaptation to low oxygen levels is called **hypoxia**. But there are other fundamental physiological adaptations. (Physiological means relating to the way the bodily parts function). One key response to hypoxia is the rise in levels of the hormone *erythropoietin*, which leads to increased production of red blood cells."

Zar loudly said, "Yes, after all, it is the red blood cells that carry oxyygen in the blood. Also, Dr. Priya called the hormone erythropoietin as *EPO* and the production of red blood cells as *erythropoiesis*. She also said the importance of hormonal control of erythropoiesis was already known at the beginning of the 20th century, but how this process was itself controlled by oxygen remained a mystery till the work done since the 1990s by Semenza, Ratcliffe and Kaelin".

After an amused glance from Usha, Zar continued in a

What is the EPO gene?

A gene is a unit of DNA that is usually located on a chromosome in the nucleus of cells. It controls the development of one or more traits or behaviour of the individual. It is the basic unit by which genetic information is passed from parent to offspring. In particular, the EPO gene produces the active EPO protein or hormone. This protein is mainly synthesized in the kidney, and is then secreted into the blood plasma. It binds to the erythropoietin receptor to promote red blood cell production, or erythropoiesis, in the bone marrow.



From https://www.nobelprize.org/prizes/medicine/2019/press-release

normal voice, "Gregg Semenza studied the EPO gene which instructs the cells to make EPO. He discovered how it is regulated when the oxygen levels vary. He used gene-modified mice, and looked at specific DNA segments located next to the EPO gene which he showed were responsible for the response to hypoxia."

Mooks went on, "Peter Ratcliffe also studied oxygen-dependent regulation of the EPO gene, and both research groups found that the oxygen sensing mechanism was present in almost all tissues, not only in the kidney cells where EPO is normally produced."

Mari smoothly said, "These findings showed that the mechanism was general and functional in many different cell types. So more researchers got interested in identifying the molecules involved in this process."

Zar continued, "The segment of DNA next to the EPO gene that Semenza discovered is now known as the *hypoxia response element* or **HRE**. He used cultured liver cells to discover a protein complex that binds to the HRE. He called this protein complex as the *hypoxia-inducible factor* (**HIF**) since it is involved in the response to hypoxia. It took a lot of effort to purify this protein complex, as well as discover the genes that code for HIF. They found there are two proteins, one whose level changed depending on oxygen levels which they called HIF-1α and another which was present all the time which they called HIF-1β".

Mari put in, "Yes, but it turned out that HIF-1β had been previously cloned and described by another group. Also since its level was not oxygen-sensitive, it became

How does VHL help to label proteins?

This has a complicated answer. If you are curious, and know some biology just beyond school level, read more details of Ratcliffe and Kaelin's work given in this box.

VHL refers to the protein coded by the tumour suppressing gene in von Hippel-Lindau or VHL disease. It is a genetic disease which leads to dramatically increased risk of certain cancers in families with inherited VHL mutations. Kaelin showed that the VHL gene encodes a protein that prevents the onset of cancer. Kaelin also showed that cancer cells lacking a functional VHL gene express abnormally high levels of hypoxia-regulated genes. However, when the VHL gene was re-introduced into cancer cells, normal levels were restored! This was an important clue showing that VHL was somehow involved in controlling responses to hypoxia.

Additional clues came from several research groups showing that VHL is part of a complex that labels proteins with ubiquitin, marking them for degradation in the proteasome.

Ratcliffe and his research group demonstrated that VHL can physically interact with HIF-1α and is required for its degradation at normal oxygen levels. This conclusively linked VHL to HIF-1α.

In 2001, Kaelin and Ratcliffe simultaneously published articles showing that under normal oxygen levels, oxygen sensitive enzymes add hydroxyl groups at two specific sites in the HIF-1α. This protein modification, called prolyl hydroxylation, allows VHL to recognize and bind to HIF-1α and explained how normal oxygen levels control rapid HIF-1α degradation with the help of oxygen-sensitive enzymes.

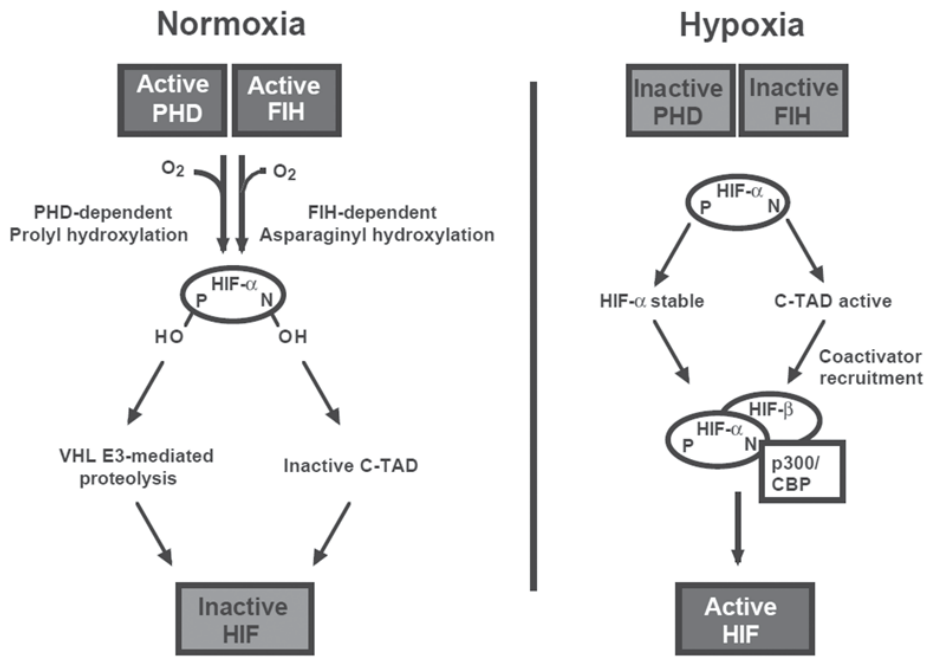
There is another control that acts like a brake on those HIF-1α proteins that escape the degradation when oxygen levels are normal. The protein HIF-1α is a transcription factor meaning it binds to regions that control the expression of hypoxia inducible genes such erythropoietin. See the figure. Semenza and his group identified a protein called *Factor Inhibiting HIF* or **FIH** that helps to add hydroxyl to a region of HIF-1α. This prevents the binding of proteins to HIF-1α. Now the HIF-1α protein though not degraded cannot still perform its transcription action and enhance gene expression of its targets.

clear that HIF-1α was the regulator of oxygen responsiveness in the HIF complex."

Mooks was meanwhile fiddling with her mobile and showed to Usha a picture of a figure in a slide from the talk saying, "When oxygen levels are high, cells contain very little HIF-1α. They are degraded quickly but then people did not know how it happened. However, when oxygen levels are low, the amount of HIF-1α increases so that it can bind to and thus regulate the EPO gene as well as other genes with HRE DNA segments. Amma, see the bottom part of the figure."

Mooks piped in, "The key role of HIF-1α had been shown by several research groups. While it is normally rapidly degraded, it is protected from degradation during hypoxia or low oxygen levels. At normal oxygen levels (called **normoxia**), a molecular machine in the cell called the *proteasome*, degrades HIF-1α .

Mari added, "The way in which proteins are degraded is also very unique. Proteins



Masson and Ratcliffe in Journal of Cell Science vol 116 pages 3041-3049 year 2003

that are to be degraded are modified by attaching to them a small peptide called *ubiquitin*. It's like a name tag: any protein with this label is destined for degradation in the proteasome."

Zar proudly added, "In 2004, the Nobel Prize in Chemistry was given to **Aaron Ciechanover, Avram Hershko** and **Irwin Rose**, for identifying the mechanism of how proteasome degrades proteins."

Mari piped in, "So HIF-1α activity has not one, but two independent mechanisms for oxygen dependent activity inhibition. This just shows that keeping HIF-1α levels properly and exactly regulated by cellular oxygen levels is necessarily a very finely tuned process."

Usha suppressed a smile and said, "All interesting. But why should they give the Nobel Prize now under Medicine or Physiology almost two decades after the discoveries?"

