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NASA's Twins Study Explores Gene Expression

Scott Kelly and Mark Kelly are identical twins; both are retired astronauts, but with two different sets of DNA. We know that identical twins have identical sets of DNA, so how did this happen?

NASA astronaut Scott Kelly returned home last March after nearly one year in space living on the International Space Station. His identical twin brother, Mark Kelly, remained on Earth. NASA used this opportunity to study the impact of space travel and zero gravity at the molecular, genetic, or DNA level. In fact, it was a great opportunity to test Nature versus Nurture. Thus the Twins Study was formed. Using Mark, a retired NASA astronaut, as a ground-based control subject, ten researchers are sharing biological samples taken from each twin before, during and after Scott's mission. From these samples, knowledge is gained as to how the body is affected by living in space for extended times. These studies are far from complete. Additional research analysis is in progress, but recently NASA released some preliminary findings.

The Twins Study brought ten research teams from around the country together to accomplish one goal: discover what happens to the human body after spending one year in space. NASA has a grasp on what happens to the body after the standard-duration six-month missions aboard the International Space Station but Scott Kelly's one-year mission is a stepping stone to a three-year mission to Mars. There were many changes that had been

observed before. For instance, Scott was two inches taller on his return. But the fact that he had an identical twin allowed NASA and the teams to study these changes in great detail.

Inflammation

One team that was a part of the study reported that altered levels of a lipid panel (lipids are fats) in Scott indicated inflammation while in space. On the ground, Mark's data indicated similar but lesser inflammation. They also measured the levels of *cytokines*, which are proteins that have an effect on well-known blood markers that indicate inflammation. There was an increase in groups of cytokines both during and after Scott's mission. There was also an increase of some proteins which help maintain normal insulin activity to regulate blood sugar after meals.

Effect of vaccines

Both brothers were given flu vaccines, on the ground and in space. There were similar immune responses in each twin, leading to the conclusion that the flu vaccine given aboard the space station is as effective as it is on the ground.

Hardening of arteries

Hardening and thickening of the arteries tell how inflammation and stress during spaceflight influences the structure and function of blood vessels. The twins' arteries were examined with ultrasound and they provided blood and urine samples throughout the duration of the mission. The carotid artery wall was thickened in Scott during and immediately after his mission, but no changes were observed in Mark. It is not clear yet whether this change is permanent or reversible.

Gut bacteria

Many thousands of types of bacteria (entire communities) live in the gastrointestinal tract and play a major role in human health. Scott's microbial species while in space were different than pre-flight, but became similar after he returned to Earth.

Study on Telomeres

Telomeres are a protective "cap" on the ends of chromosomes, which are made of DNA which carry genetic information. Telomeres usually decrease in length as a person ages. However, one team reported that Scott's telomeres significantly increased in average length while he was in space. Once he returned to Earth, his telomeres shortened in length within about 48 hours of landing, then stabilized to nearly the same levels as before his space stay.

The reasons for the lengthening of Scott's telomeres in space are still under investigation, but may be from his rigorous exercise regime and restricted caloric intake while on the space station.

Biochemical Profile

One team that was a part of the study found that Scott Kelly's body mass dropped during flight. His **folate** status was low before flight, but his folate went up while in space, perhaps due to better food choices from the space food system. Kelly's body mass decline and folate increase agree with the findings of telomere lengthening: the healthier lifestyle could have resulted in lengthening telomeres.

Genetic changes

Identical twins are genetically indentical, so they have identical DNA. The entire genome of both twins was sequenced. It showed that each twin has hundreds of unique mutations in their genome, more than expected, and some were found only after spaceflight, circulating in the blood as "cell-free DNA". This is thought to be from the stresses of space travel, which can

cause changes in a cell's biological pathways and ejection of DNA and RNA. Such actions can trigger the assembly of new molecules, like a fat or protein. It can also turn genes on and off, which change cellular function. Significant responses were found for at least five biological pathways in Scott during his time in space. These responses are important for future missions:

- hypoxia (likely from lack of oxygen and high CO_2 levels);
- mitochondrial stress and increased levels of mitochondria in the blood (indicating damage to the "power houses of cells");
- telomere length, DNA damage, and DNA repair (likely from radiation and caloric restriction);
- collagen, blood clotting, and bone formation (likely from fluid shifts and zero gravity);
- and hyperactive immune activity (from the new environment).

