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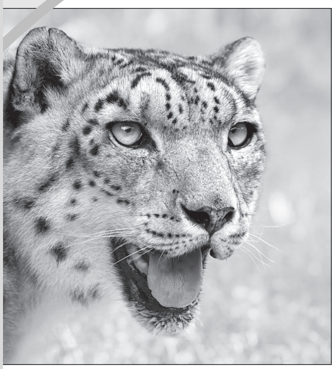

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website : http://hsb.iitm.ac.in/~jm

Brain Teasers

1. ***Con-Fusing Puzzle:*** *In front of you are several long fuses. You know they burn for exactly one hour after you light them at one end. The entire fuse does not necessarily burn at a constant speed. For example, it might take five minutes to burn through half the fuse and fifty-five minutes to burn the other half.*

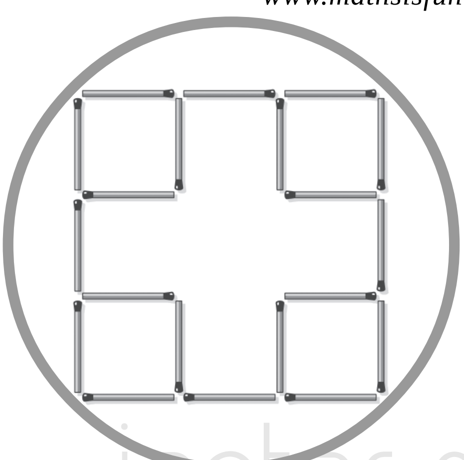
With a match-box and using these fuses, how can you measure exactly three-quarters of an hour of time?

2. ***Egg Puzzle:*** *You need to boil eggs for exactly 9 minutes, or else your nitpicky guest will complain, and you will lose your job as head chef.*

But you have only 2 hourglasses; one measures 7-minutes, and the other measures 4-minutes. How can you correctly measure 9 minutes?

3. ***Matchstick Puzzle:*** *There are five squares (one 3x3 and four 1x1) formed with 20 matchsticks, as shown in the illustration. Move two matchstick to get seven squares. Overlapping or breaking of matchsticks or "loose ends" are not allowed.*

Adapted from: http://www.mathsisfun.com/



Answers to last issue's Brain Teasers

1. *There are 100 coins each in 10 bottles. Each of the coins weighs 10 gms. However, the manufacturers made a mistake and so one of the bottles contains coins that weigh only 9 gm each. How can you find out which bottle contains the defective coins by making just one weighing in a weighing machine?*

Ans: Here it is not important whether one set is lighter or heavier than the rest: it is critical to know the actual weights of both the normal and the different sets of coins.

Of course if you weigh a coin from each bottle, you can find out which set is different but that needs 10 weighings and you have to do it in one go. Suppose you make the problem simpler:

you have just two bottles full of coins and one set weighs 9 gm while the other weighs 10 gm. Now, if you take a coin from each set and weigh them together, you know the weight you will get is (10+9=) 19 gm. This will not tell you which is the lighter one, though! How can you improve upon this?

Suppose you took one coin from the first bottle and two from the second and weighed them together. What weight will you see? This will depend on which bottle has the lighter coins. There are two possibilities. If the first bottle had the lighter coins, then you have taken 1 lighter coin and two normal ones, so the weight you will see is (1x9 + 2x10) = 29 gm. If instead the second bottle had the lighter coins, you will measure a weight of (1x10+2x9) = 28 gm.

But now these two answers are different! So you can immediately tell which bottle had the lighter coins: if the weight is 29 gm, the lighter coins are in the first bottle and if the weight is 28 gm, they are in the second bottle. One way to understand this answer is to see that if both bottles had identical coins, you would have measured 30 gm. So, if the answer you get on actually weighing the coins is 1 gm less, then the first bottle has the lighter coins, and if the answer is 2 gm less they are in the second one.

Now we have solved the problem if there are just two bottles. How can we extend this result to 3, 4, ... 10 bottles? A little thought will tell you that the key to the problem is to weigh in one go, different numbers of coins from each bottle. Hence the answer is the following:

Take 1 coin from the first bottle, 2 from the second, 3 from the third and so on upto 10 from the 10th bottle. So you have (1+2+3+...10) = 55 coins in all. If all were the same weight, you would have got 550 gm. If the actual weight you get is 1 gm less than this, then the lighter coins are in the first bottle. If you get 2 gm less, they are in the second bottle and so on. You can see that it is important not really to know the different weights, but the amount by which the weights are different.

2. You have 12 balls identical in size and appearance but one is *lighter or heavier than the rest.*

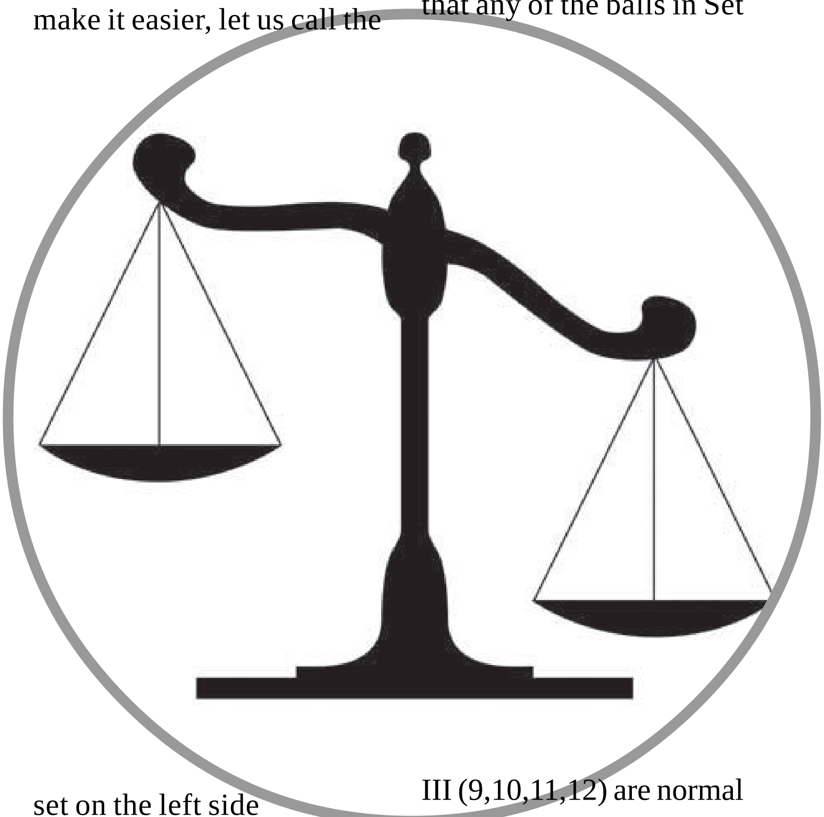
You have a set of scales (balance) which cannot tell you the exact weight but can tell which is the heavier or lighter of two objects (the scale will tip over to the side of the heavier object or stay balanced if the two objects have the same weight).

Can you find out which is the odd ball with just three chances to weight them on the balance? Also, can you find out whether it's heavier or lighter than the rest at the same time?

Ans: This is yet another endless variation on the weighing problems. Each is slightly different and each one is nothing short of amazing in its inventiveness!

You do not know the weight of any of the balls, so clearly in this puzzle you have to weigh the balls against each other. There are 12, so let's start by weighing them 6 to a side. One lot is heavier and one lot is lighter. Now you don't even know if the odd ball is heavier or lighter, so we have come to a dead end fast! Clearly this cannot be the first weighing.

Let us instead try and weigh some of the balls. For instance, weigh 4 on a side, so take only 8 of them. To make it easier, let us call the set on the left side containing balls 1,2,3,4 as Set I and the ones on the right with balls 5,6,7,8 as Set II (so that the left-over ones, 9,10,11,12, are Set III).



There are two possibilities: either the odd ball is in Set I/II or it is in Set III. If it is in Set I/II, then when we do the first weighing, the scales will not balance and we will know that the odd ball is one amongst these eight. More importantly, we will know that any of the balls in Set III (9,10,11,12) are normal and can be used as a measure of the correct weight.

For simplicity, let us assume that Set I came out to be lighter than Set II. Since we do not know whether the odd ball is lighter or heavier than the rest, we cannot tell if it is in Set I or Set II. All we can say is that, if the odd ball is lighter, then it must be one of balls 1,2,3,4. Let us call them LN balls (either light or normal). If the odd ball is heavier, it must be one of the balls in Set II, i.e., 5,6,7,8. (Let us call them HN balls, either heavy or normal.) Set III balls are all normal, so we call them N.

To find out which is the odd one, then, we must weigh these balls against any one of the balls that we know are "normal" ones from Set III, let us say 9. Here is the trick that allows you to find the answer in three weighings: Suppose we weigh an LN ball against an N ball. If they weigh the same, the LN ball is actually normal, and if not, it is the odd (and light) ball. However, if we proceed this way, we may have to keep on weighing until we find the odd ball and we certainly cannot do this in 2 more weighings. We have to be smarter than this. So, in the second weighing, weigh not just one LN ball against an N ball, but in the following way: LN,LN,HN against LN,HN,N. For example, 1,2,5 against 3,6,9. We have therefore kept aside one LN ball (4) and two HN ones (7,8). Since we have a complicated combination, either side could be light or heavy, or they could balance. Let us examine each in turn.

(A) The two sides balance. So either 4 is the light odd ball or one of 7,8 is the heavy odd ball. Weigh 7 versus 8 (third weighing). If they balance the odd ball is 4 and it is lighter. If they don't balance, the heavier one is the heavy odd ball (since we know that they are HN, i.e., either heavy or normal).

(B) The two sides don't balance. Suppose 3,6,9 is heavier than 1,2,5. Now 3 can only be light/normal (LN) not heavy, while 5 can only be heavy/normal (HN) not light, so these can't be the odd balls. (Remember 9 is normal). Then ball 6 is heavier or either one of 1,2 is the odd light ball. Just as before, weigh 1 against 2 (the third weighing). If they balance, then 6 is the heavy odd ball; if they don't then the lighter of the two is the light odd ball.

(*C) The two sides don't balance* but now 3,6,9 is lighter than 1,2,5. Since 9 is a normal ball, this can happen if 3 is light or 5 is heavy To find which of 3 and 5 is the odd ball, weigh any one of them against a normal ball, say 9 (this will be the third weighing).

If Set I is heavier than Set II, you can repeat the entire argument above, interchanging the choices from Set I and Set II.

Finally, we have the case that in the first weighing, Set I and Set II balance each other. Then the odd ball is in Set III and we can weigh any three of the balls in Set III against any three normal balls from the remaining sets. Repeat the arguments above carefully and find out that in this case also, we can not only find the odd ball in three weighings, but also determine whether the odd ball is heavier or lighter than the rest.

Quasi-crystals
The Nobel Prize in Chemistry, 2011

The Nobel Prize in Chemistry 2011 has been awarded to **Dan Shechtman**, Israel Institute of Technology, Haifa, Israel, for the discovery of *quasicrystals*.