Zar exclaimed, "Of course, oxygen level control is so important at the cellular level for many diseases and physiological states. For example, kidney diseases can disrupt the process of red blood cell generation leading to anaemia. A number of potential drugs that increase HIF function by inhibiting the PHD enzymes are already far along in clinical trials, with a recent series of publications from a Chinese group demonstrating their clinical efficacy in treatment of anaemia. Future applications to inhibit the HIF pathway are also on the horizon. These are likely a way to slow the progression of some cancers that are induced by VHL mutations."

Mari had to have the last word

and said, “Increasing HIF function using drugs may help in the treatment of a wide range of diseases, as HIF has been shown to be essential for phenomena as diverse as immune function, cartilage formation, and wound healing. Inhibition of HIF function could also have many applications: increased levels of HIF are seen in many cancers as well as in some cardiovascular diseases, including stroke, heart attack, and pulmonary hypertension. It is likely that we are only at the beginning of applications of these Nobel Prize-winning discoveries, since the response to oxygen in cells, tissues and organisms is one of the most central and important physiological adaptations of animals.”

But Usha with a twinkle in her eye posed the question, “So what happens in plants and bacteria – do they not need mechanisms to respond to oxygen levels?”

Mari, Mookayi and Zareena looked stumped and looked at each other thinking “No one asked this question in the talk. Why?”

References:

1. https://www.nobelprize.org/prizes/medicine/2019/press-release

2. Masson and Ratcliffe in Journal of Cell Science vol 116 pages 3041-3049 year 2003 ●

Maths is fun(ny)!

1. Why should you never talk to Pi?

Because he’ll go on and on and on forever.

2. How do you stay warm in any room?

Just huddle in the corner, where it’s always 90 degrees.

3. Did you hear about the statistician who drowned crossing the river which he said was only three feet deep?

It was three feet deep on average.

4. Why was the math lecture so long?

The professor kept going off on a tangent.

5. What kind of snake does your math teacher probably own?

A pi-thon.

6. What’s the best place to do math homework?

On a multiplication table.

7. How do you get from point A to point B?

Just take an x-y plane or a rhom’bus.

8. What happens when you hire an odd-job guy to do 8 jobs?

They only do 1, 3, 5 and 7.

From: https://thoughtcatalog.com/

Story of the world's most powerful battery

Lithium and its ion

Lithium is a metal. It has just one electron in its outer electron shell. It is easy to remove this electron, leaving a positively charged lithium ion which is more stable than the atom. The ion forms salts; in fact, pure lithium has a tendency to catch fire and so must be stored in oil so it does not react with air. Lithium's weakness – its reactivity – is also its strength. In the early 1970s, **Stanley Whittingham** used lithium's enormous drive to release its outer electron when he developed the first functional lithium battery. In 1980, **John Goodenough** doubled the battery's potential, creating the right conditions for a vastly more powerful and useful battery. In 1985, **Akira Yoshino** succeeded in eliminating pure lithium from the battery, instead basing it wholly on lithium ions, which are safer than pure lithium. This made the battery workable in practice. Lithium-ion batteries have brought the greatest benefit to humankind, as they have enabled the development of laptop computers, mobile phones, electric vehicles and the storage of energy generated by solar and wind power. Ultimately this fetched them the ***Chemistry Nobel*** prize in Nov, 2019. How did they achieve all this?

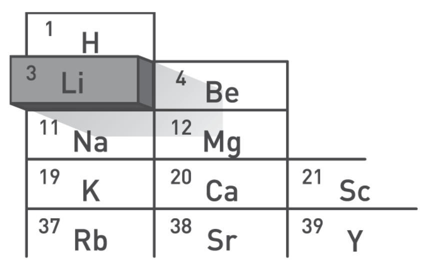
Did you know?

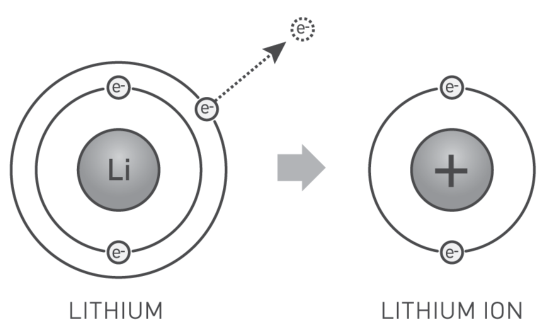
In the mid-20th century, there were really only two types of rechargeable batteries: the heavy lead battery that had been invented 100 years earlier in 1859 (and which is still used as a starter battery in petrol-driven cars) and the nickel-cadmium battery that was developed in the first half of the 20th century.

How to catch an ion

Whittingham was from Stanford University. He was working on solid materials with atom-sized spaces in which charged ions can attach. This phenomenon is called intercalation. The materials' properties change when ions are caught inside them. Whittingham added potassium ions to tantalum disulphide, which is a superconductor.

He observed that it had a very high energy density. The interactions that arose between the potassium ions and the tantalum disulphide were surprisingly energy rich and, when he measured the material's voltage, it was a couple of volts. This was better than





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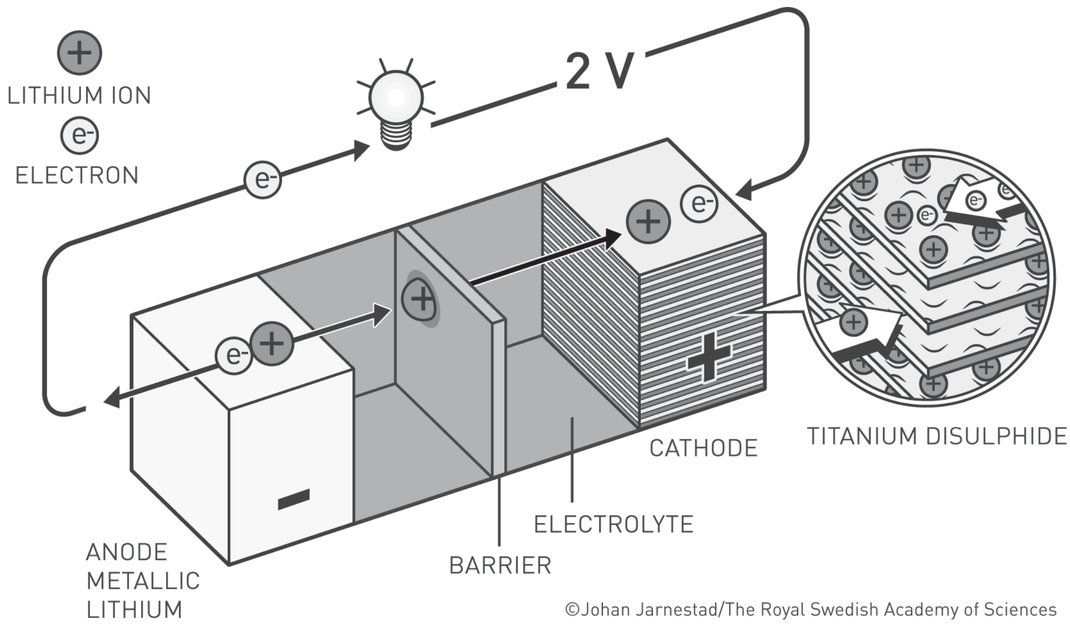


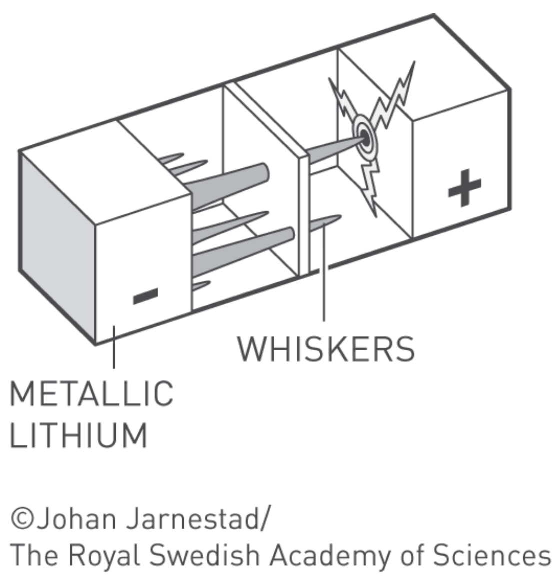
many of that time's batteries. Stanley Whittingham quickly realised that he could develop new technology that could store energy for the electric vehicles of the future. However, tantalum is one of the heavier elements and the market did not need to be laden with more heavy batteries – so he replaced tantalum with titanium, an element which has similar properties but is much lighter.

Where is the Lithium?