Although 93% of genes' expression returned to normal postflight, a subset of several hundred "space genes" were still disrupted after return to Earth. Hence, space travel has altered Scott's genes due to mutation. While most returned to normal after landing, the remaining 7% point to possible longer term changes in genes related to his immune system, DNA repair, bone formation networks, hypoxia, etc.

Summary findings

By measuring large numbers of metabolites, cytokines, and proteins, researchers learned that spaceflight is associated with oxygen deprivation stress, increased inflammation, and dramatic nutrient shifts that affect gene expression.

After returning to Earth, Scott started the process of readapting to Earth's gravity. Most of the biological changes he experienced in space quickly returned to nearly his preflight status. Some changes returned to baseline within hours or days of landing, while a few persisted after six months.

The Twins Study was an amazing opportunity to understand potential risks to the human body in space. This will help realise various possiblilities for long-term space travel, such as a journey to Mars (where the one-way outward journey itself lasts six to eight months), or even farther.

Source: NASA <http://www.nasa.gov/twins-study/about

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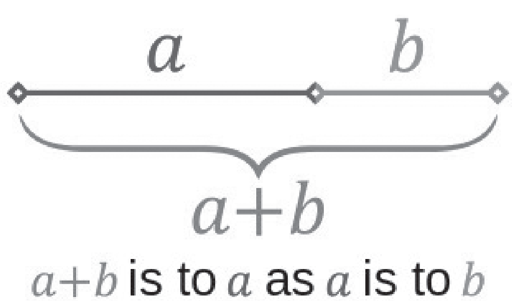
Beauty and the Fibonacci Sequence

As we saw in the article on the "***Spread of Arithmetic***", **Leonardo Fibonacci** was born some time in the later part of the twelfth century and learned and formalised a lot of arithmetic from Arab merchants whom he met while travelling along the Mediterranean coast. He is famous for popularising the Hindu-Arabic numerals in the book, "*Liber Abbaci*", which is the basis for the modern decimal system we use today. He also popularised a sequence noted by Indian mathematicians in the sixth century, which now goes by the name of Fibonacci Sequence.

The Fibonacci Sequence

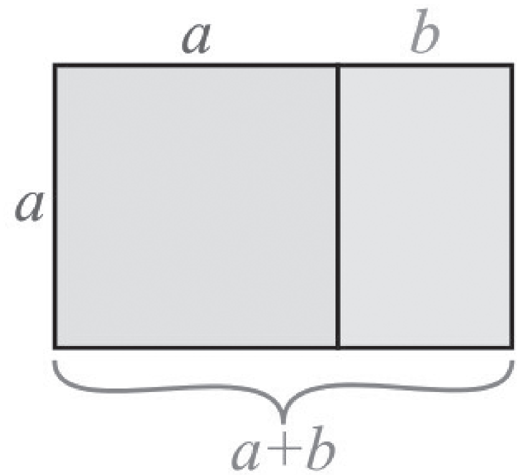


It is a simple sequence obtained by starting with 1 and adding the previous two numbers to get the next number:

1,1,2,3,5,8,13,21,34,55,89,144,...

Fibonacci discussed this sequence in the context of how rabbit populations multiply so rapidly. Fibonacci may not have known that the ratio of successive numbers in the sequence converges (that is, tends to the value) to the golden ratio.

Golden Ratio

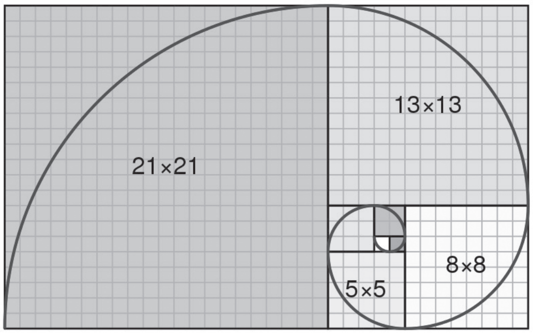


Architects believe that a rectangle with sides in the golden ratio looks aesthetically most pleasing to the eye. This ratio is given by an irrational number,

f = (1+\sqrt (5)/2)=1.618...

That is, if the length and breadth of a rectangle are in this ratio, the rectangle will look pleasing to the eye. This mysterious number is the ratio of a rectangle with sides (a+b) and (a) so that (a+b)/a=a/b=f, the golden ratio. If you know how to solve a quadratic equation, you can solve this to get the value given above. This ratio can also be expressed as a continued fraction.