Almost all solid materials, from ice to gold, consist of ordered crystals. Inside a crystal, atoms are ordered in repeating patterns. So when you observe them under an electron microscope, you will see a uniform *diffraction* pattern because of the refraction of the electrons with the regularly placed atoms in the crystal. Moreover, these patterns can have a specific *symmetry* such as 2-fold, 4-fold, etc. For instance, a square has a 4-fold symmetry because it looks the same when you rotate it through ¼ of a circle, but a rectangle has only a 2-fold symmetry: you need to rotate it by ½ a circle to get back the same view. Researchers in diffraction patterns made by atoms had shown that certain symmetries were not possible. When Shechtman was studying a mix of aluminum and manganese, the diffraction pattern showed that the atoms inside the metal were packed into an ordered crystal with ten-fold symmetry. This was considered at the time to be impossible. In fact, no-one believed his results for a long time because it questioned the most fundamental understanding of crystals.

The explanation came with developments in mathematics by answering

the question: can a mosaic be laid with a limited number of tiles so that the pattern never repeats itself, to create a so-called *aperiodic mosaic*. Many answers were found and many such mosaics were discovered.

The crystallographer **Alan Mackay** was curious as to whether atoms, the building blocks of matter, could form aperiodic patterns like the mosaics. He found that he could get a 10-fold symmetry from one of the mosaics called the **Penrose** mosaic.

Soon physicists **Paul Steinhardt** and **Dov Levine** made the connection between the two: a solid that is almost periodic, but not exactly, can give such symmetries. Quasicrystals got their name.

Previously, chemists interpreted regularity in crystals as a periodic and repeating pattern.

A crystal had been defined as “a substance in which the constituent atoms, molecules, or ions are packed in a regularly ordered, repeating three-dimensional pattern”. The new definition after this new understanding in 1972 became “any solid having an essentially discrete diffraction diagram”. Discrete means that it is not continuous. This definition is broader and allows for possible future discoveries of other kinds of crystals.

Since their discovery in 1982, hundreds of quasicrystals have been synthesized in laboratories around the world. They also occur in nature. Quasicrystals have also been found in one of the most durable kinds of steel in the world. This steel is now used in products such as razor blades and thin needles made specifically for eye surgery. Many other uses in applications have been found. But one of the main lessons from this story is that keeping an open mind and daring to question established knowledge may in fact be a scientist’s most important character traits.

The Accelerating Universe
Nobel Prize in Physics 2011

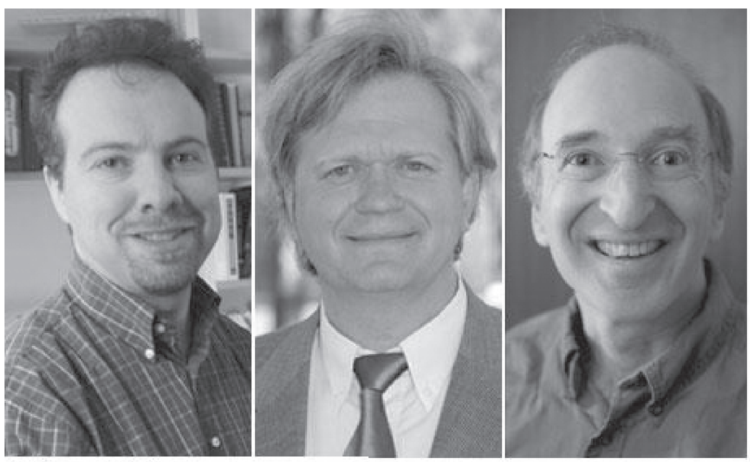
M V N Murthy,
The Institute of Mathematical Sciences,
Chennai

The Nobel prize in Physics in 2011 was awarded to *Saul Perlmutter* (Lawrence Berkeley National Laboratory, Berkeley, USA), *Brian P. Schmidt* (Australian National University, Australia) and *Adam G. Reiss* (Johns Hopkins University, USA) for the discovery of the accelerating expansion of the Universe through observations of distant supernovae. While half the prize goes to Permutter, the other half will be equally shared by Schmidt and Reiss.

The origin and evolution of the universe that we inhabit is a fascinating story. The sky with its planets, innumerable stars and galaxies that is visible to naked eye is an object of curiosity for every one. From the beginnings of human civilisation, people have observed the sky and wondered about the nature of the universe. Poets, philosophers and scientists alike have written about it in their own differing ways. Did the universe have a beginning and will it have an end? How does the universe evolve? Or has it been there for all times just as we see it today? How far is the far away star? Is it moving at all? Such questions have been asked over centuries-the discovery of Perlmutter, Reiss and Schmidt takes us closer to the answers that we are seeking but at the same time points to some as yet unknown phenomenon that governs the universe as we see it today.

It was **Newton** who first told us that the many stars and galaxies that we observe are held together by an attractive force called gravity. The strength of the force is proportional to the masses of the objects and inversely proportional to the square of the distance between them. The discovery of law of gravitation by Newton was a huge step in understanding the inner workings of the universe. The law of gravitation applies to every thing, from sand grains on the beach to the stars and galaxies. Newton presupposed the existence of space and time in which the law of gravitation operates.

Along came **Einstein** who clarified the notion of space and time. In fact he hyphenated them, space-time. Through his *Special Theory of Relativity* and later through his formulation of *General Theory of Relativity*, Einstein told us that space-time is itself intricately linked to the presence of matter. The geometry of space time is dictated by the presence of matter. General Theory of Relativity is the foundation for our understanding of the Universe. In fact the theory, as originally formulated, says that the Universe has to either shrink or expand. This was a disturbing conclusion to which Einstein could not reconcile, so he introduced a change in his equations involving a constant, called the *cosmological constant*, in order to prevent the universe from expanding—a change he would soon



Adam G Riess   Brian P Schmidt   Saul Perlmutter regret.

About a decade later it was discovered that the galaxies were actually receding. Astronomer **Edwin Hubble** profoundly changed our understanding of the Universe by confirming the existence of galaxies other than our own Milky Way. He also showed that the visible light from distant galaxies shift towards red colour in proportion to the distance of the galaxy from Earth. This is known as *Hubble's Law*. In 1927, **Georges Lemaitre**, a Belgian Catholic priest and physicist showed that the data collected by Hubble and others supports a model of an expanding universe using Einstein's theory. (At this point, Einstein's equations were used, setting the cosmological constant to zero). If we assume that the universe is ever expanding, it automatically leads to the conclusion that it must have had a beginning (the point at which it began to expand). It is this idea that forms the basis for the Big Bang Theory of the Universe. The present standard view is that the Universe was created in the Big Bang almost 14 billion years ago. It is the beginning of space and time and the universe has been expanding ever since. Because of this, all galaxies (and other objects) in the universe are constantly moving away from each other. In particular, therefore, distant galaxies appear to be receding from us due to this.

What is the nature of this expansion and what drives it? The answer to this question is contained in part in this year's Nobel prize winning discovery. Measuring distances between cosmological objects is now a precision science due to some technological break throughs in recent years. In the beginning of the 20th century the American astronomer **Henrietta Leavitt** was analysing photographic plates taken by large telescopes. She found many stars whose light had periodic

Measuring Distances to Stars

Astronomers use many techniques to measure distances to stars. The oldest technique is called the trigonometric parallax which uses geometric methods. The principle behind this method is simple—Earth orbits around the Sun and we know the radius of the orbit (1 Astronomical Unit). Suppose we observe the star in June and December. We are observing the nearby star from two ends of the orbit against the distant stars, which are so far that they are stationary (see figure). Then the parallax angle p between the two measurements can be determined by $\tan(p)=r/d$, where r is the radius of the earth's orbit around the sun and d is the distance to the star. Since r is well known, and angle p is measured, we know the distance to the star. This works well for stars up to a distance of 500 light years.

For those beyond 500 light years, astronomers use the brightness measured from the Earth. Typically absolute brightness of the star is related to their colour/temperature. By spectroscopic analysis one can determine the spectrum of the star which gives information about its absolute brightness. Tens of thousands of stars have been measured this way. Using the Sun as a source for calibration astronomers use a standard diagram called Hertzsprung-Russel diagram to determine the *absolute brightness* of these stars. If b is the *observed brightness* of a star from Earth and B is its absolute brightness (measured from its colour/temperature), the distance from the Earth to the star

is then calculated using the *inverse square law* for intensities: $b=B/d^2$. This method works for stars as far away as 150,000 light years.

Cepheid stars are used for distances even beyond where the pulsating period from maximum to minimum brightness and back is related to its absolute brightness. For distances beyond a few billion light years, Cepheid stars are not standard candles, and are replaced by *Supernovae* which are the standard candles for distance measurement. This has been made possible by the recent technological advances like placing the telescopes in the sky and sophisticated digital cameras.

Once the distance to the star is identified, the characteristic red shift or elongation of its wavelength give an indication of how it is moving in the sky. It is this measurement that showed that the distant galaxies are indeed accelerating.

variations. These stars are called *Cepheids*. She also noticed that brighter ones had longer periods. She could therefore use these periods to calculate the intrinsic brightness of Cepheids. The period-luminosity relation was calibrated from observations of nearby Cepheid variables whose distances are well determined. Thus if we know the precise distance to just one such Cepheid star, the distance to any other Cepheid star can be established by measuring its observed brightness and intrinsic brightness. These Cepheids are called *standard candles* and provided a *cosmic yardstick*. The use of a cosmic yardstick along with the studies of redshift, where the wavelength of the source light gets stretched due to motion, led astronomers to conclude that the galaxies are receding from each other.

Over the next six decades or so astronomers located distant stars and galaxies and mapped how they move. However, to observe even beyond, billions of light years away, became difficult as Cepheids are no longer visible as they get dimmer and dimmer with distance. New and far brighter standard candles are needed to extend the cosmic yardstick. In the last two decades new standard candles are used—these are *Supernovae* or exploding stars. For a matter of a few weeks a supernova is as bright as an entire galaxy. There are different types of supernovae. Of special interest are the Type I supernovae. In the visible universe about ten supernovae of this type occur every minute. Because of their brightness they are visible over distances when ordinary Cepheids are not visible. They are the new standard candles. This is because most of their light is emitted during the first few weeks (about 100 days). This is plotted on a graph in what is called their *light curves.* These curves are similar for all of them and can thus be used as new standards.

The work of this year's Nobel Laureates was done around 1997-98. They were studying the evolution of the Universe using the new supernova standard candles, reaching farther and farther into regions of the sky which were not accessible before. They were aided by yet another Nobel Prize winning work on *Charge Coupled Device* (CCD) cameras which were sensitive to even the faintest of light. A distant supernova shows up as a dot or a pixel in these cameras. The telescopes are focused on a particular patch of the sky just around the new moon and observe the same patch three weeks later before moonlight swamps the sky. A new dot appearing is a sign of a distant supernova. Many problems, like the background light from galaxies and intergalactic dust etc, had to be accounted for and removed so as to get the correct brightness of the supernova. It was a logistical nightmare that challenged the limits of science and technology. Their technique/strategy allowed them to sample large regions of sky to look for candidate supernovae which ultimately helped gather enough data to make the discovery. The picture shows two images of the same small piece of sky three weeks apart. On the second image, a new small dot of light appeared! Its status as a type IA supernova (named Supernova 1995ar) was established after studying its light curve.

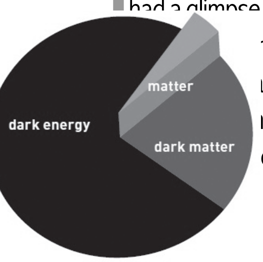
Once the right kind of supernova was identified, its light curve and redshift had to be measured. All this had to be done without delay since the supernova fades quickly. In all about 50 supernovae were found whose light appeared weaker than expected. Why is the light from these supernovae weaker? The surprising conclusion that emerged was that the Universe was not just expanding uniformly but actually it was accelerating, that is receding faster and faster.