To have a battery, you need both positive and negative electrodes (cathodes and anodes) and lithium was a good choice of anode. That's because of its ability to give away its valence electron. The result was a rechargeable lithium battery that worked at room temperature and – literally – had great potential.

The first set-back

Unfortunately, there was a hitch: as the new lithium battery was repeatedly charged, thin whiskers of lithium grew from the lithium electrode. When they reached the other electrode, the battery short-circuited which could lead to an explosion. The fire brigade had to put out a number of fires and finally threatened to make the laboratory pay for the



special chemicals used to extinguish lithium fires.

To make the battery safer, aluminium was added to the metallic lithium electrode and the electrolyte between the electrodes was changed. Stanley Whittingham announced his discovery in 1976 and the battery began to be produced on a small scale for a Swiss clockmaker that wanted to use it in solar-powered timepieces.

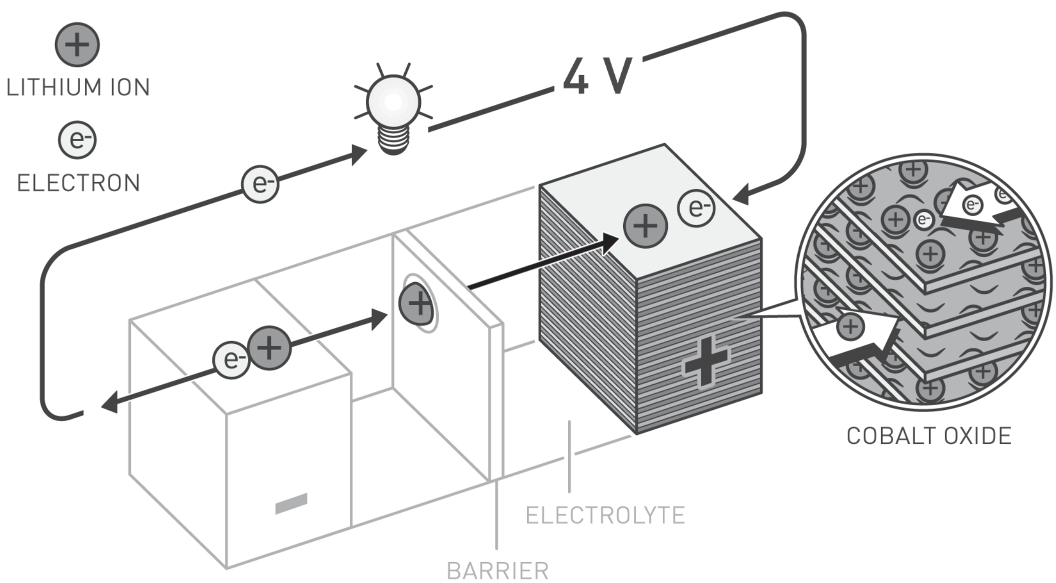
Enter Goodenough

John Goodenough knew about Whittingham's revolutionary battery, and he was an inorganic chemist. His specialised knowledge told him that its cathode could have a higher potential if it was built using a metal oxide instead of a metal sulphide. His research group began to search for a suitable oxide and they were successful. Whittingham's battery generated more than two volts, but Goodenough discovered that the battery with a cathode made of lithium cobalt oxide was almost twice as powerful, at four volts.

How did they achieve this? An old-style battery is already charged when bought in the store. But Goodenough realised that batteries did not have to be manufactured in their charged state. Instead, they could be charged afterwards. (Sounds familiar today?!) In 1980, he published the discovery of this new, energy-dense cathode material which, despite its low weight, resulted in powerful, high-capacity batteries. This was a decisive step towards the wireless revolution.

Japan and the electronic revolution

Japanese companies were looking for lightweight, rechargeable batteries that could power innovative electronics, such as video cameras, cordless telephones and computers. One person who saw this need was Akira Yoshino from the Asahi Kasei Corporation. While Goodenough's lithium-cobalt oxide as the cathode was fine, Yoshino tried to further decrease the weight of the battery by using various carbon-based materials as the anode.



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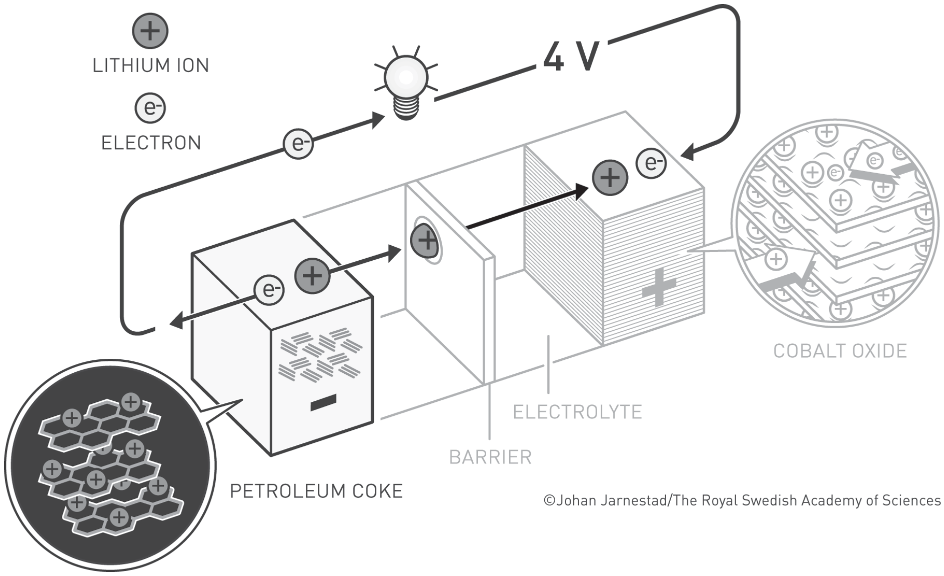


Changing the anode

Researchers had previously shown that lithium ions could be intercalated in the molecular layers in graphite, but the graphite was broken down by the battery's electrolyte. Akira Yoshino tried using petroleum coke, a by-product of the oil industry. When he charged the petroleum coke with electrons, the lithium ions were drawn into the material. Then, when he turned on the battery, the electrons and lithium ions flowed towards the cobalt oxide in the cathode, which has a much higher potential. So the lithium ions move back and forth between the two electrodes, which gives the battery a long life.

The battery developed by Akira Yoshino is stable, lightweight, has a high capacity and produces a remarkable four volts. The greatest advantage of the lithium-ion battery is that the ions are intercalated in the electrodes. Most other batteries are based on chemical reactions in which the electrodes are slowly but surely changed.

When a lithium-ion battery is charged or used, the ions flow between the electrodes without reacting with their surroundings. This means the battery has a long life and can be charged hundreds of times before its performance deteriorates. Another big advantage is that the battery has no pure lithium, which is important for safety.

Like almost everything else, the production of lithium-ion batteries has an impact on the environment, but there are also huge environmental benefits. The battery has enabled the development of cleaner energy technologies and electric vehicles, thus contributing to reduced emissions of greenhouse gases and particulates. Through their work, John Goodenough, Stanley Whittingham and Akira Yoshino have created the right conditions for a wireless and fossil fuel-free society, and so brought the greatest benefit to humankind.

Source:
Nobel Prize Foundation website:
www.nobel.org

Ujwal K Santhosh,
Madras Christian College, Chennai

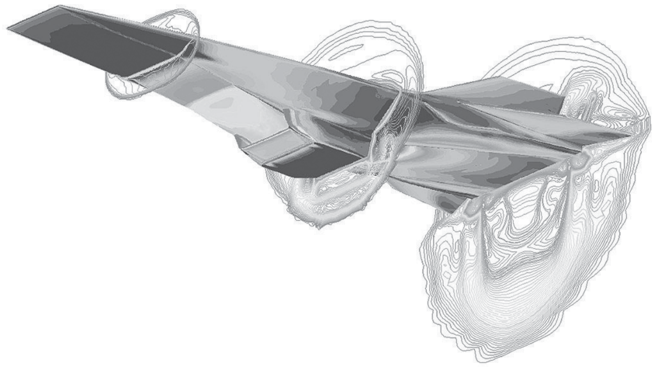
What do we mean when we say that something is moving at hypersonic speed? A hypersonic speed implies that an object is travelling at a very high speed. A quick aside before we start: We're going to be thinking about objects moving at high speeds through gases and also flow at high speeds moving past stationary objects.