What does the golden ratio have to do with Fibonacci sequence? Try dividing the successive numbers in the sequence. You will get 1, 2, 1.5, 1.67, 1.625, 1.615, 1.619, 1.618, 1.618, 1.618, 1.681, ... Very quickly the successive ratios give you the golden ratio.



Fibonacci Spiral

The Fibonacci spiral can be drawn using these numbers. Draw a square of unit size (first entry of the sequence). Place one adjacent to it of the same size (second entry of the sequence). Now you have a rectangle of sides 2:1. Place a square of size 2 (third entry) so that it is touching the longer side of length 2. Keep going, to get larger and larger squares that 'spiral' out as seen in the figure. The arcs have been drawn in to show the spiral clearly.

Both the Fibonacci sequence and the Fibonacci spiral appear everywhere in Nature.

Shells

As you may have guessed by the curve in the box example above, shells follow the progressive proportional increase of the Fibonacci Sequence. Shells are probably the most famous example of the sequence

because the lines are very clean and clear to see, as in the picture of the nautilus shell shown. They are also fun to collect and display. And then, there you have it! Your own little piece of math.

Trees

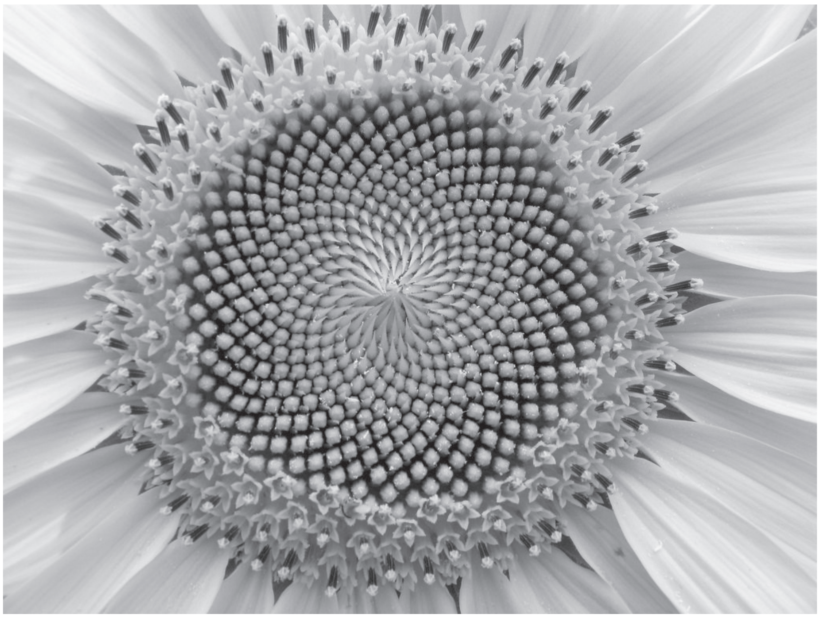
Trees — we see them everywhere, but do you look and analyse the structure of how the branches grow out of the tree and each other? If you did, you would see the Fibonacci Sequence evolve out of the trunk and spiral and grow as the tree becomes taller and larger. Some truly majestic trees are in existence today, utilizing this pattern.