This was an astounding fact since an accelerating universe according to Einstein's equations requires a nonzero cosmological constant. Einstein had introduced it to make the Universe static. Now, the universe is not just static or expanding, but expanding with increasing acceleration. The same mechanism of cosmological constant can lead to an accelerating Universe, but the cosmological constant has to have the opposite sign to what Einstein needed for a static universe. Indeed introduction of cosmological constant was a brilliant move in hindsight.

So what is accelerating the Universe? It cannot be just gravity alone since the cosmological constant introduces

Birth and Death of a star

Stars have a finite life time. In the 19th century it was thought that the stars are held together by gravity. The compressional force of gravity was thought to produce heat and light which was responsible for stars shining. However, if it was gravity alone, then the stars do not last more than about 30-40 million years. It was only in the first half of 20 the century we had a glimpse of how that stars shine. ...howed that the core of a ... big furnace burning ...rough fusion. Driven by ... compression, the core ... temperature keeps in- ... the nuclei of lighter el-ements are squeezed very close to each other. The fusion then occurs when lighter elements like hydrogen and helium combine to produce heavier elements and emit energy in the process. The enormous heat produced during fusion produces an outward pressure which balances the gravitational compression for a very long time.



In heavier stars, more than ten times bigger than the Sun, the fusion reaction in the core of the star proceeds in several stages producing heavier elements like oxygen, silicon, etc., up to iron, releasing huge amounts of energy. Beyond iron the fusion cannot be sustained and it stops. However gravity never stops, so the infalling material from the envelope of the star continue to be compressed. But the core is incompressible. So the infalling material is thrown off in an explosion called *supernova*. The death of a heavy star results in what is called type II supernova. These are so bright that they are visible to the naked eye and many have been observed over time, by **Chinese astronomers, Kepler** and more recently by several scientists in 1987. Such heavy stars live for tens of million years peacefully but the end comes almost in a matter of seconds during which fusion of iron begins and ends. We know all this due to the work by **S. Chandrasekar**, **Hans Bethe** and others.

In lighter stars, the fusion produces carbon, nitrogen and oxygen and then stops since the core by then would have exhausted the amount of hydrogen fuel required to drive the fusion. It takes about a few billion years to reach such a stage in lighter stars. Stars such as our Sun are not massive enough for such supernova explosions to occur; they simply grow in size over the years into what is called a *red giant* and then fade off into a *white dwarf*. All stars that start off lighter than a critical value called the *Chandrasekhar limit* (of 1.4 solar masses) will not explode. This will be the fate of our own Sun in a few billion years from now. But sometimes, a white dwarf may have a companion star which is orbiting around it. Over the years the companion may become a red giant. Then the white dwarf can gather mass from the companion star, become slowly more massive, cross the Chandrasekar limit and explode. These are called the Type IA supernova and are of particular interest.

They have characteristic light curves that are different from other supernovae. Most importantly, it is possible to determine the absolute luminosity from these light curves, thus making them standard candles. It is these Type IA supernovae that were used in the Nobel prize winning work.

a new element into the dynamics of the universe. For want of a better adjective, we simply now call it the *dark energy* that is needed to drive the acceleration. But it remains a riddle that is yet to be solved.

Our present understanding is that, about 75 percent of the Universe is dark energy, and the rest is matter. The puzzle does not end here. The visible matter, the stuff of galaxies, stars, living things, etc, is only about 5 percent of the Universe. Nearly 20 percent of matter is therefore again hidden from observation at present. We call this *dark matter*. While dark energy is responsible for accelerating the Universe outwards, dark matter is needed to account for the effects of gravity which the visible matter cannot do. The findings of 2011 Nobel Laureates in Physics is but a step in posing clear questions on the riddles of dark energy and dark matter.

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The man who was loved by formulas

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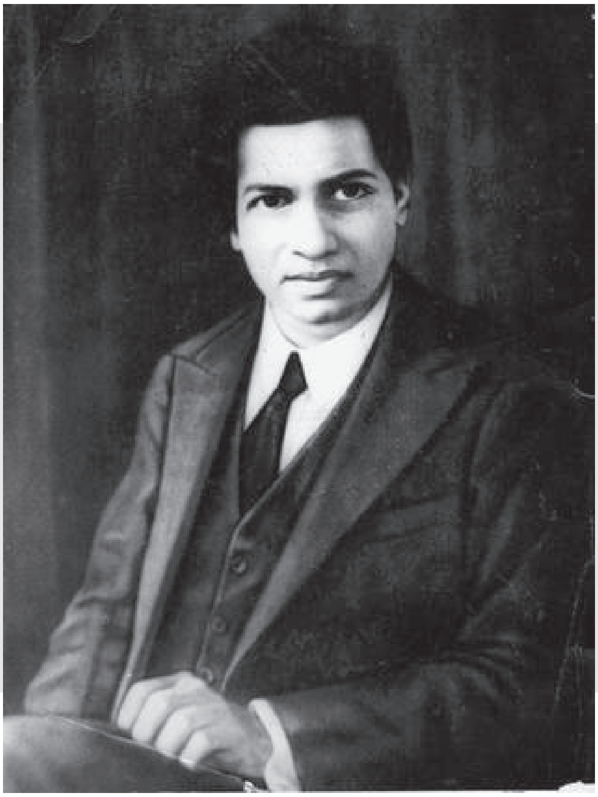


This month we enter the 125th birth anniversary of one of the greatest mathematicians of the 20th century, and perhaps one of the greatest ever. We are fortunate to bask in the reflection from his glory, since he was born in India, and spent much of his life in Tamil Nadu. **Srinivasa Ramanuja**n shone brightly as a star in an all too short life, but left a legacy of mathematical gems that sparkle even today.

Most of us know his story, but love to hear the tale yet again. Ramanujan was born on 22 December 1887 in Erode. He showed an early penchant for mathematics, mastering trigonometry and proving his own theorems by the age of 12. By the age of 17, Ramanujan conducted his own mathematical research on *Bernoulli numbers* and the *Euler-Mascheroni constant*. But then Ramanujan was bad at other subjects, failed exams and lost his scholarship. He worked as a clerk in the Accountant-General's office at the Madras Port Trust Office to support himself while continuing his independent mathematical research.

In 1912-13 Ramanujan sent samples of his work to three mathematicians at the University of Cambridge, England. One of them, **G. H. Hardy**, a great mathematician in his own right, was intrigued. He consulted **Littlewood**, another eminent mathematician, and they were both fascinated by Ramanujan's theorems. Ramanujan went to England and worked with them, eventually becoming a Fellow of the Royal Society and a Fellow of Trinity College, Cambridge. But cold England took its toll on Ramanujan: at the early age of 32, he died of

Taxi-cab numbers

There is a famous story about Ramanujan. When he was ill, Hardy arrived at his residence to visit him. Being generally awkward, Hardy did not know what to say and told Ramanujan that the number of the taxicab he had come in was 1729, a number that seemed to be uninteresting.

Ramanujan replied, on the spot, that it was actually a very interesting number mathematically, being the smallest natural number representable in two different ways as a sum of two cubes:

$10^3 + 9^3 = 1729 = 12^3 + 1^3$.

Mathematicians have now generalized this concept to so-called "taxicab numbers". The nth taxicab number, typically denoted Ta(n), is defined as the smallest number that can be expressed as a sum of two positive algebraic cubes in n distinct ways, where n is a number such as 1,2,3.... Ta(1) = 2 = 1^3^3 + 1^3^3. Ta(2) is the Ramanujan number above while Ta(3) is a number that you should be able to write in *three* different ways:

$Ta(3) = 87539319 = 167^3 + 436^3 = 228^3 + 423^3 = 255^3 + 414^3$.

In 1954, Hardy and Wright proved that Ta(n) exists for every n, and the proof can be transformed into an *algorithm* that can be run on a computer.

illness caused by malnutrition and possibly liver infection. He left behind several notebooks containing densely packed formulae written by hand.

BOX 2: **House counting**

Ramanujan was remarkably adept at problem solving, and could carry out long and complicated manipulations of formulas inside his head. He was sharing a room with **P. C. Mahalanobis** who had a problem to solve. He had found the problem in the English magazine *Strand* in December 1914.

Ramanujan was stirring vegetables in a frying pan over the kitchen fire when Mahalanobis read this problem to him. After listening to this problem, still stirring vegetables, Ramanujan asked Mahalanobis to take down the solution, and gave, not just the solution to the question, but the most general solution to the problem.

The problem: Imagine that you are on a street with houses marked 1 through n. There is a house in between (let us call it x) such that the sum of the house numbers to the left of it equals the sum of the house numbers to its right. If n is between 50 and 500, what are n and x?

Ramanujan did not merely answer the problem but gave the answer with a twist: he gave a continued fraction (see definition below). The unusual part was that it was the solution to the whole class of problems. Mahalanobis was astounded and asked how he did it. "It is simple. The minute I heard the problem, I knew that the answer was a continued fraction. Which continued fraction, I asked myself. Then the answer came to my mind", Ramanujan replied.

If m is the number of houses in that street and n is the number of the particular house, then:

1 + 2 + ... +(n-1) = (n+1) + (n+2) + ... + m.

Summing both sides, using 1+2+...+k=k(k+1)/2, we have

n (n-1) / 2 = (m (m+1) / 2) - (n (n+1) / 2).

Collecting terms and regrouping: $(2m+1)^2 - 2(2n)^2 = 1$.

This is of the general form x^2 - 2y^2 = 1, the Brahmagupta-Bhaskara equation, also called Pell's equation. This can be solved by using continued fraction, as Ramanujan did, or by other (more boring) methods.

The answer, incidentally, is: m = 204, n = 288.

What is a continued fraction?

A simple infinite continued fraction, for example, is:

1 + 1/(2 +1/(3 + 1/(4 +1/(5 + ...))) ....).

If you truncate it at each step, you get what are called the successive *convergents* of the continued fraction, thus:

1 ; 1 + 1/2 = 3/2 ; 1 + 1/(2 + 1/3) = 1 + 3/7 = 10/7 ;

1 + 1/(2 + 1/(3 + 1/4)) = 1 + 1 /(2 + 4/13) = 1 + 13/30 = 43/30 ;

and so on, endlessly.

Let us consider a simpler version of the problem. We are to solve the equation: $x^2 - 10 y^2$ = +1 or _1.

Mahalanobis tries it and comes out with the answer x = 3 and y = 1 in no time. Now Ramanujan, as soon as he hears the statement of the problem, dictates the following continued fraction:

3 + 1/(6 + 1/(6 + 1/(6 + 1/(6 + ...))) ...)

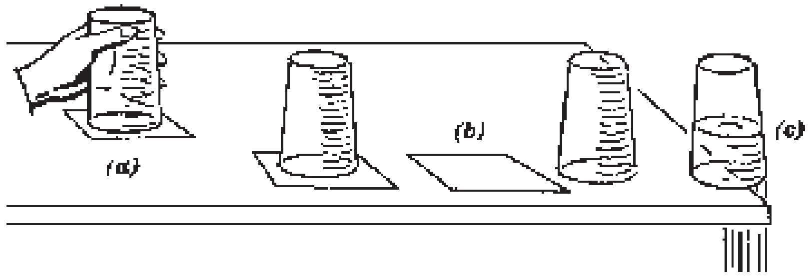
Here 3 (=3/1) is the first convergent. The numbers 3 and 1 are the first answers to x and y which Mahalanobis has himself discovered by trial and error. Now Ramanujan's continued fraction answer not only gives this first elementary answer but gives an infinity of answers on the assumption that the street may have an infinite number of houses in it! Thus the second convergent, 3 + 1/6 = 19/6 gives the pair, 19 and 6 for x and y. This can be verified to be a true answer: 19^2 _ 10 x 6^2 = +1.