The experiments revolving around hypersonics are conducted in a *wind tunnel*. Inside this tunnel, we usually hold the object stationary and move the air around it. Say you're on the ground on a calm day and you look up and see a jet aircraft flying past. We'll ignore any wind for now. You see the plane moving through stationary air at high speed. Now imagine that you're in that aircraft, now you feel like you're stationary and the air moving past you at high speed. It's the speed of the air relative to the aircraft that is important. So we can **simulate** the flow around an object in a wind tunnel by blowing air past a stationary model.

So back to our topic — **hypersonics**: The "sonic" part of hypersonic refers to the speed of sound. So a hypersonic speed implies an object is travelling at many times the speed of sound. You have probably heard of Mach number, named after the famous Austrian physicist, Ernst Mach. The Mach number indicates how many times the speed of sound an object is moving. Therefore, the Mach number M is the speed of the object divided by the speed of sound. So an object travelling at half the speed of sound would have a Mach number of 0.5 – and an object travelling at twice the speed of sound would have a Mach number of 2. An object travelling at ten times the speed of sound would have a Mach number of 10. The Mach number is an important parameter that helps us distinguish between different types of flow where various phenomena occur.

When an object is travelling at a speed that is low relative to the speed of sound, the fluid ahead of the object can receive information that the object is approaching. We talk about objects that travel at speeds less than the speed of sound as being travelling at **subsonic** speeds. Subsonic refers to Mach numbers from 0 to just under 1.

If an object is travelling at a speed that's higher than the speed of sound, we say that it's travelling at a supersonic speed. So anything travelling at a Mach number higher than 1 is referred to as supersonic. There are some important differences between subsonic and supersonic flows. Some strange results occur when the flow speed is more than the speed of sound - and some of these seem counterintuitive from our experience with low-



speed flows. And it is in supersonic flows that we find **shock waves**.

So we have subsonic and supersonic speeds - what about hypersonic?

Hypersonic speed implies that an object was travelling at many times the speed of sound. So you might be thinking, surely that means it is supersonic — if it is travelling at many times the speed of sound then it is travelling at more than Mach 1, so it's supersonic. And you would be right in thinking that — but you don't get any marks for that just yet.

So what is the hype about hypersonic? Well, there are some important things that occur when the Mach number gets high — for one thing, the temperature can get very high. If the temperature gets high, then we start getting changes occurring in the chemistry of the gas. For air, we start dissociating the oxygen molecules into oxygen atoms. And at higher temperatures start dissociating the nitrogen molecules into nitrogen atoms. This takes some energy out of the gas and changes the properties of the gas.

So, how fast does something have to be travelling before these sorts of effects become important and we start calling the flow hypersonic?

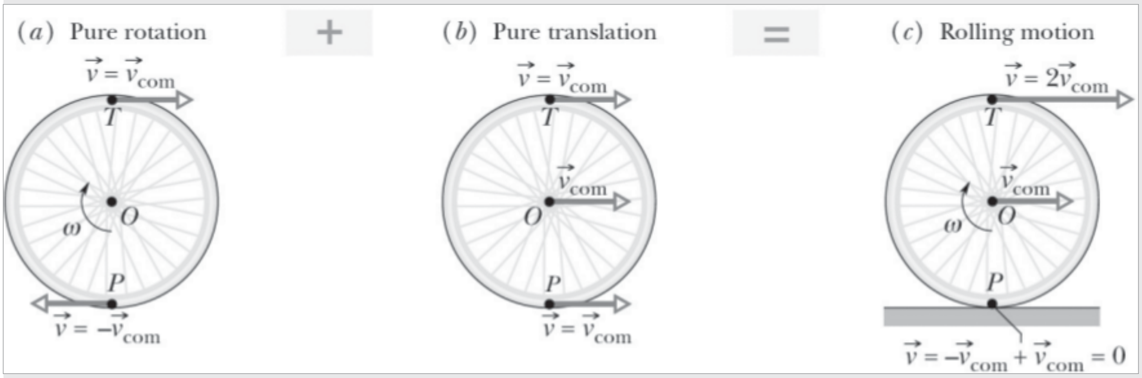
There is no distinct border between supersonic and hypersonic flows — but we usually set the demarcation at Mach 5 — five times the speed of sound. So anything travelling at faster than Mach 5 is referred to as travelling at hypersonic speed. It is at around this Mach number that the character of the flow is different enough from that at lower supersonic speeds that we need to start to look at it differently.

Because of the high temperatures, the density of the air (gas) through which the aircraft is travelling varies a lot. This gives rise to vortices and turbulence. See the figure that shows the air movement around the NASA-X43 hypersonic aircraft. The disturbance is much larger at the back of the aircraft.

In addition to all these, there is also the regime of speeds that we call **transonic**. Transonic is not as precisely defined as subsonic and supersonic flows. When an object is travelling at close to the speed of sound, there are usually regions around the object where the flow is subsonic and regions where it is supersonic. This is the transonic regime and it is usually taken to occur for Mach numbers between 0.8 and 1.2.

So the next time you see a jet crawling high up in the sky, know that it must be moving fast in Mach numbers.

Hypersonic planes like NASA's first experimental air-breathing space plane, the X-43A, use oxygen from the atmosphere as fuel. So they do not carry any oxygen, thus cutting down the weight they carry. Combustion occurs in the engine only at supersonic speeds because the air has to be flowing at a high rate to be compressed. Hydrogen fuel is injected into the air stream, and the expanding hot gases from combustion accelerate the exhaust air to create tremendous thrust, which allows the high speeds to be reached. But here is a peculiar feature. Since these planes do not carry oxygen aboard, they cannot lift off like conventional space-craft do. So the X-43A is strapped on to a booster rocket, which is carried into space by yet another aircraft! Typically, the aircraft releases the launch vehicle at a height of about 6,000 m. The photo shows the B-52 aircraft carrying the X-43A. The booster rocket then switches on and reaches a speed of Mach 5 or more and reaches a height of about 30,500 m (typical commercial aircraft fly at about 10,000 m). The photo shows the Pegasus rocket booster accelerating NASA's X-43A shortly after ignition during test flight (March 27, 2004). The X-43A separates from the booster rocket and flies on its own, using pre-programmed controls. The photo shows the X-43A being dropped from under the wing of a B-52. It usually lands back in an ocean. While NASA is building hypersonic aircraft with a view to send people to space, many countries including India are also building hypersonic missiles for war-time use. ●



Answer to last issue's Did You Know?

Suppose you have a solid cylinder of wood, and a hoop of iron, both of the same mass and same outer radius. Which of the two will be down first?

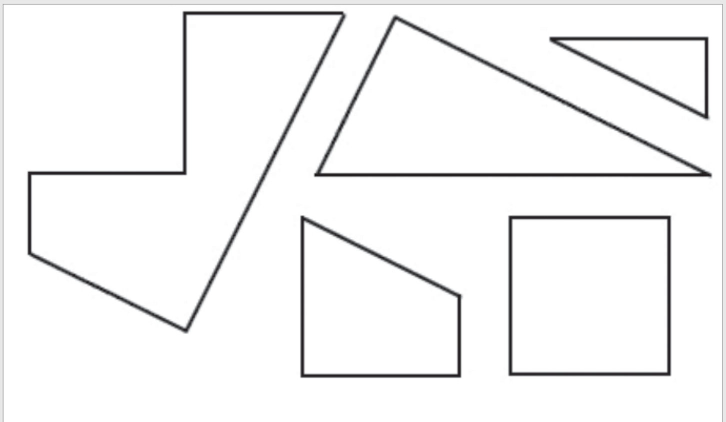
Ans: We learned in the last issue that a ball of wood and a ball of iron of the same size will reach the bottom at the same time when rolled down a slope. Now the question is about a solid versus a hollow cylinder. Both of them start from the top of the slope at rest, with the same potential energy due to their height *h*, given by *mgh*, where *m* is their (common) mass. As they come down the slope, they lose this energy, which is converted into different forms, according to the law of conservation of energy.

Both of them are rolling down the slope, so they have **rotational energy**. Both are moving downwards so they both have **translational energy** (technically, their centre of mass is moving down). Hence, the potential enery is going to get converted into translational and rotational energy. For an object to reach the bottom first, it must have *maximum speed*. To maximize the speed of an object, we must minimise the energy spent in rotation.