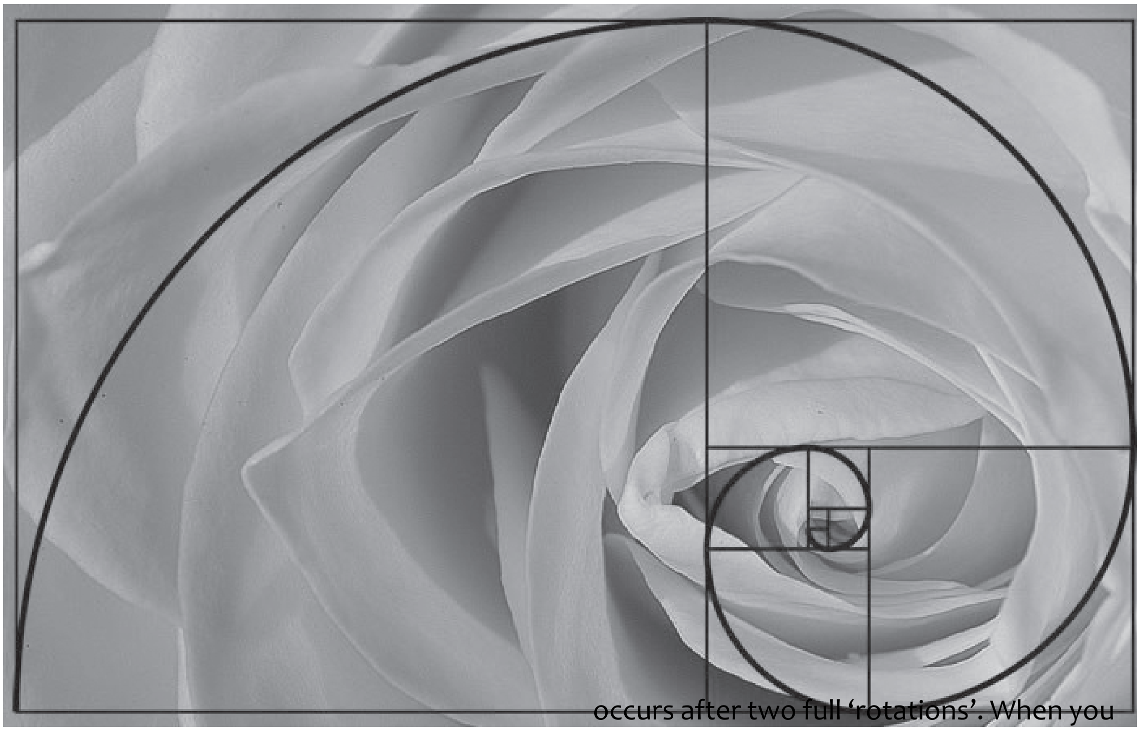
Flower Pistils

The part of the flower in the middle of the petals (the pistil) follows the Fibonacci Sequence much more intensely than other pieces of nature, but the result is an incredible piece of art. The pattern formed by the curve the sequence creates used repeatedly produces a lovely and intricate design. Sunflower pistils are particularly complex.

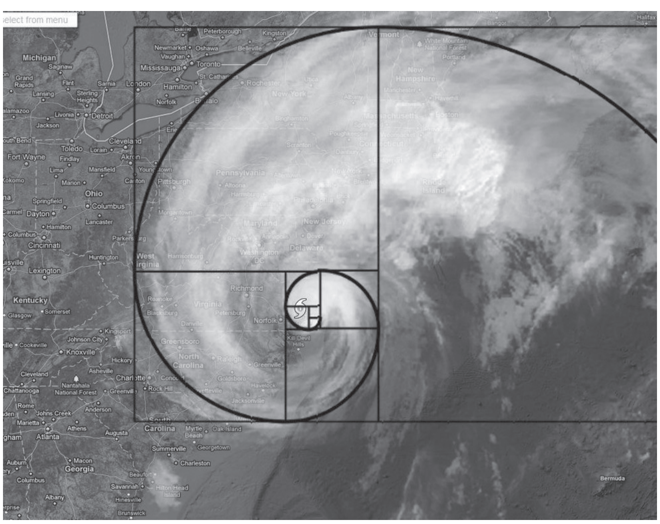
Flower Petals

Flowers of all kinds follow the pattern, but roses are an excellent example of the Fibonacci Sequence because the petals aren't spread out and the spiral is more obvious and clear, like with the shell. The





petals unfold more and more and the sequence increases. Roses are beautiful (and so is math). The front cover shows a 'rainbow rose'. Rose petals are arranged in a Fibonacci 5-spiral. This means that petal number one and six will be on the same vertical imaginary line. But the sixth petal



occurs after two full 'rotations'. When you cut the stem vertically into four equal parts and transfer each end into a different glass with coloured water, the petals will take up the dye depending on their position in the spiral. That's how the cover photo was obtained. However, it is not easy to achieve the clean separation between the colours. The technique was developed by **Peter van de Werken** from River Roses, a flower company located in Holland.

Storms

Cyclones (also called hurricanes or tornadoes) and many other storm systems follow the Fibonacci Sequence. On a map, at least, cyclones look cool. I guess we could say this example proves math can be beautiful and destructive.

Adapted from the article by Victoria McGraw,

http://theodysseyonline.com

Sweet birthdays in math exams!