The third convergent, 3 + 1/(6+1/6) = 3 + 6/37 = 117 / 37 gives the answer x = 117 and y = 37 which also satisfies the relation specified by the problem. The fourth convergent can be calculated to be 721/228 and this pair x = 721 and y = 228 can also be verified to satisfy the relation.

And so on it goes. Every convergent gives a pair of numbers, which constitute an answer. The greatness of Ramanujan was that as soon as he heard of the problem, without effort he decided that the answer could be given in the form of a continued fraction and immediately gave the continued fraction, which not only solved the problem but gave an infinity of solutions to it!

Fast and lazy, or slow and active

D. Leela,
Chennai



"We had fun with the falling bottles last week-end, didn't we?" asked Leela.

"Yes," said Maya, "and I also found out something nice in school.'"

"What is it?" asked Leela.

"It was Amrit who found out. We had this ball with the rubber-band attached to it. You are supposed to keep hold of one end of the rubber-band and throw the ball and try and catch it."

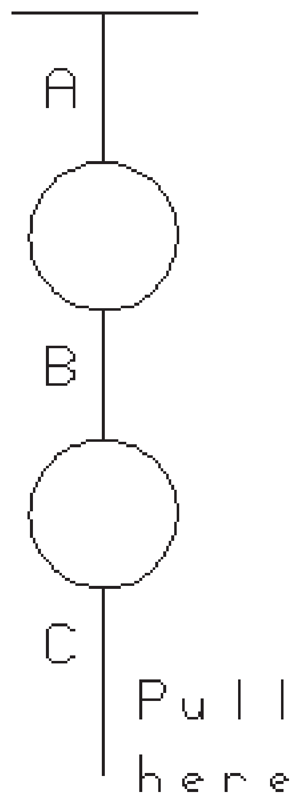
"Yes, I know," said Leela impatiently. "We bought one in Delhi near the India Gate, don't you remember? I wonder where it is."

"Anyway," continued Maya. "We stapled the free end of the rubber-band to the bottom of a paper cup. On the inside. Then we would hold the cup in our hands, try to throw the ball and then catch it back in the cup."

"It must be easy," said Leela at once.

"Wait, that's not it," said Maya. "Well, as I said, it was Amrit who was throwing the ball and he accidentally let go. That is, he let go the ball as well as the cup! When the ball started to fall, it fell right into the cup. Then the cup and ball fell down together!!"

"So I suppose all of you tried to repeat it," asked Leela.



"That was just it," said Maya. "Every time we tried to repeat it, it worked! I mean, we thought it was a coincidence that the ball fell straight into the cup the first time. But each time the ball fell, it always fell into the cup. It was very strange."

"I can't understand it either," said Leela. "Let's ask Mother."

Just then a familiar voice called out. "Leela! Maya! Are you there? Can you please bring me the paper that is under the paper-weight in your room?"

"Yes, Amma, I'll do it," said Leela.

"No, me," shouted Maya, reaching out for the paper-weight. At that moment, Leela grabbed the paper and neatly yanked it out from underneath the weight. Both of them looked at the weight; it hadn't even moved.

Both of them forgot Mother and her paper. "Let's do it again!" they said.

Leela put the paper back under the weight and said, "OK, you try this time."

Maya gingerly caught hold of one end of the paper and pulled cautiously. The paper slid towards her, along with the paper-weight which moved along with the sliding paper.

"No, both are moving," she said.

"I think it had something to do with the speed," said Leela. "Try pulling it out faster."

Maya bunched up the ends of the paper and yanked hard on it. The paper-weight promptly rolled over.

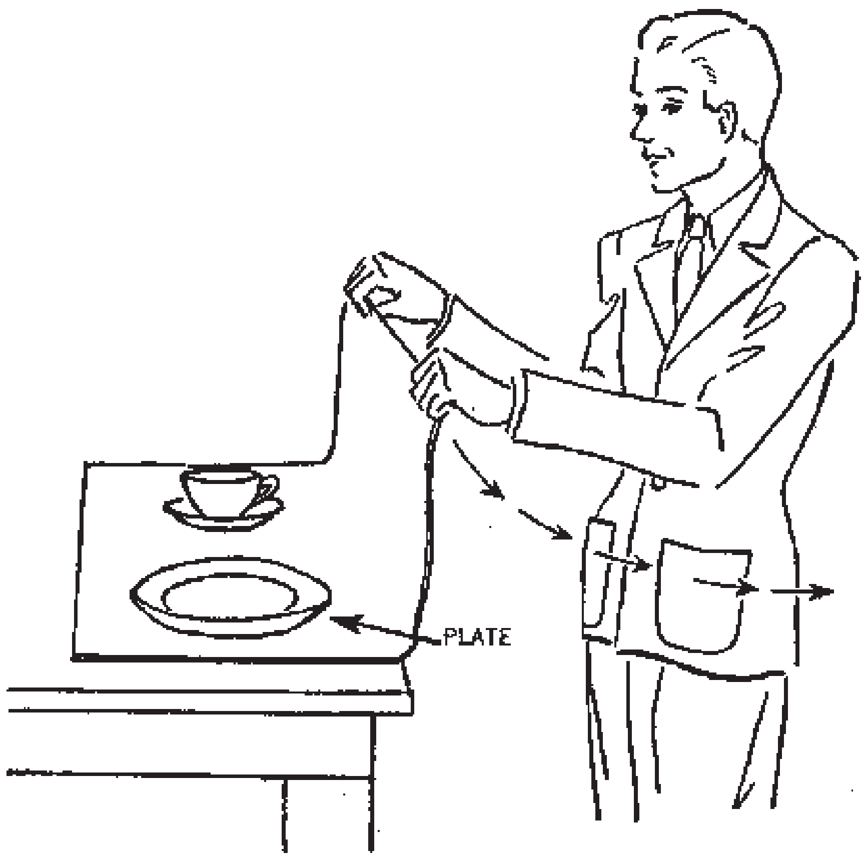
"No," said Leela. "Don't fold or crease the paper. Here, let me try." She smoothed out the paper, put it back under the weight and yanked on it. The paper smoothly came out in her hand, while the paper-weight had again barely moved.

At that moment, Mother came in to the room, wondering why the children had not yet brought her the piece of paper. The children promptly showed her their discovery.

"Ah, yes, inertia," she murmured.

"What's that?" asked Leela.

"It just means that objects are



like you, basically lazy! If you pull fast enough on the paper, there's not enough time for the paper to `tell' the weight that it is moving! So the weight just stays in place, since it prefers to stay at rest. It's just plain lazy. But if you do it slow enough, the weight has enough time to feel the motion of the paper and it decides to move along with it - the friction causes them to move together."

Both children looked puzzled. "But what does inertia do?" asked Maya.

"I've learned about forces," said Leela. "If you apply so much force on an object, it will move so much distance. What does fast or slow have to do with it?"

"Let's do another experiment," said Amma. She cut out one half of an old greeting card and placed it on a glass tumbler. Then she put a coin on the card.

"See, if you move the card slowly, the coin will come with it, but if you yank the card, or even flick it with your finger (like playing carroms), the card will fly off and the coin will drop into the tumbler."

The children played this for a while. Then Leela said, "I still don't understand what inertia actually means. How does it make the force larger or smaller?"

Mother said, "There are many things involved. For instance, take the paper-weight or the coin. They have weight because they are pulled down by Earth's *gravity*. In fact, weight is just a special force. Now Newton, a famous scientist, said that the action of every force has an equal and opposite *reaction*."

"That's Newton's third law," said Leela.

"Yes," said Mother. Then she looked at Maya and said, "Think of it this way. If gravity pulled you to the centre of the Earth, why are you still here? Why are you simply not sinking through the Earth and going towards its centre?! That's because there is an equal and opposite reaction to the force of gravity. This is the solid ground pushing you upwards so that you don't fall through."

"What's pushing the Moon up then?" asked Maya.

"A very interesting question," said Amma. "But let us keep that for later and stick to inertia. I have one more fact to tell you. When you pull or push some object, for it to move it has to overcome *friction*."

"Yes, I know that," said Maya. "Rough surfaces cause more friction than smooth ones."

"Yes, but the interesting fact here is that the frictional force is *proportional* to the reaction force. It depends on the weight of the body and the smoothness of the surface but it doesn't really care whether the cloth is being moved fast or slowly."

"How is that fact going to help us here?" asked Leela. "After all, we are looking for something that differentiates between slow and fast motion."

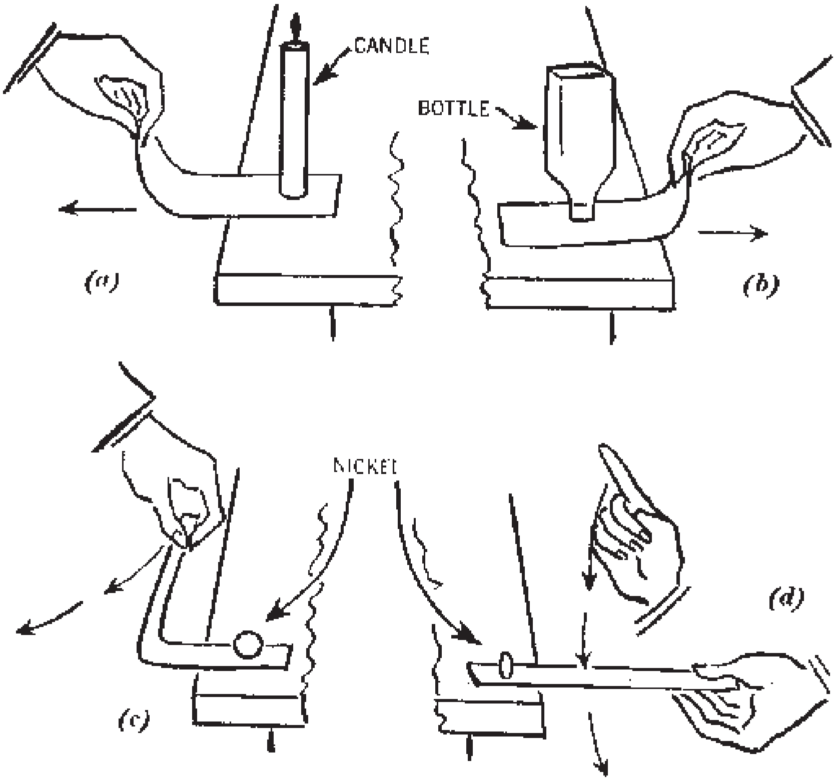
"Perhaps it's not so easy to understand after all, but let me try," said Mother. "We have said that what is important is the frictional force, but what is really relevant is how long this force lasts."

"Ha!" said Leela. "At last we see the dependence on fast and slow: it's the time for which we pull that makes a difference."

"Exactly," said Mother. "If you pull slowly, the time duration is longer. In physics, you will say that the *impulse* (= *Force X time duration*) lasts longer. If the time is short, the impulse is small."