While they have the same translational energy, their rotational energy depends on their **moment of inertia**, which indicates how their mass is distributed with respect to their centre of mass. For objects where the mass is further away from the centre, such as in a hoop of iron, where all the mass is concentrated on the outside, the moment of inertia is large. The moment of inertia of a solid cylinder where the mass is uniformly distributed is much smaller. As the moment of inertia *decreases*, the energy in rotation *decreases*, so that more of the potential energy is converted into translational energy. Since the solid cylinder has more translational energy, it means that it moves faster and so reaches the bottom first.

If you also rolled a **sphere** along with the hoop and cylinder, you would find the sphere reaches even earlier than the cylinder. Of course, the fastest to reach the bottom would be a **solid block** (of any material, when friction is ignored) since it has no rotation at all and simply slides down to the bottom. ●

Make the shapes!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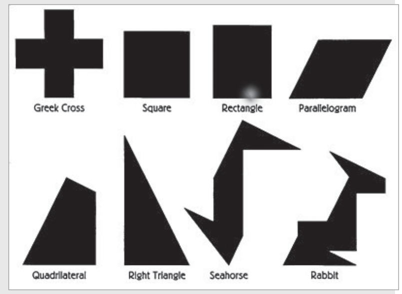
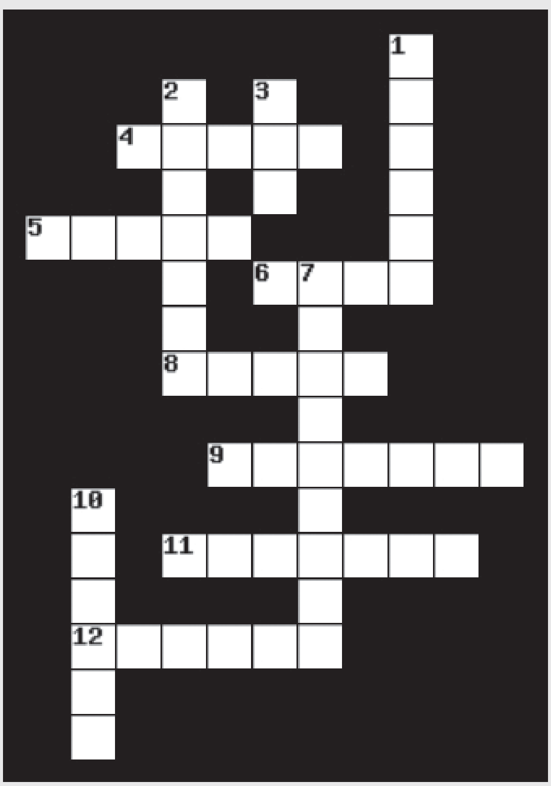


Print out the five shapes on a thick piece of paper and cut them out. Or print them out and stick them on cardboard to make them stiff. Put them together to make the shapes given below. Notice that none of the shapes repeat, so this is different from tangrams.

From: AIMS Education Foundation http://blog.aimsedu.org *Answers on page 35*



The Solar System Crossword

ACROSS

4. Although not the closest to the sun, this planet is the hottest because of a thick atmosphere of carbon dioxide.
5. This object is no longer considered to be a planet.
6. Its two satellites are named Phobos and Deimos (Fear and Panic).
8. You were born on this planet, hopefully.
9. The closest planet to the sun, it orbits the sun once every 88 days.
11. This planet is more massive than all of the others combined.
12. This planet's axis is so tilted that it orbits the sun on its side.

DOWN

1. Made mainly from ices and dust, these objects can form tails millions of kilometers long when they pass near the sun.
2. Named for the Roman god of the sea.
3. This object is at the center of the Solar System.
7. Chunks of rock, most of which are found between the orbits of Mars and Jupiter.
10. This planet possesses the Solar System's most impressive system of rings.

From https://education.jlab.org

Do You Know?

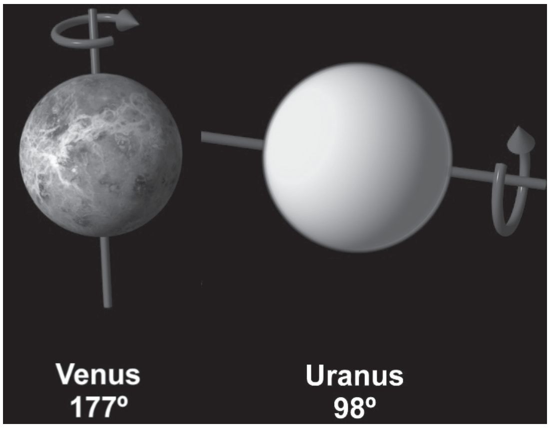
1. I love eating ice cream. Can i survive by just eating different flavours of ice cream (and nothing else)?
2. Why do clothes look darker when they get wet?
3. Can we genetically modify an animal so that it could live on another planet or on the moon?
4. Do fish feel pain?
5. How far do we travel through space every day?

Answers to last issue's Do You Know?

1. Does Venus really spin backwards?

Ans: Yes, Venus spins backwards compared to most of the other planets. It spins or rotates in the opposite direction that Earth rotates. This means that on Venus the Sun rises in the west and sets in the east. On Earth the Sun rises in the east and sets in the west. Venus also spins very slowly - only once every 243 Earth days. Venus is the slowest spinning planet in the Solar System. Actually, a day on Venus is longer than a year on Venus! A year on Venus (the time it takes for it to orbit the Sun) is 225 Earth days.

No one really knows why this is so. Also, for instance, Uranus' spin axis is tilted perpendicular to most of the other planets (its spin axis is in the plane of the solar system) and many other planets in the solar system have a variety of different spin axis angles (for example, Earth's spin axis is tilted about 23 degrees from the plane of the solar system). All these could be due to the same reason.



Another theory is that any planet has to conserve its total angular momentum, which is directly related to its net spin axis. The net spin axis is made up of the spin axis of its core (the iron part of the planet) plus its mantle (the rocky part of the planet) plus its atmosphere. Because Venus is believed to have a liquid core (like the Earth does) and it has a thick atmosphere, it's possible for friction forces to exchange angular momentum between the core and the mantle or between the atmosphere and the mantle. This can result in changing the spin axis of the mantle by changing the spin axes of the core and/or atmosphere. So it might be that interactions between the different layers of Venus have resulted in tilting the planet's mantle so that the mantle is spinning retrograde (or backwards). It's the mantle spin axis that we equate with the planet's spin axis since that is the part that we see rotating. In order for this theory to work, it helps that Venus is a slow rotator (a day on Venus is 117 Earth days!).

2. We forget so many things that we learn, but we never forget how to ride a bicycle. Why is this?

Ans: Most of us learn how to ride a bike during childhood. But as we grow older, many of us stop riding and put those once-beloved bikes in storage. Years later, when we discover these relics and hop on, it's as if we never stopped biking.

This is surprising because our memories let us down in so many other instances, such as remembering the name of a place or a person we once knew or where we put our keys. So how is it that we can ride a bicycle when we haven't done so in years?

As it turns out, different types of memories are stored in distinct regions of our brains.

Long-term memory is divided into two types: declarative and procedural

There are two types of declarative memory: Recollections of experiences such as the day we started school are called episodic memory. This type of recall is our interpretation of an episode or event that occurred. Factual knowledge, on the other hand, such as the capital of France, is part of semantic memory. These two types of declarative memory content have one thing in common—you are aware of the knowledge and can communicate the memories to others.

Skills such as playing an instrument or riding a bicycle are, however, anchored in a separate system, called procedural memory. As its name implies, this type of memory is responsible for performance.

One of the most famous studies showing the separate memory systems was that of an epileptic named Henry Gustav Molaison (aka H. M.). In the 1950s he underwent the removal of portions of his brain, including large parts of his hippocampus. After the operation doctors found that although the number of seizures had decreased, H. M. was unable to form new memories. Many of his memories of the time before the operation were also erased.

To learn more about his amnesia, neuropsychologists carried out various tests with H. M. In one, they asked him to trace a five-pointed star on a sheet of paper while only looking at it and his hand in a mirror—meaning the image was reversed. Although H. M.'s hand–eye coordination skills improved over the several days he performed this task, he never remembered performing it. This meant that he could develop new procedural, but not declarative, memories.

Is procedural knowledge then fundamentally more stable than explicit knowledge? As it turns out, the former is more resistant to both loss and trauma.