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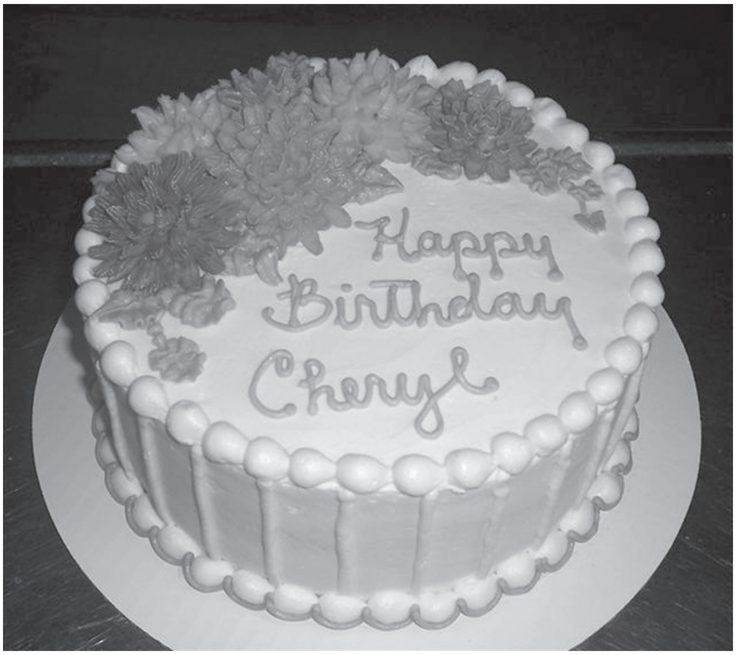
Hannah's Sweets

These are exam times and we keep hearing children exclaiming, "Oh that was easy!", or "What a weird question paper!", or "Whatever did they mean in that question?" and so on.

Here is a question that stirred up people greatly a few years ago. It was a problem asked in the GCSE mathematics examination in June 2015 (equivalent of our Class X in the UK):

- *Hannah has a bag containing a total of n sweets, of which 6 are orange. If the chances of Hannah picking two orange sweets one after the other is one-third, use this to prove that* $n^2-n-90=0$.

How does one reason with this? Many children simply see this as factorization, or 'solving the quadratic equation' and are hence puzzled by all the fuss about Hannah and her sweets. It would be so much easier if it was simply a matter of finding the value of *n*. And apparently that is what most children did, missing the question asked by the examiners. How do we actually solve this problem?



Probability Analysis

The information given is about probability. What is the probability of the ***first*** sweet Hannah picked being orange? That's easy: there are 6 orange out of *n* sweets, so the probability of picking an orange sweet is $6/n$. Well then, what is the probability that the ***second*** sweet Hannah picked was orange as well? Now there were (n-1) sweets left over, with 5 among them being orange, so we get $5/(n-1)$. Now what is the probability of these two events happening, one after the other? Since the two events are ***independent*** of each other, it is the product of the two probabilities:

$$(6/n) \times (5/(n-1)).$$

But this is given to be one-third. So we get the equation:

$$(6/n) \times (5/(n-1)) = (1/3).$$

Simplifying, we have

$$(30/(n^2 - n)) = (1/3), \text{ or}$$

$90 = n^2 - n.$

Hence we get the given equation.

If you really want to solve this equation, you will get n=19. Substitute and check if you don't know how to solve a quadratic equation.

Cheryl's Birthday

Before Hannah there was **Cheryl**. A few months earlier, in April 2015, an exam question from Singapore caused a great deal of discussion all over the world. This was an exercise in pure logic.

Albert and **Bernard** friends are new friends of Cheryl, and they want to know when her birthday is. Cheryl gives them a list of 10 possible dates:

in *May*: 15, 16 or 19;

in *June*: 17 or 18;

in *July*: 14 or 16;

in *August*: 14, 15 or 17.

Cheryl then tells Albert ***separately*** the month of her birthday and and Bernard ***separately*** the day of her birthday. The following conversation takes place between Albert and Bernard.

Albert: I don't know when Cheryl's birthday is, but I know that you don't know it either.

Bernard: Before you said this, I didn't know Cheryl's birthday, but I know it now!

Albert: Then I also know Cheryl's birthday!

So when is Cheryl's birthday?"

Such questions require you to think calmly about the given information and reason out the possibilities.