"Why is it that the impulse is important? Normally, we talk about forces and their effects," asked Leela.

"Do you recall how forces af-



fect objects?" asked Mother.

"Yes, it's Newton's second law. Every object remains in a state of rest or uniform motion unless acted upon by an external force. I guess that means when a force acts on a body, it changes its speed. In fact, I know that it causes it to accelerate, or sometimes decelerate, since we write $F=ma$, where F is the force, m the mass and a the acceleration."

"Yes, that's the key point. Change in speed. Actually, velocity times mass is called the *momentum* of an object. So you can also say that a force causes an object to change its momentum."

"You will see that *Force X time* has the same dimensions as momentum. Hence it is the impulse that changes the momentum of objects and that is why impulse is what ultimately decides whether the coin will move with the card, or be lazy and fall into the glass. In general, this whole complicated explanation is simply replaced by the one word `inertia'!"

"Actually, I knew this stuff already," said Maya importantly. Then, as the others looked disbelievingly at her, she continued, "When I'm combing my hair in a hurry and yank on it, I notice it breaks off near the end, where the comb is. Perhaps that's because it doesn't have time to tell the rest of the hair to get pulled or stretched. But if I simply hold both ends of the hair and pull, perhaps it will stretch and stretch and finally break somewhere near the middle? Shall I try?!"

Both Leela and Mother laughed.

"I don't think you need to sacrifice your hair in the cause of science. Perhaps an ordinary thread would do. Also, you can knot beads into the string so you can easily tell exactly where it breaks off. Hold one end fixed or tie it to some support. Then try yanking on the string or else pulling it slowly until it can't stretch any longer and breaks."

"I think if you pull it slowly, it will break at the top end, because it's supporting the maximum weight of all those beads," said Leela. "Any way, let's do it and see."

The two children rushed off to get the beads and thread while Mother picked up the forgotten piece of paper and left the room smiling.

Grains into food

Kamal Lodaya,
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Around 20,000 years ago the Earth faced the last *ice age*, when most of the northern continents were covered with ice sheets. Around 13,000 years ago the climate had become warmer and much of the Earth had long dry seasons. *Annual plants*, those which live for less than a year and die in the dry season, leaving a seed or tuber, flourished in these conditions. All the grains we use are such annual plants, as also other foods we eat (such as green peas and *dals*).

The earliest evidence of plant cultivation that we have is of wild rye (a grain like barley or wheat), from Syria before 10,000 BCE. The *Fertile Crescent*, spreading from Israel to Syria to Iraq, is where we find the earliest evidence of agriculture, although it is possible that agriculture was invented in several places across the world. The early farmers selected plants with abundant plump grains, improving the edibility of the plant. Around 9500 BCE, two kinds of wheat, barley, lentil (*masoor dal*), chickpea (*chana dal*) and peas all appear in the Fertile Crescent. These are the earliest domesticated plants.

Wheat

Einkorn wheat has one grain on each spikelet, and grows wild in the southeast parts of Turkey. It is *diploid*—there are two sets of 7 chromosomes in each cell. (Humans are diploid with 46 chromosomes). Einkorn was crossed with a wild grass *Aegilops squarrosa* to give a tet-

raploid—four sets of 14 chromosomes. This wheat is used to make *semiya*, *pheni* and vermicelli.

Another wild "goat" grass, *Triticum tauschii*, was now crossed to produce our modern wheat, a tetraploid with 21 chromosomes. This happened somewhere near the southern end of the Caspian Sea around 8500 BCE. Having four sets of chromosomes is of advantage to a species, for example the modern wheats are more resistant to cold weather. Hexaploid wheats have been grown by farmers but are not widely used.

In India we have at least three species of wheat. *Triticum aestivum* is used to make bread and *roti*s all over the world. The dwarf variety *Triticum sphaerococcum*, called *shot wheat*, is grown in north India. *Triticum compactum* or *club wheat* used to be grown widely a hundred years ago but is now not so popular. It has ears with spikelets packed closer together. The shorter dwarf varieties of wheat were developed by Japanese farmers in the 1930s and are less damaged by wind. In 1952 **Norman Borlaug** crossed them with traditional Mexican varieties to obtain high-yielding varieties which heralded the *Green Revolution*. When awarded the Nobel peace prize in 1970, Borlaug credited Indian scientists, in particular **M.S. Swami nathan**, for the "team effort" on the Green Revolution.

Barley (*yava*)

Like wheat, barley is found in our earliest civilization, in Harappa, Mohenjodaro and other Indus Valley sites, which flourished from 2500 BCE to 1500 BCE. It is mentioned in the Aryan texts and may have been the staple grain eaten

around 1500 BCE.

Wild barley, *Hordeum vulgare spontaneum*, is a diploid with 14 chromosomes. (The latin word *vulgare* means “common”.) It is a grass which grows everywhere from North Africa to Tibet. This barley has two rows of grains. Cultivated barley has two rows of grains or six rows (*Hordeum vulgare hexastichum*). The six-row barley has more nutritional content, while the two-row barley has more fermentable sugar content and is used in making alcoholic drinks like beer.

Millets

Ragi (*kezhvaragu* in Tamil) is the botanical species *Eleusine coracana*, also called finger millet. Bajra (*sajje* in Kannada and *kambu* in Tamil) or pearl millet has the botanical name *Pennisetum glaucum*. Thennai or *kangni* is foxtail millet, *Setaria italica*.

Millets are small-seeded grasses which are very hardy and can grow in very dry areas. Ragi is found in the southern sites of the Indus Valley civilization, dated to around 1800 BCE. Bajra is found

in Karnatak, on the the Tungabhadra river, 500 BCE. Ragi is very and ragi balls (*mudde* ada) are popular in a. Ragi is also used in g the Maharashtrian *bhakhri*.

There is an *Eleusine indica*, a diploid weed species used for lawns and golf courses, but it cannot cross with the tetraploid ragi. The origins of ragi are in *Eleusine africana* which grows wild in southern Ethiopia and Uganda. So ragi is also called African millet. Bajra is found in northern Mali around 2500 BCE. These grains may have been brought from Africa to India around 2000 BCE. The earliest cultivation of thennai is known in China near the Huang He (yellow river) around 6000 BCE.

Jowar (cholam in Tamil), botanically sorghum bicolor, is sometimes called a millet. It is one of the most drought-resistant crops. In times of drought it rolls its leaves to lessen water loss, and if drought continues, it becomes dormant instead of dying.

Where jowar comes from is a mystery. Most cultivated varieties can be traced to Africa south of the Sahara, but the earliest evidence of its cultivation is from the southern Indus Valley sites around 2000 BCE, where it is not a native crop. The name “sorghum” comes from “grain of Syria”.

Rice

There are around two lakh varieties of *Oryza sativa*, and around one lakh in India alone. It is the

most important staple food for a large part of the world’s population.

Wild rice is a grass which grows on the edges of ponds and lakes, for example in the deltas of rivers like the Indus, Ganga and Mahanadi. It seems to have been first cultivated in the valley of the Yangtze river in China around 8000 BCE. Soon after are found two varieties, one with long shining grains (the subscpecies called *Oryza sativa indica*) and one with short sticky grains (*Oryza sativa japonica*). Today *indica* is more commonly grown in India (perhaps because it is more convenient to eat it with the hands like we do), and *japonica* in China and Japan (perhaps because they eat it with chopsticks). Rice is found at the Lothal and Rangpur sites in Gujarat of the Indus Valley civilization.

At the International Rice Research Institute in the Philippines, high-yielding varieties of rice were created in 1966 by crossing Indonesian and Chinese varieties. This yielded a *Green Revolution* for rice as well.

Based on *The story of our food* by K.T. Achaya

Do You Know?

1. Why do memories of vivid dreams disappear soon after waking up?

2. Are strange science theories like Quantum Mechanics actually useful in everyday life? Should scientists waste public money on such research simply for their curiosity?

3. I have heard that watching TV can be bad for children. But can't regular physical exercise counteract any negative effects of TV watching?

4. Can people actually die because of hot weather as in a "heat wave"?

5. Is it possible for a muscle to turn into a bone?

6. I read of a cricketer developing a "stress fracture". What is it, and how does it develop?

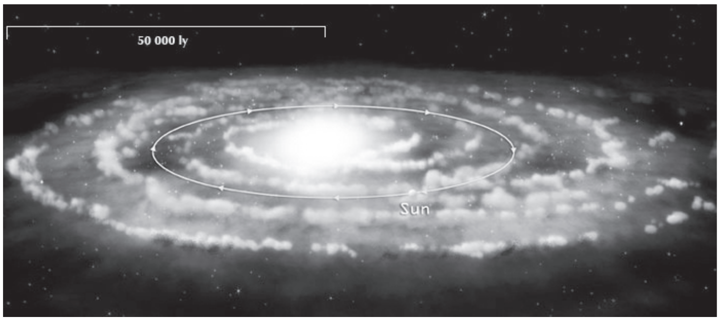
Answers to last issue's Do You Know?

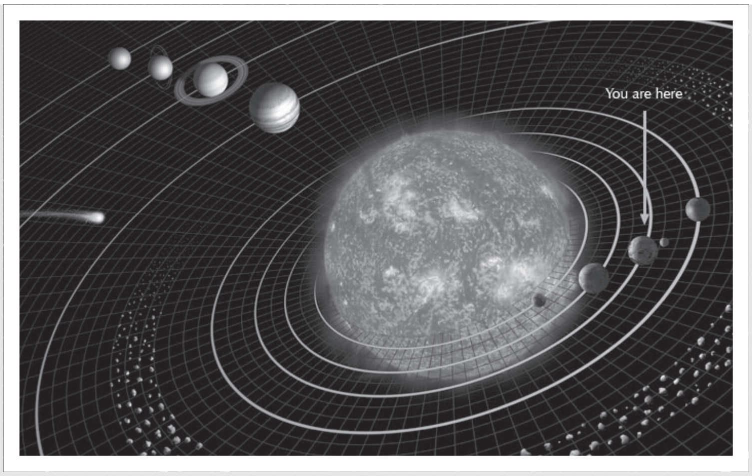
1. How fast is the Earth moving?

Ans: This question can be meaningfully answered only if you ask back, "Compared to what?". All questions about motion need a {\em frame of reference}. If I am moving, and you are moving faster than me, we can talk of your relative speed with respect to me. Consider the movement of the Earth's surface with respect to the planet's centre. The Earth rotates once every 23 hours, 56 minutes and 4.09053 seconds, called the sidereal period, and its circumference is roughly 40,075 kilometers. Thus, the surface of the Earth at the equator moves at a speed of 460 meters per second.

At school, we learn that the Earth is moving about our Sun in a very nearly circular orbit. It covers this route at a speed of nearly 30 kilometers per second. In addition, our solar system — with the Earth and everything else — whirls around the centre of our galaxy at some 220 kilometers per second. As we consider increasingly large size scales, the speeds involved become truly huge!

Each of the motions described above were given relative to





some structure. Our motion about our Sun was described relative to our Sun. The question arises: Is there some universal frame of reference relative to which we can define the motions of all things? The answer may have been provided by the *Cosmic Background Explorer* (COBE) satellite.

In 1989, the COBE satellite was placed in orbit about the Earth (again, the Earth is the frame of reference!) to measure what is known as the *cosmic microwave background radiation* (CBR) that remains from the immensely hot and dense primordial fireball that was produced in the early Universe. The CBR presently pervades all of space. It is the equivalent of the entire universe "glowing with heat".