Even with traumatic brain injury the procedural memory system is hardly ever compromised. That's because the basal ganglia, structures responsible for processing nondeclarative memory, are relatively protected in the brain's center, below the cerebral cortex. However, it's not clear, beyond brain damage, why procedural memory contents are not as easily forgotten as declarative ones are. According to one idea, in the regions where movement patterns are anchored fewer new nerve cells may be formed in adults. Without this neurogenesis, or continuous remodeling in those regions, it's less likely for those memories to get erased.

One thing we know for sure, however, is simple sequences of movements we internalize, even far in the past, are typically preserved for a lifetime. Or as the saying goes, it's "just like riding a bicycle."

3. Smells seem to vanish after some time. Where do smells go?

Ans: If you are smelling something, you are inhaling gases, particles, or a combination of the two. They don't normally build up in the atmosphere because of three reasons: transport/dilution, chemistry, and deposition. Yes there is plenty of fresh air out there, but over billions of years there would be a lot of accumulation of odorous compounds if it weren't going somewhere. Though, stinky air

does get trapped near the ground sometimes during stagnation events, caused by a temperature inversion close to the surface which prevents mixing with the upper air. Atmospheric chemistry usually involves the hydroxyl radical (OH) in some way. Rapid chemical conversions of gases often depends on OH, which is cycling and replenished thanks to the abundance of oxygen and water vapor in the atmosphere. Many gaseous pollutants will go through a series of chemical reactions with OH, other chemicals, and/or sunlight. They are then converted to simpler chemicals that we don't really smell. Most odorous pollutants are chemically converted quickly (e.g. hours, days). Some pollutants do take years to convert (e.g. methane) and so accumulate in the atmosphere. We don't smell them, though, because our ability to "smell" things is limited to organic compounds and other molecules like hydrogen sulfide and ammonia.

4. Why are lemons yellow and limes green?

Ans: All citrus fruits are green while they are still growing on the tree. Lemons lose their green colour as they ripen because the chlorophyll pigment is replaced with a chemical called anthocyanin.

Many lime species would also turn yellow if you left them on the tree long enough, but they never get a chance. This is because ripe citrus fruits are too soft to travel well, so farmers always pick the fruits while they are green and under-ripe.

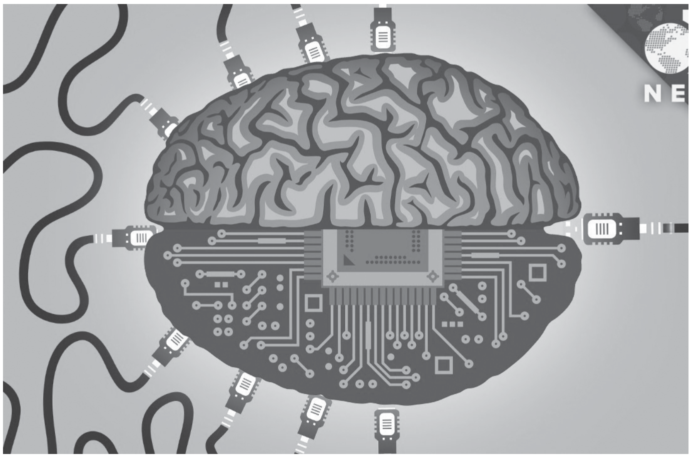
Oranges and lemons will continue to ripen on their way to the supermarket, but a quirk of biology means that limes stop ripening once they are picked.

5. When we start uploading our brains to computers, will our sense of self be uploaded too?

Ans: Our sense of self emerges from the activity of a poorly understood network of neurons, glial cells and blood vessels in the brain, which together produce the electrical and chemical processes that give us our thoughts and consciousness.

One day, it might be possible to scan all of this activity with perfect fidelity – this would be a hugely intensive process, involving recording the activity of every cell and chemical at an atomic level. This digital scan could be turned into a computer simulation, essentially allowing you to go on living after death. In theory, the simulated version of your brain would believe that its sense of self had been successfully uploaded, transferred from a biological body to an artificial one.

However, it's not quite as simple as that. If scientists can develop a way to perfectly scan the brain without destroying it (which isn't a given), then your original brain (and sense of self) would still exist, trapped in a body that



will eventually fail. Your digital self might come to the realisation that it's a copy, triggering an existential crisis.

And what if someone decides to make a hundred copies of this digital self? Now there are a hundred digital versions of 'you', each with its own sense of self. Is each of these selves equally valid? Does the second sense of self know that it's the original copy, and thus expect a higher status? Could the separate selves decide to share their experiences and become a super-intelligent 'hive mind'?

We don't yet know the answers, but one way to limit any potential complications might be to become immortal piece by piece. We naturally change as we age, so if you slowly replaced failing biological tissue with computerised prostheses, then by the time all of your body and brain had been replaced, your sense of self will have been transferred without leaving behind a biological remnant.

Just watch out for the delete key… a digital brain is much easier to wipe than an organic one!

—From many sources

Science News

R. Ramanujam,
The Institute of Mathematical Sciences, Chennai

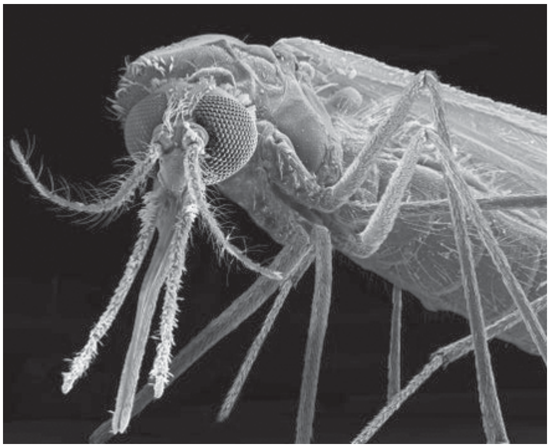
Headlines

- *Using smell to detect malaria*
- *How birds adjust to mountain climbers*
- *From tiny bacteria to the global carbon cycle*
- *A giant gas wave right next to us!*

Read more about these articles below.

Using smell to detect malaria

Scientists have known for some time that malaria parasites alter the odours of infected people (and other animal hosts). We know that the anopheles mosquito carries the malaria parasite. The theory is that the change in smell helps to attract mosquitoes that will carry them to new hosts. Recently scientists have tried to see whether this can be used as a tool to detect the presence of malaria parasites even among people who do NOT show symptoms of malaria. The answer is YES, they can!



This was a clinical study conducted in Kenya, with nearly 400 children under the age of 12. Medical researchers collected two kinds of samples from each of them: blood samples and odour—chemical samples (one from a foot and one from a forearm). How did they get the latter? They sealed the children's feet and arms in plastic bags, ran air through the bags and collected the chemicals from their odour on a filter.

They tested the blood samples for malaria using rapid diagnostic tests, microscopy and parasite DNA analysis. They used special techniques called mass spectrometry and gas chromatography to that separates the different odour chemicals by their mass or structure. They constructed patterns and used the created patterns of one-third of the children's samples to see if they could predict the malaria status of the other two thirds – only based on the odour chemicals.

They divided the children into three groups: uninfected (134), those that showed malaria symptoms (134) and those that did

not show symptoms (62). The "gas chromatogram" technique clearly showed that each of these three groups showed a different chemical pattern in the odour samples.

It turned out that the chemical patterns are very reliable as a diagnostic tool – using this model they were able to identify 95% of the children with malaria. In addition they also found that foot odour was a better indicator of malaria than arm odour.

This is an important line of research in dealing with a deadly disease like malaria. Many infected people who do not show symptoms do not seek treatment. Searching for parasite DNA is the best, but that is too expensive. So any sensitive method that does not involve the taking of blood samples is welcome.

How birds adjust to mountain climbers

Exploring the great outdoors is a wonderful way to connect with nature. However, as visitor numbers increase, they can harm the environment. In the western world, rock climbing is a recreational activity in which athletes climb up, down, and across natural rock formations. Despite the heights, climbers enjoy this peaceful experience in

nature. Lately, more and more people are visiting climbing destinations around the world.

The question is: does all this climbing affect the cliff environment adversely? Of course, human climbing cannot harm the rock. But cliffs provide habitat for many life forms. Cliff habitats are special, and some life forms can survive only there. Scientists have known for some time that climbing activity disturbs the nesting of birds of prey.