Albert is told the ***month***. In each of them there is more than one possibility, so of course he does not know which of the days in the month is her birthday.

Bernard is told the ***day***. Notice that the dates 18 and 19 do not repeat. So if he was told 14, 15, 16 or 17, he would be uncertain, but if it is 18 then he immediately knows that it is June 18. Similarly if he were told 19, it has to be May 19.

Albert says that he knows that Bernard does not know the birthday. If he had been told May or June, there was no way for him to rule out 18 or 19 and hence he could not be sure of Bernard's ignorance. Hence we conclude that Albert was told either July or August. But so can Bernard conclude this as well!

Notice that Bernard says that he knows the birthday now. Clearly, Bernard heard 14, 15, 16 or 17. Had he heard 14, he would still be unsure whether it was July or August, so he must have heard 15, 16, or 17. So we conclude that the birthday is August 15, July 16, or August 17. But then so can Albert conclude this as well.

But then Albert says he knows the birthday too, so he could not have heard August. (If so he would be unsure whether it was the 15th or the 17th.) Hence Cheryl's birthday must be on July 16.

This line of problems follows the famous "sum—product" puzzles popularized by **Martin Gardner**, the great American puzzle-maker (1914 to 2010). *Jantar Mantar* has carried articles on him and on such puzzles. Children in Singapore would have benefited from reading Jantar Mantar for cracking their Board examinations!

What keeps the Moon up in the Sky

The Earth attracts every body because of gravity. That's why when we throw a ball up, it falls down again. If gravity acts on the moon as well, why doesn't the moon fall into the Earth? The answer is also, gravity.

Types of forces

What do forces do to an object? In short, you can say that forces ***change*** the motion of the object.

Let us look at three different cases for forces.

1. *Force pushing in the same direction as the velocity of the object.* Suppose an object is moving to the left with a force pushing in the same direction. See the diagram. Let this force be constant. Then, since the force and object's velocity are in the same direction, the force makes the object speed up or accelerate. This is as per Newton's second law of motion, which states that objects change their momentum or accelerate when acted upon by an external force.

2. *Force pushing in the opposite direction as the velocity of the object.* This is almost the same case as above, but for an object moving to the right the force would be to the left.

Gravity

Gravity is one of the earliest known forces. Any bodies that have mass interact with each other through gravity. From the days of **Isaac Newton**, scientists have been trying to find out more about gravity. In school, you might have read that the force between two masses, m_1 and m_2, is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

This means that the larger the mass, the greater the force. The further apart they are, the lesser the force, and the dependence on the "inverse square" distance means that if you move the masses twice (thrice) the distance apart, the gravitational force between them will become four (eight) times smaller ($1/2^2=1/4$ and $1/3^3=1/8$). This means that the objects experience gravity even if they are placed very very far apart, with the gravitational force going to zero only when the objects are infinitely far apart.

However, the most important property of gravity is that it is *always attractive*. This is in contrast to electric or magnetic forces, for instance, which can be repulsive or attractive depending on whether the charges (or poles) are the same or different. Hence the gravitational force always brings bodies closer to one another, and that is why the ball falls back on Earth.

Here the object slows down. Again, there is acceleration, but the slowing down is referred to as deceleration, like when you put on the brakes of a car.

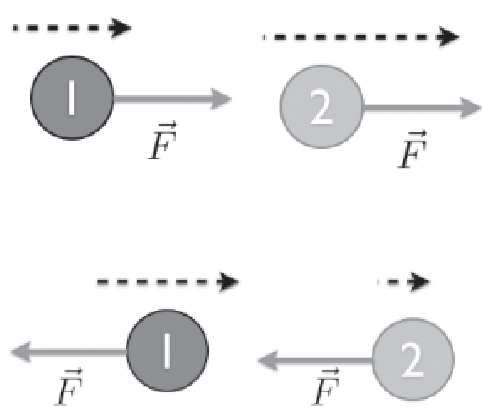
3. *Force pushing perpendicular to the velocity of the object.* Let us call this a "central" force.

In this case, the object doesn't speed up and it doesn't slow down. It just turns in a circle; hence the name. Of course, in order to exert a continuous central force, the force would have to point in a different direction as the object turns. Here is an example. Take a ball at the end of a string - or maybe a yoyo since the string is already attached. Swing the ball around in a circle. Why does it move this way? The string pulls on the ball. But since the string can only pull in the direction of the string (you can't push with a string), the ball has a central force on it and changes direction. Such a force that is pointing to the centre of the circle is called centripetal force.