One of COBE's discoveries was that the Earth was moving with respect to this CBR with a well-defined speed and direction. Because the CBR permeates all space, we can finally answer the original question fully, using the CBR as the frame of reference.

The Earth is moving with respect to the CBR at a speed of 390 kilometers per second. We can also specify the direction relative to the CBR. It is more fun, though, to look up into the night sky and find the constellation known as Leo (the Lion). The Earth is moving toward Leo at the dizzying speed of 390 kilometers per second. It is fortunate that we won't hit anything out there during any of our lifetimes!

2. Is it true that hot water freezes faster than cold water or that cold water boils faster than hot water?

Ans: No, cold water does not boil faster than hot water. Cold water absorbs heat heat faster while it is still cold; once it gets up to the temperature of hot water, the heating rate slows down and from there it takes just as long to bring it to a boil as the water that was hot to begin with. Because it takes cold water some time to reach the temperature of hot water, cold water clearly takes longer to boil than hot water does. As a general answer, note that the rate of heating of a liquid depends on the *temperature difference* between the liquid and its surroundings; in fact it depends on the fourth power of this temperature.

Then why do many people think that cold water boils faster than hot water? Cold water starts boiling sooner than one might expect because of the greater heat absorption rate we mentioned, and this gives such a feeling.

Does hot water freeze faster than cold water? Not usually, but possibly under certain conditions. It all depends on how fast the cooling occurs, and it turns out that hot water will not freeze before cold water but will freeze before lukewarm water. Water at 100 degrees C, for example, will freeze before water warmer than 60 degrees C but not before water cooler than 60 degrees C.

We know that water boils at 100 degrees Celsius. It takes 100 calories to bring one gram of liquid water from 0 degrees Celsius to 100 degrees C (1 calorie per degree). However, it takes another 540 calories to convert the gram of water at 100 degrees to steam by vapourizing it. When water is hotter than 80 degrees C, parts of it vapourize. The energy needed to vapourize (540 calories per gram) is taken from the remaining water, so this cools rapidly. When water is colder than 80 degrees, very little of it vapourizes. So when it is left alone, it simply cools by thermal conduction (its heat is given away to its surroundings such as its container). This just needs 1 calorie per Celsius degree and so is a much slower process than the rapid cooling of the water that was at 80 degrees.

3. Do humans have some kind of homing instinct, possibly involving navigation by magnetism like certain birds do?

Ans: Sadly, no. There has been a lot of research on this but there is no conclusive evidence that human beings have any homing instinct like some birds seem to have.

Having a magnetic compass sense is not equivalent to having a homing instinct, because knowing which way is north does you no good if you do not know whether you are north, south, east or west of home. Many animals, including humans, keep track of where they are (and hence the direction to home) by a method known as dead reckoning: as they move about, they keep track of each individual movement, adding these up to derive their net change in position.

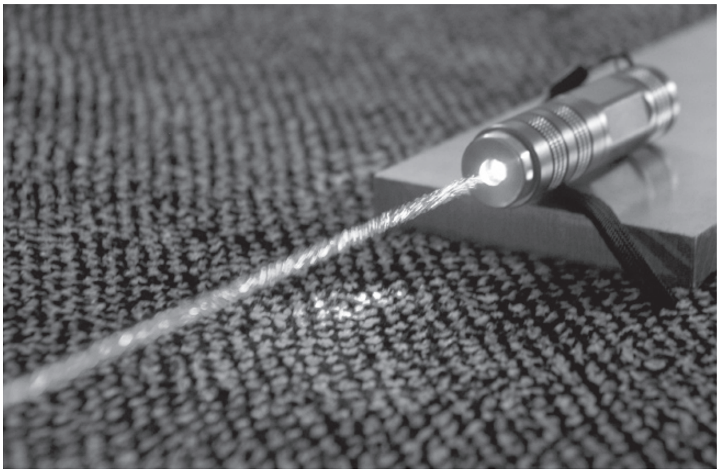
Navigational systems have been detected in rats, though. When a rat is placed in a large recording chamber and allowed to forage for food, there are cells in some parts of the brain that fire whenever the rat faces one particular direction. It does not matter where the rat is in the chamber; whenever it faces in that direction, those cells fire like crazy. Each of the head-direction cells has its own, unique directional preference, so that the direction the rat faces at any given moment is signaled by the firing of some particular combination of these cells.

Do human beings possess such systems? Nobody knows, as yet.

4. Can a pocket laser pointer damage the eye?

Ans: Eye damage from a pocket laser is unlikely, but could be possible under certain conditions. Red laser pointers that are "properly labeled" in the 3-5 mW range

seem to be safe but green lasers may exceed safety limits. Many laser pointers are in the range of 1 to 5 milliwatts (mW) and are mostly safe.
Why even worry about 5 mW (5 thousandths of a watt), which is less than one percent of one percent of the power of a 60 Watt incandescent bulb?
First, the numbers are used differently. Light bulb wattage measures the power it uses. It only converts about 10 percent of that electrical power into light. In a laser, the power is a measure of the light output.
Second, the light bulb gives light in all directions so you only see a small part of the whole. As you move away from the bulb, you see a quarter of the light every time the distance is doubled. A laser gives light in one small beam. If it gets into the eye, you receive all the laser's energy, not just a fraction of it.
Third, a light bulb gives off light at many different wavelengths (different photon energies). A laser is a pure tone, only one wavelength. The coherent light is more damaging.
The common red laser pointer is a diode laser, really just a special type of transistor, or diode. Because of the unique features of laser light, it is magnified by 100,000 times as it passes through the eye. The light passes to the back part of the eye, the retina, which is where we perceive vision. The eye actually sees a small part of the electromagnetic spectrum that runs from short cosmic ray energies to long radiowaves. We see only from violet to red. Infrared (IR) and ultraviolet (UV) are just outside our ability to see. The eye is most sensitive to yellow-green light (550 nm). At the same power, 670 nm red light is only 3 percent as bright.
The real danger is that a regular pointer laser can overwhelm the eye with light, typically called flash blindness.
Some basic rules with lasers: Never direct a beam onto another person, especially their face. Do not shine it onto a mirror or mirror-like surface. Do not look at the beam through binoculars or a microscope.



5. How are traits passed on through DNA?

Ans: Proteins do much of the chemical work inside cells, so they largely determine what those traits are. But those proteins owe their existence to the DNA (*deoxyribonucleic acid*), so we need to understand them.
The best place to start with is its basic building blocks. DNA consists of four different sugars that interact with each other in specific ways. These four sugars are called *nucleotide bases* and have the names adenine (A), thymine (T), cytosine (C) and guanine (G). Think of these four bases as letters in an alphabet, the alphabet of life!

In this language, there are words like GATCATCCG: we now have a little piece of DNA, or a very short word. A much longer piece of DNA can be seen as connecting words to make a sentence, or gene, that describes how to build a protein. And a still longer piece of DNA could contain information about when that protein should be made. All the DNA in a cell gives us enough words and sentences to serve as a master description or blueprint for a human (or an animal, a plant, or a microorganism). Actually it is all more complicated, but this is the idea. In practice, active stretches of DNA must be copied as a similar message molecule called RNA. The words in the RNA then need to be "read" to produce the proteins, which are themselves stretches of words made up of a different alphabet, the amino acid alphabet. The *Central Dogma* of heredity says that the DNA code turns into an RNA message that has the ability to organize 20 amino acids into a complex protein: DNA -> RNA -> Protein.

To understand how this all comes together, consider the trait for brown eyes. DNA for a brown-eyes gene is copied as a brown-eyes RNA message. That message is then translated into the brown protein pigments found in the cells of the eye. For every trait we have – eye colour, skin colour and so on – there is a gene or group of genes that controls the trait by producing first the message and then the protein. Sperm cells and eggs cells are specialized to carry DNA in such a way that, at fertilization, a new individual with traits from both its mother and father is created.

6. How do frogs survive winter in very cold countries? Why don't they freeze to death?

Ans: Frogs are amazing animals, yes. They can be found at the Arctic Circle, in deserts, in tropical rain forests and practically everywhere in between. Some of their survival strategies are nothing short of ingenious. Various frog species use two strategies to deal with environmental extremes: *hibernation* and *estivation*. Hibernation is a common response to the cold winter of temperate climates. After an animal finds or makes a living space (*hibernaculum*) that protects it from winter weather and predators, the animal's metabolism slows dramatically, so it can "sleep away" the winter by utilizing its body's energy stores. When spring weather arrives, the animal "wakes up" and leaves its hibernaculum to get on with the business of feeding and breeding.

Estivation is similar to hibernation. It is a dormant state an animal assumes in response to adverse environmental conditions, in this case, the prolonged dry season of certain tropical regions.

Terrestrial frogs normally hibernate on land. American toads (*Bufo americanus*) and other frogs that are good diggers burrow deep into the soil, safely below the frost line. Some frogs, such as the wood frog (*Rana sylvatica*) and the spring peeper (*Hyla crucifer*), are not adept at digging and instead seek out deep cracks and crevices in logs or rocks, or just dig down as far as they can in the leaf litter. These hibernacula are not as well protected from frigid weather and may freeze, along with their inhabitants.

And yet the frogs do not die. Why? Ice crystals form in such places such as the body cavity and bladder and under the skin, but a high concentration of glucose in the frog's vital organs prevents freezing. A partially frozen frog will stop breathing, and its heart will stop beating. It will appear quite dead. But when the hibernaculum warms up above freezing, the frog's frozen portions will thaw, and its heart and lungs resume activity — there really is such a thing as the living dead!

Aquatic frogs such as the leopard frog (*Rana pipiens*) and American bullfrog (*Rana catesbeiana*) typically hibernate underwater, in mud. They must be near oxygen-rich water and spend a good portion of the winter just lying on top of the mud or only partially buried. They may even slowly swim around from time to time.

Several species of frog are known to estivate. Two of the better-known species are the ornate horned frog (*Ceratophrys ornata*) from South America and the African bullfrog (*Pyxicephalus adspersus*). When the dry season starts, these frogs burrow into the soil and become dormant. During the extended dry season, which can last several months, these frogs perform a neat trick: they shed several intact layers of skin, forming a virtually waterproof cocoon that envelopes the entire body, leaving only the nostrils exposed, which allows them to breathe. These mummies remain in their cocoons for the duration of the dry season. When the rains return, the frogs free themselves of their shrouds and make their way up through the moist soil to the surface.

Next time you meet a frog, show it some respect!

Science News

Headlines

. Neutrinos faster than light?
. Aerosols affect rainfall patterns
. Dinosaurs used to migrate too
. Teenage brains change rapidly
. Lasers reveal a gem's origins
. Did you notice a ripple in one of Saturn's rings?

Read more details about these below.

Neutrinos faster than light?