Recently some scientists decided to study how climbing impacts all the different birds living together on a cliff (known as a community). Studying the Flatiron Cliffs of Colorado in the USA, they selected 16 areas in with lots of climbing (more than 500 climbers per year), and 16 areas with not much climbing (less than 100 climbers per year). They looked at climbing sites facing different directions: north, south, east, and west (called "cliff aspect"). They sat 20 metres away from the cliff base, and watched a 30 metre wide section of the cliff, and the air space above. They noted how many birds they saw, what species and where the birds were. They also recorded whether there were climbers at the site (and how many). Each observation was 1-hour long and they conducted 5-6 observations at each of their 32 study sites. This took a lot of patience!

They used a mathematical model to calculate which things had the biggest influence on "avian diversity" (the number of different bird species on a cliff). They also calculated which things affected "avian abundance" (the number of birds on a cliff). They considered things like whether climbers were present, cliff height, cliff aspect, and how close the cliff was to roads.

They found that both bird diversity (that means the variety and type of birds) and abundance (their number) differed between east and west facing cliffs. Their results show that rock climbing does not much impact the number of birds, but it does reduce the diversity of birds on each cliff. It seems likely that some bird species put up with human activity well, and some do not; but this needs to be researched further.

However, this research does suggest opening up new routes for climbers where there is less diversity. Science based information for decision making is the best way to conserve our environment.

From tiny bacteria to the global carbon cycle

Do you know that the oceans teem with not only fish but also tiny photosynthetic microbes and bacteria? Scientists have wondered for long about how these microscopic life forms contribute to the oceanic carbon cycle (which explains how carbon is gained and lost from Earth and our environment). Recent research that combines insights and techniques from chemistry, biology and computer science offers hope for solving this mystery.

Carbon is the elemental building block for all living things. Over time, carbon moves through the land, air, and oceans in a process called the carbon cycle. For example, part of the carbon cycle happens when we breathe: animals exhale carbon dioxide into the air, and plants take in carbon dioxide from the air during photsynthesis.

Carbon moves into the ocean when microscopic underwater cells, called phytoplanktons take carbon dioxide from water for photosynthesis, just as plants on land do from the air. Even though phytoplanktons are tiny, they are vast in number, and therefore affect the carbon cycle. They also release carbon-based materials that dissolve into the ocean, just like sugar dissolves into hot tea. These materials, known as dissolved organic carbon are food for bacteria in the sea. These bacteria are part of the carbon cycle, (see back cover), because they use some types and then ooze out other types of dissolved organic carbon into the water (the bacterial equivalent of poop!) and release carbon dioxide back into the atmosphere.

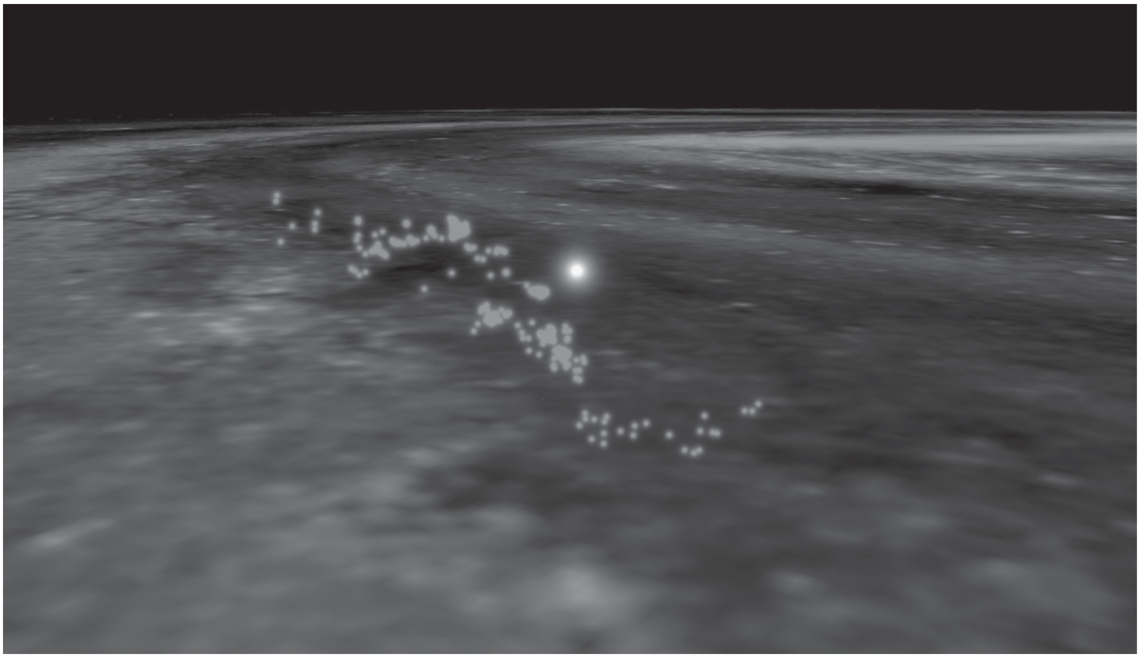
While this is a nice story, scientists do not know many details. For instance, how quickly does dissolved organic carbon move from the ocean back out into the atmosphere? Scientists want to know these things in terms of actual numbers and rates, which is not easy at all. This is where collaboration between chemists, marine biologists and data scientists, combined with the immense power of today's computers, have proved to be very useful. Recent research, reported in the journal Proceedings of the National Academy of Sciences (USA) offers many technical answers. They show that much of the dissolved organic carbon is produced at the surface of the water, where bacteria gobble it up quickly, in seconds, whereas in deeper water this process can take months or even years. Apparently, in the deepest parts of the ocean, dissolved organic carbon can hang around for a very long time: on average for 6000 years!

As scientists map more and more bacterial genes, we understand just a little more about the mystery of the oceans. One big question interesting the scientists now is how climate change affects the oceanic carbon cycle. Does hotter water make bacteria eat faster, cycle carbon more quickly back into the atmosphere?

A giant gas wave right next to us!

The new year began with a bang for science: on January 7, speaking at the American Astronomical Society conference, Dr Alyssia Goodman, a physicist from Harvard University, announced that a giant gas rope has been found, right next to our solar system! The Earth and sun are right next to a wavy rope of star-forming gas, but astronomers only just noticed it.

Many of the well-known "stellar nurseries" nearby (where stars are being formed, for example in the Orion nebula) are actually strung along a thread of gas that stretches roughly 9000 light years, according to the report. The thread resembles a sine wave, soaring above and below the disk of the galaxy by about 500 light years, and at one point, coming within a 1000 light years of our solar system. (The picture shows the Radcliffe wave data superimposed on an image of our Milky Way Galaxy.) Though it is "so close", scientists have noticed it only recently, because apparently until now we



have not had the ability to pinpoint distances to star-forming clouds. Scientists looked at stars behind these clouds and deduced how dust within those clouds altered the colours of the stars. Now they can do 3-dimensional mapping of these, and have "seen" this rope-like structure.

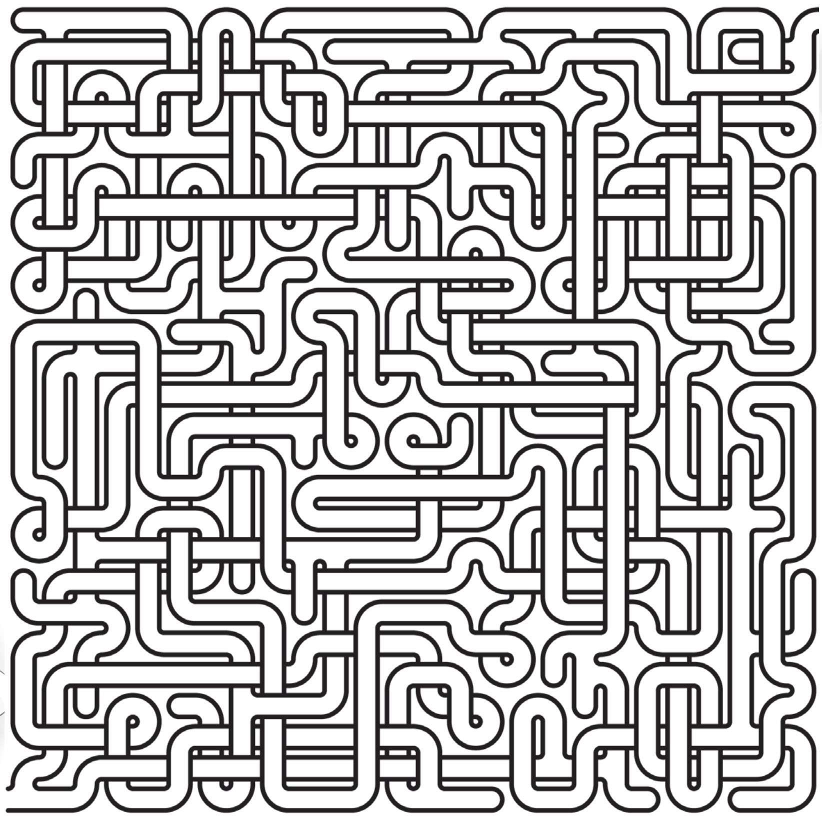
The wave has been named "Radcliffe Wave" honouring Radcliffe College in which many early 20th century female astronomers studied.