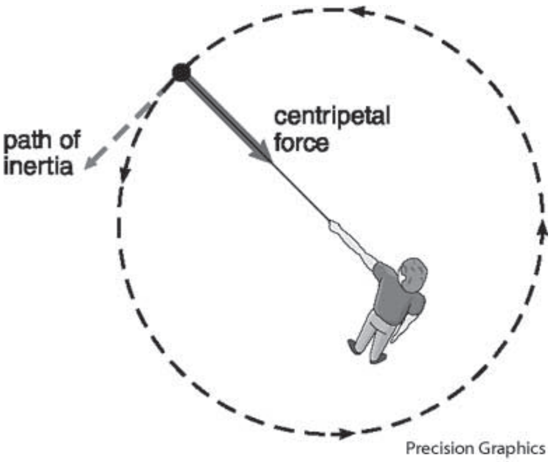
Trajectories

What about the Moon, then? Why is it not subject to gravity? Or, is it? Let us first look at the action of a ball when it is thrown sideways. (Or you can think of a shotput or javelin throw).

The picture shows Barbora Spotakova of the Czech Republic on her way to winning the gold medal in the Women's Javelin Throw Final on day seven of the 11th IAAF



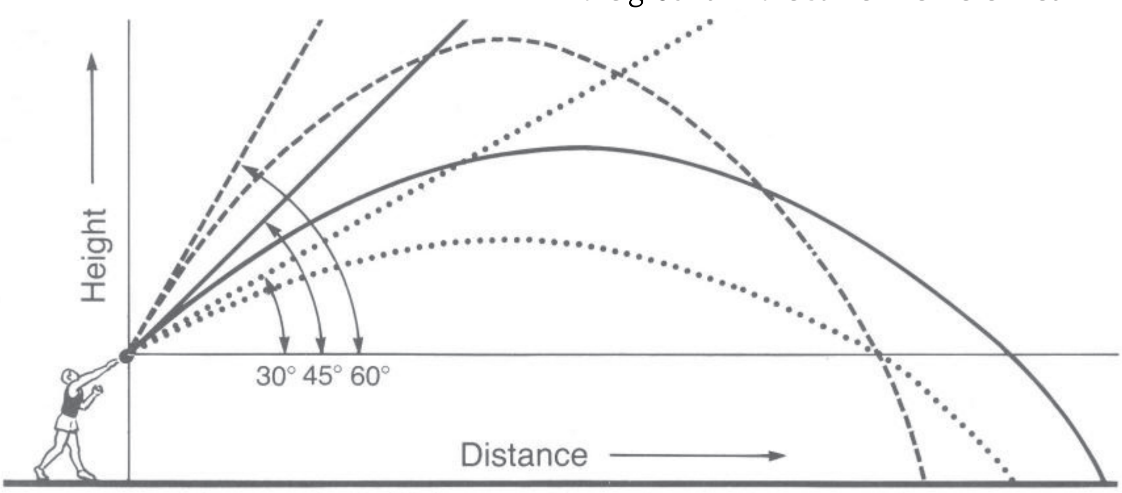
World Athletics Championships on August 31, 2007 at the Nagai Stadium in Osaka,



Japan. Look at the 'angle of attack'. The distance the javelin travels depends on the angle at which it was launched or thrown, as can be seen from the figure. The important thing to note is that once the javelin has been released, the only force on it is the vertical downward force of gravity. The horizontal force which allows it to travel farther and farther (and hence win the gold medal for the most distant throw) is given by the athlete when it leaves her hands.

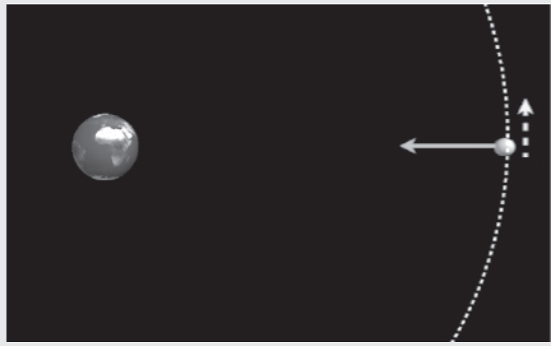
The shape of the path that the javelin travels is called its ***trajectory***. The trajectory shown has a special name: it is called a parabola. Any object that is sent upwards with non-zero velocity and is acted upon only by gravity has a trajectory like a parabola, as can be seen from the picture of the water fountains. The larger the initial velocity, the farther the object travels.