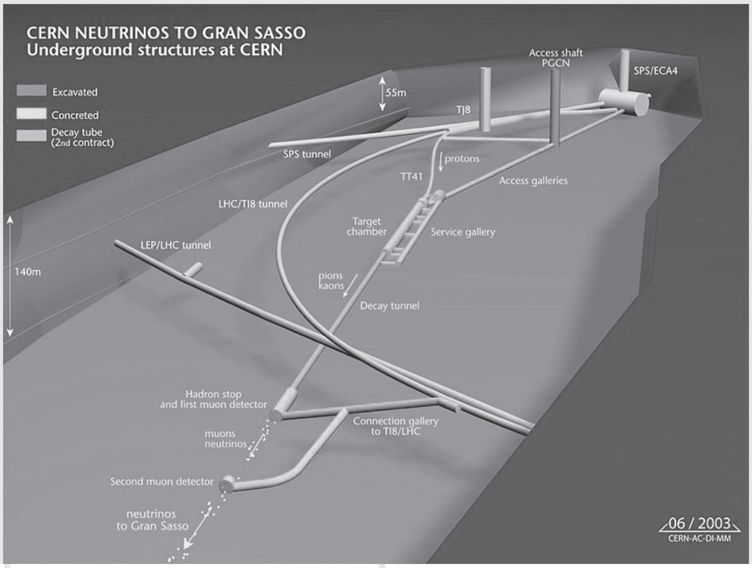
The OPERA experiment in Europe has detected neutrinos that appear to travel faster than light. Einstein's special theory of relativity says that nothing can travel faster than light in vacuum. (In water or any medium, for instance, it is possible for particles to travel faster than the speed of light in water or that medium). So this discovery is testing fundamental assumptions in physics and is a subject of inquiry and debate: if independently confirmed, it could have far-reaching implications for our understanding of physics, including exotic options such as time travel to the past, etc!

Dario Autiero, who leads the OPERA team's analysis of the faster-than-light result, has stated that further scrutiny and independent tests are necessary to definitely confirm or refute the results. Independent tests by other collaborations are under way.

What is this experiment? Protons are accelerated in a beam pipe called the SPS at CERN in Geneva, Switzerland. These very fast protons hit a target and produce secondary particles, which later decay to produce neutrinos. All this happens over a kilometer of distance. But now comes the amazing part: these neutrinos travel through the Earth for another 730 km before they are detected at the Gran Sasso laboratory (LNGS) in Italy! A typical track from a neutrino is seen in the figure.

How is this possible? That is because neutrinos are very special particles. These are usually produced in association with particles such as electrons and muons. Neutrinos have no charge and so do not feel electromagnetic interactions. So even though they are copiously produced (in the Sun, in stars, in Earth's atmosphere, in radioactivity) they are rarely observed. In this experiment, mostly muon-type neutrinos were produced.

Since they are so weakly interacting, they can travel large distances without disturbing anything in their path. While protons, electrons and even light are absorbed quickly by Earth, the neutrinos can on average go through



seven Earth diameters without interacting even once! So it is very difficult to study them. However, they have exotic properties which scientists believe would help them understand fundamental properties about the formation and nature of the Universe; hence there are several neutrino experiments around the world.

The OPERA experiment measured the speed of the neutrinos. Since speed equals distance divided by time, they had to know the distance from CERN to LNGS very precisely. They also had to know the time taken by the neutrinos (arrival or detection time at LNGS minus the production time at CERN) correctly. For the timing measurement, they used GPS (Geographic Positioning Systems). However, one clock was used to measure the production time and another the detection time (since these are in two different places, actually in two different countries!). Because of this, the clocks had to be *synchronised* very accurately. GPS along with atomic clocks were used to give an accuracy of 2.3 nanoseconds (one nanosecond (ns) is 1 billionth of a second, i.e., 1/1000000000 s).

But this is not enough. The GPS signal only came to the main control room. From here, it had to be routed by cables and electronics to the neutrino beam control room 8 km away! This needed the length of the cables to be found, and the delay due to this was calculated to be more than 10,000 ns. A similar delay occurred in the detection end at Gran Sasso. All this needed each element of the system to be accurately measured.

Standard GPS has only 100 ns accuracy. To improve this to the 1 ns range, OPERA researchers used a precise PolaRx2eTR GPS timing receiver which allowed measurement of the time offset between an extremely precise atomic clock and each of the satellite clocks. In addition, highly stable cesium clocks were installed both at LNGS and CERN to cross-check GPS timing and to increase its precision. The travel time (called time of flight) was eventually measured to an accuracy of 10 ns.

Now for the distance. The detector is underground so it was not a simple matter of starting with a measuring tape at CERN and measuring the distance to the detector. While GPS was used to measure the coordinates of the source, special techniques had to be used to link the coordinates of the detector with the location just overhead overground. In fact, to connect the surface GPS location to the underground site, traffic had to be diverted on the access tunnel to the lab! Finally, when all the corrections were put into place, the researchers calculated the distance to an accuracy of 20 cm within the 730 km path!

There were further complications: individual neutrinos are not measured, but only bunches of them. Indeed, bunches of protons were measured at the source and signals for neutrinos were measured at the detector.In the final analysis, the experimental result was that the neutrinos on the average arrived about 60 ns earlier than light could have traveled over that distance. This is a value much larger than the experimental uncertainty due to measurement error, so the group is very confident of their results. The experiment was repeated recently and the result was confirmed.

Many experiments around the world are planning to modify their equipment to cross-check this measurement. In the meanwhile, theorists have been busy, trying to understand the consequences of such a dramatically new result. More than 80 papers discussing the experiment have been posted on the *arXiv* website which is a forum for discussing and exchanging results in many sciences. Most try to explain the anomaly theoretically, while a small minority claim the experiment has problems. The view of CERN theorists was that "there was no consistent theoretical model that could accommodate the measurement."

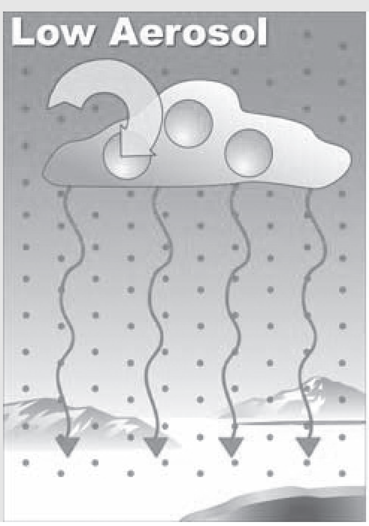
We may have to wait at least a year for independent confirmation before we know the truth. So don't plan that trip to meet Gandhi-ji yet!

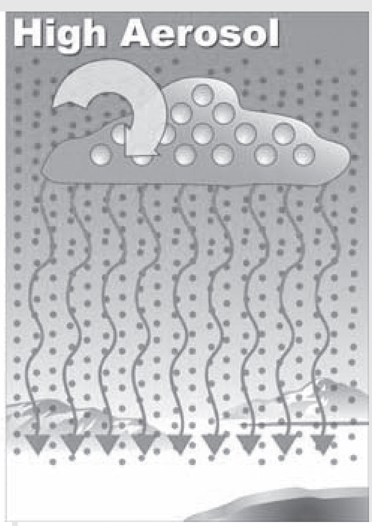
Aerosols affect rainfall patterns

If you're near a window, look up at a cloud and *really* look at it. If you look up again in a few minutes, you'll see that the cloud has changed shape and probably moved. Clouds contain cloud droplets, tiny quantities of water too small to overcome the wind and fall to the ground. Clouds also contain water molecules that condense, or concentrate, on tiny airborne particles called *aerosols*, forming drops of water. When drops get heavy enough, they fall as rain.

Some of these particles occur naturally and include dirt and dust. Other aerosols come from human activities and represent air pollution. Once these particles get swept up into a cloud, they start to make changes. Imagine what would happen with too many aerosols: the water molecules would condense, but not enough on any individual aerosol to make it heavy enough to cause rain.

Recent research has found a strong link between pollution and rainfall. They studied 10 years' worth of data to know how aerosols in the air affect cloud development. They learned that rainfall depended on the amount of aerosols in the clouds, as well as the type of cloud and amount of moisture. They found a link between large amounts of aerosols and extreme weather. The clouds in dry regions may hold their water longer, contributing to droughts. Clouds drifting over moist areas may lose their water more quickly, leading to severe rains. Both situations may pose severe problems for farmers.





Dinosaurs used to migrate too

Animals migrate to survive. Golden eagles head south for the winter, salmon swim upstream to lay eggs and locusts move on when it gets too crowded. Scientists now say that 150 million years ago, plant-eating dinosaurs called *sauropods* living in North America may have migrated, too. The new study suggests that these enormous animals traveled at the change of the seasons, leaving dry riverbeds in search of well-watered areas thick with plants.

The dinos' giant size kept them safe from smaller, sharp-toothed, carnivorous dinos, like *Allosaurus*. Scientists compared the chemicals in minerals with those in the teeth of sauropods called *Camarasaurus* to discover

the dinosaurs' wandering ways. When animals drink water, the oxygen in that water gets incorporated into the bloodstream and eventually into tooth enamel. Oxygen comes in different forms, called isotopes. Different sources of water may contain different isotopes, so the oxygen in a mountain stream may be slightly different from the oxygen in swamp water.

Scientists compared isotopes in the dino tooth enamel with isotopes in minerals near where the teeth had been excavated. The scientists found different levels in the teeth and the minerals, which suggests the sauropods had another source of water.

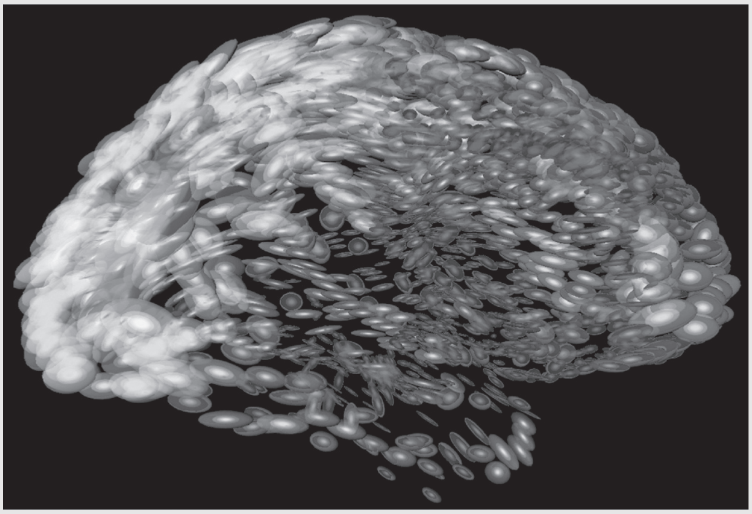
So teeth tell a tale of travel!

Teenage brains change rapidly

In 2004, neuroscientist Cathy Price of the University College London and her colleagues tested the IQs of 33 teenagers who ranged in age from 12 to 16. (An IQ, or intelligence quotient, attempts to measure a person's ability to think and reason.) At the same time, the scientists took pictures of the teens' brains using MRI, or magnetic resonance imaging. An MRI produces images of the brain using radiation and a powerful magnetic field.

A few years later, in 2007 and 2008, the participants returned to the lab. Like the first time, the scientists tested the teenagers' IQs and used an MRI to see their even further.

When Price looked at the brain scans, she discovered more surprises. The brains of teens whose scores went up on verbal IQ tests had more gray matter than before in an area called the left motor cortex, which is involved in speaking. She found other connections between increased IQ scores and gray matter, which is tissue containing brain cells.



brains. But when Price compared the old and new results, she was shocked. Many of the teenagers' IQs had changed dramatically over the years. One person had lost 18 IQ points; another had gained 21. Some people with high IQs on the first test had even higher IQs on the second. And some low-scoring individuals saw their scores fall

Scientists do not understand *why* teenagers' brain scans show so many changes, but that teenage brains change so much is interesting.