Much is unknown: we do not know how the wave formed, or what it means for understanding our Milky Way galaxy. But they can tell, tracing the motion of the sun backward in time, that our solar system passed right through the Radcliffe Wave roughly 13 million years ago. Life forms on earth at that time must have had a spectacular nighttime show!

Sources: Nature, Health for kids, Environmental science journal

Show the way!

Let the twins meet!!



Answers to last issue's Crossword

ACROSS

1. Gold 4. Silver 6. Chlorine 8. Nickel 10. Aluminum 12. Copper 13. Iron 14. Cobalt 15. Helium

DOWN

2. Oxygen 3. Calcium 5. Potassium 7. Hydrogen 9. Sodium 11. Nitrogen

Nightskywatching

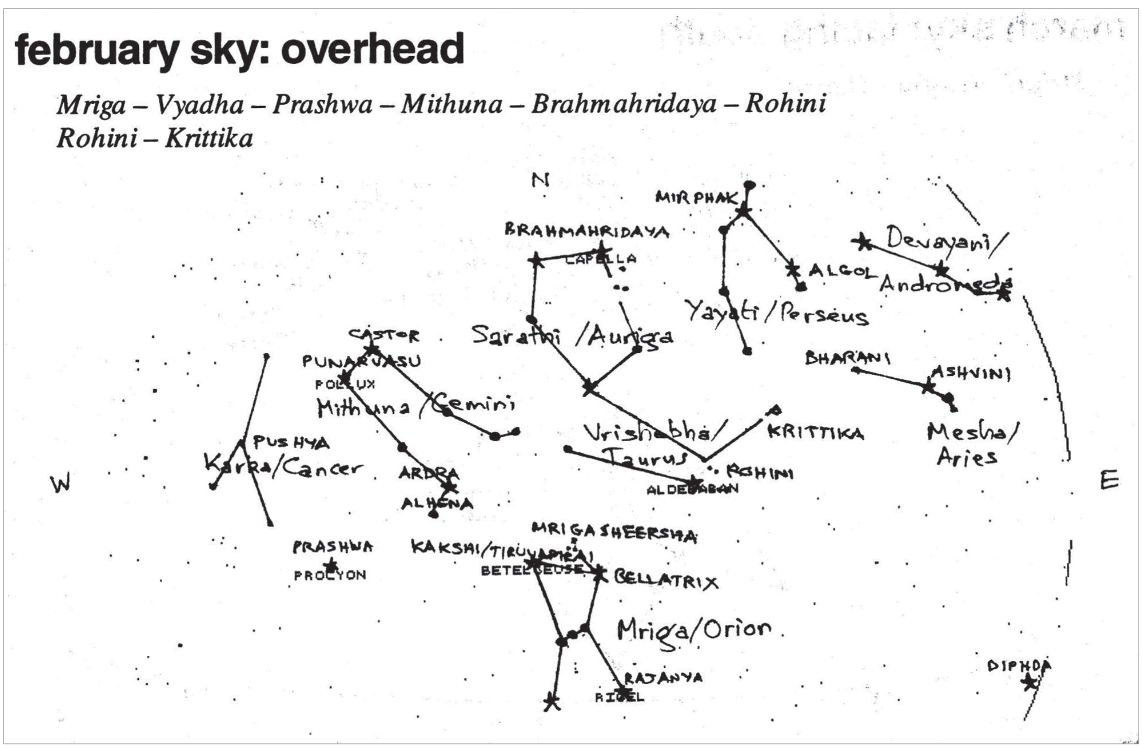
Kamal Lodaya

When I was in high school, we lived in a city. On clear winter nights we could look up and see the stars. Today city lights are so bright that we have to go to a place where they are blocked to see the darkness of the night sky. Using a small book of maps, I learnt to recognize constellations. A constellation is an area of the sky, which people from ancient times have recognized by the pattern of stars inside it.

These patterns were different in different cultures. In India we saw three stars forming a line as an arrow in the body of a deer, which forms the constellation Mriga (deer in Sanskrit). In Tamilnadu and in Europe, the same three stars are seen as a belt worn by a hunter. The constellation is called Vettaikkaran (hunter in Tamil) or Orion (a name in Greek).

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

The map shows stars seen at 9 pm on



February 1st, or at 8 pm on February 15th, or at 7 pm on February 29th. Take a few minutes to let your eyes get adjusted to the darkness. Then you will start seeing stars. Use a small torch (maybe from your phone) covered with red paper to give a soft red light to the map. Red light interferes least with your ability to see things in the dark.

What do you see?

The brightest star (vinmeen) that you see in front of you, halfway up the sky, is called Vyaadha, Rudran in Tamil and Sirius in English. To its left and downwards, you will find a star called Prashwa or Procyon. Further left, this time you will reach two stars. These are together called Punarvasu, in English they have separate names Pollux and Castor. They are in a constellation called Gemini.

Above Vyaadha, a little to the left, overhead in the sky, you can see three stars in a line that form the arrow of Mriga, or the belt worn by Orion. These stars are inside a large rectangle, with the upper right star a bright white (Raajanya or Rigel) and the lower right star a bright yellowish-red (Aardraa, Tiruvaadirai or Betelgeuse). Together they form the constellation Mriga or Orion.

Continuing the line from Vyaadha to the arrow in Mriga by the same distance upwards beyond the arrow is another bright yellowish star. This is Rohini, called Aldebaran in Arabic and English. A little beyond Rohini you will see a little cluster of half a dozen stars, this is called Krittika, Kartikkai, or the Pleiades.

Now we are going to construct a large hexagon. Begin with Vyaadha. Turn left to Prashwa. Go left to the two stars called Punarvasu. Now go up and left, you will reach a bright taare called Brahmahridaya or Capella. Turn right and up and reach Rohini. Right and down is Raajanya, upper right of Mriga. Come down to Vyaadha.

Did you get it? It is a huge figure, this winter hexagon going up from the Eastern sky to overhead and into the Western sky. Each star is in a taarapunja of its own. We learnt Mriga, the other names we will learn another time. At the centre of the hexagon is the bright Aardraa.

In many Indian languages, the word nakshatra is used for stars. But some stars are special, and they were called nakshatras in our history. Krittika, Rohini, Aardraa and Punarvasu are nakshatras. The other stars are not nakshatras. Why are these stars special? We will find out in the next issue of JM.

Activity:

On 2nd February there was a half Moon, high up behind you in the Western sky. In the next few days, as the phase of the Moon became bigger, it came into the Eastern sky, lower and lower. If you can recognize the stars in the hexagon, mark the position of the Moon on the map every day.

Questions:

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

Galileo Galilei

Galileo Galilei (15 February 1564 – 8 January 1642) was an Italian physicist, mathematician, astronomer and philosopher who played a major role in the Scientific Revolution. His achievements include improvements to the telescope and consequent astronomical observations, and support for the theory that the Earth revolves around the Sun.

Galileo studied speed and velocity, gravity and free fall, the principle of relativity, inertia, projectile motion and also worked in applied science and technology, describing the properties of pendulums and "hydrostatic balances", inventing the thermoscope and various military compasses, and using the telescope for scientific observations of celestial objects. His contributions to observational astronomy include the telescopic confirmation of the phases of Venus, the observation of the four largest satellites of Jupiter, the observation of Saturn's rings, and the analysis of sunspots.

Not surprisingly, Galileo has been called the "father of modern observational astronomy", the "father of modern physics", the "father of science", and "the Father of Modern Science".

Shown on the front inside cover is a 1636 portrait of Galileo by Justus Sustermans, a Flemish Baroque painter.

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