Lasers reveal a gem's origins

Can you look at a gem and say where it was mined? Does it come from Australia or the

Congo?

Beneath the surface of a gemstone, on the tiny level of atoms and molecules, lie clues to its origin. Scientists have reported on a technique that uses lasers to unravel these clues and identify a stone's homeland.

Just as heat can turn ice into water or water into steam, energy from a laser beam can change the state of matter of a mineral. The laser changes a miniscule portion of the gemstone into *plasma*, a gaseous state of matter in which tiny particles called electrons separate from atoms.

The plasma, which is super-hot, produces a light pattern. (The science of analyzing this kind of light pattern is called *spectroscopy*.) Different elements produce different patterns, but gemstones from the same area produce similar patterns. People have already collected patterns from thousands of gemstones, including more than 200 from diamonds. They can compare the light pattern from an unknown gemstone to patterns they do know and look for a match. The light pattern acts like a signature, telling the researchers the origin of the gemstone.

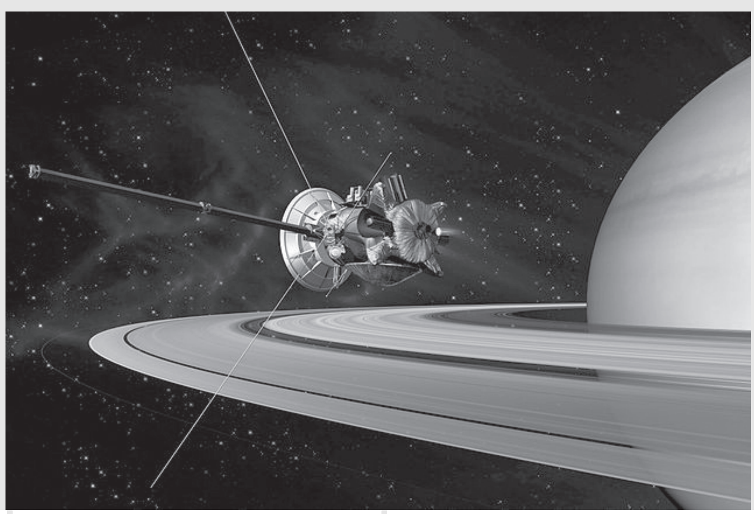
Did you notice a ripple in one of Saturn's rings?

No, you couldn't have, unless you were working on the *Cassini* spacecraft, which orbits Saturn and beams back information about the planet and its moons and rings. This happened when a comet plowed through Saturn's rings and blasted apart, some 600 years ago — more than 200 years before *Galileo Galilei* first gazed through the telescope and mistook Saturn's legendary rings for handles or mammoth moons.

Those rings are actually vast seas of individual rocks. Just as an object creates waves when it splashes in water, the comet disturbed the rocky rings on its final flight. Patterns in Saturn's rings allow astronomers to learn about the planet's past.

Scientists found the ripples in Saturn's C ring, a faint band inside the more familiar and giant A and B rings. Over time, the ripples bunched up. They were highly regular little wiggles that rippled over hundreds of kilometers in a very specific pattern. The scientists didn't see the ripples in pictures. Instead, they found telltale disturbances in radio waves from a Cassini experiment.

Scientists found similar waves in the rings of Jupiter too. In the case of the 600-year-old ripples on Saturn, they identified two distinct wave patterns of similar sizes, which suggests that the plunging comet passed twice near the ring and never had a chance of escape the second time.



Saturn's rings are beautiful, and the study of astronomy offers plenty of drama as well.

Activity page

Boggle'd

Boggle is a word game designed by Allan Turoff and trademarked by Parker Brothers and Hasbro. Here we play a smaller version of the traditional game.

How to play

S	A	P
O	C	L
E	N	I

Search for words that can be constructed from the letters of sequentially adjacent squares, where "adjacent" squares are those horizontally, vertically or diagonally neighboring. Words must be at least three letters long, may include singular and plural (or other derived forms) separately, but may not use the same letter square more than once per word.

An example "SOAP" is already done for you.

The original game has a time limit of 3 minutes and uses 4 X 4 squares. Here, your time limit is the next JM issue! Do write in your word list to the JM address given in the magazine and we'll print the ones with the most number of words. Don't forget to write in your name and address.

S	A	P
O	C	L
E	N	I

Sudoku

Rules

. Use the numbers from 1 to 6.

. Every row must have all the numbers from 1 to 6

. Every column must have all the numbers from 1 to 6

. Every sub-rectangle must have all the numbers from 1 to 6

. The central shaded square (in the medium puzzle) must have the numbers 1 to 4

(A sub-rectangle is the 2 X 3 rectangle; the 6 X 6 square is broken up into 6 such sub-rectangles.)

Use the numbers already filled in as hints to complete the grid. Each Sudoku puzzle has a unique solution.

Send in your answers to us at the JM address given elsewhere in the magazine. Don't forget to write in your full name and address.

EASY

1				6	
					2
	4	3			
			5	3	
	2				5
				1	

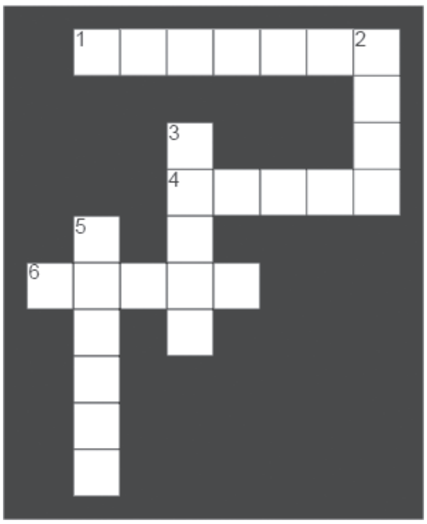
MEDIUM

		1			4
	5				2
3					
	2			5	

Cross Word

Cross Word

In this International Year of Chemistry, find out more about your body.
Credit: Thomas Jefferson National Accelerator Facility – Office of Science Education, http://education.jlab.org/elementcrossword/the_body_01.html.



Across

1. This element's name comes for the Greek word for hidden.

4. This element makes up nearly 1% of the earth's atmosphere.

6. Ions of this element were used as a propellant aboard the space probe Deep Space 1.

Down

2. This element is the fourth most abundant element in the universe.

3. This radioactive gas sometimes seeps into and accumulates in houses.

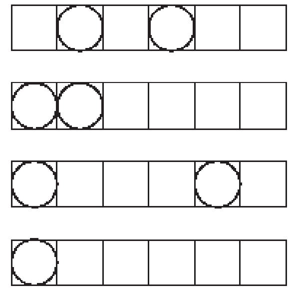
5. The first member of the Noble Gases, this element is the second most abundant element in the universe.

MREATS

BARNOC

GHRUNE

LHYOUR



The Chemistry Scrambled Words Game

Find out the chemical elements whose names are scrambled, using the clues given along-side. From http://education.jlab.org

LIUSNMEE

Clue: This element was discovered because it was contaminating the sulfuric acid being produced at a particular factory in Sweden.

UCAEMMIIR

Clue: This element was named for the Americas.

LENIOURF

Clue: This element joins with carbon to form a class of compounds known as fluorocarbons.

HRUMNEI

Clue: This element's chemical symbol is Re.

UPMIYDEOSAMR

Clue: This element is primarily alloyed with magnesium to make high-strength metals that are used in aircraft engines.

BMETRIU

Clue: All atoms of this element contain 65 protons.

HLUAMLIT

Clue: This element's chemical symbol is Tl.

GMSMUAEIN

Clue: Since it burns with a brilliant white light, this element is frequently used in fireworks.

IEUNTSNIIME

Clue: This element was discovered in the radioactive debris produced by the detonation of the first hydrogen bomb.

IMRUUC

Clue: This element was first produced by bombarding

Solutions to previous issue's Activities

Solutions to JM September-October issue's Activities

Boggle'd

Possible words are age, ages, are, ate, bear, beat, beg, beget, begs, beige, berate, big, eager, ear, eat, gate, gates, gear, get, gibe, great, rag, rage, rages, rags, rat, rate, rates, sea, sear, seat, siege, set, tag, tar, tear.

Alas. No-one sent in solutions to Boggle'd. Try out the one in this issue: it's a great way to improve your visual skills.

Cross Word

Across

1. Larynx 2. Circulation 3. Epidermis 5. Tendon 6. Pulse

Down

1. Ligament 4. Pupil

Jumble

1. TRACTOR 2. GENERIC 3. SLITHER 4. CURTAIN

Opposites Attract.

Answer: Electric Charges

Energy Hunt

Battery, Calorie, Dam, Engine, Hybrid car, Joule, Kilowatt, Nuclear, Power, Solar, Thermal, Turbine, Wind

EASY

1	2	5	3	6	4
6	4	3	2	1	5
2	5	4	1	3	6
3	6	1	4	5	2
5	1	2	6	4	3
4	3	6	5	2	1

MEDIUM

2	4	3	5	1	6
6	1	5	4	3	2
1	5	2	3	6	4
3	6	4	1	2	5
4	3	6	2	5	1
5	2	1	6	4	3

G	G	T	H	E	R	M	A	L	V	H
I	O	U	U	B	A	T	T	E	R	Y
P	O	P	K	R	O	M	I	N	E	B
U	U	U	I	Q	B	S	F	U	Y	R
Y	C	A	L	O	R	I	E	C	R	I
D	T	Y	O	E	Y	G	N	L	X	D
D	P	T	W	I	N	D	G	E	L	C
S	O	L	A	R	L	A	I	A	A	A
W	W	W	T	X	X	X	N	R	R	R
S	E	K	T	M	M	E	E	R	C	S
N	R	O	Y	D	A	M	E	L	A	W

Nature Diary

Snow Leopard

The snow leopard (Uncia uncia or Panthera uncia) is a moderately large cat native to the mountain ranges of South Asia and Central Asia. Snow leopards live very high up between 3,000 and 5,500 metres above sea level in the rocky mountain ranges of Central and South Asia.

Snow leopards show several adaptations for living in a cold mountainous environment. Their bodies are stocky, their fur is thick, and their ears are small and rounded, all of which help to minimize heat loss. Their paws are wide, which distributes their weight better for walking on snow, and have fur on their undersides to increase their grip on steep and unstable surfaces; it also helps to minimize heat loss. Snow leopards' tails are long and flexible, helping them to maintain their balance, which is very important in the rocky terrain they inhabit. Their tails are also very thick due to storage of fats and are very thickly covered with fur which allows them to be used like a blanket to protect their faces when asleep.

Snow leopards are carnivores and actively hunt their prey, though, like all cats, they are opportunistic feeders, eating whatever meat they can find, including carrion and domestic livestock. They can kill animals three times their size, such as the Bharal, Himalayan Tahr and Markhor but will readily take much smaller prey such as hares and birds. Unusually among cats, snow leopards also eat a significant amount of vegetation, including grass and twigs.

In 1972, the International Union for Conservation of Nature (IUCN) placed the snow leopard on its Red List of Threatened Species as globally "Endangered"; the same threat category was applied in the assessment conducted in 2008.

Their secretive nature means that their exact numbers are unknown, but it has been estimated that between 3,500 and 7,000 snow leopards exist in the wild; a few hundred of these live in India in regions such as Hemis National Park, in east Ladakh. Between 600 and 700 live in zoos worldwide while the bulk of them are in China.