The figure shows an example of a bullet being fired by a tall man (about 1.7 m above the ground). For a velocity of about 1.4 km/s, which is really fast for a bullet, it would travel almost 1 km (0.84 km) before it hits the ground. If the same rifle were fired



The parabolic flight path for various release angles

Earth-Moon distance



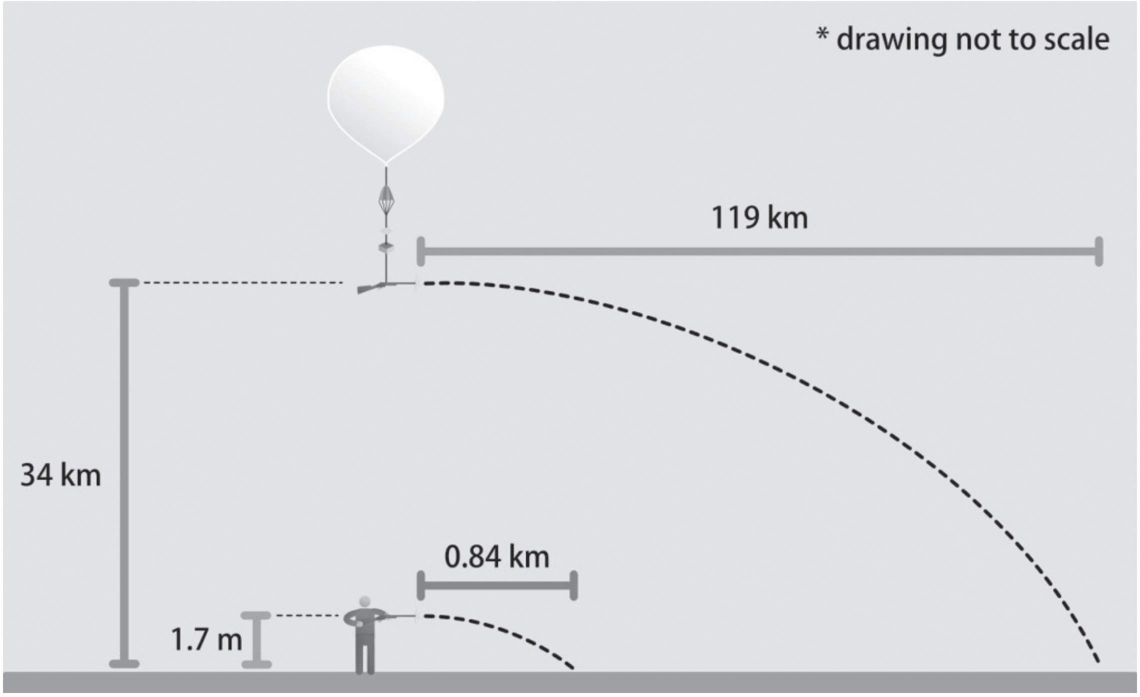
Look at the actual sizes and distances of the Earth and Moon in the picture. It is not drawn this way in text books because it is difficult to see. So the picture is usually not drawn to scale, as in the second figure where the moon is only 1/5th the distance it is suppose to be (but the correct relative size).

In the figure, the arrow represents the gravitational force on the moon. If the moon were moving in a perfect circle, the gravitational force would always be "central" (towards the centre of the circle) and just cause it to change its direction.

from a balloon 34 km above the earth, it would travel 119 km before it hit the ground. As the velocity is increased more and more, the bullet would travel farther and farther, until it starts to "miss" the ground. At this critical velocity, it simply goes into orbit around the Earth.

The moon does the same thing: it is falling towards the Earth so fast that it actually misses! In fact, all satellites do the same thing. The **International Space Station** (ISS) is orbiting the Earth at a mean velocity of about 7.6 km/s or 27,600 km/hr. If the velocity is increased even more then the object can "escape" from Earth's gravity and enter space. That is how space ships are launched. This escape velocity is about 11.2 km/s.

Circular versus Elliptical Trajectories



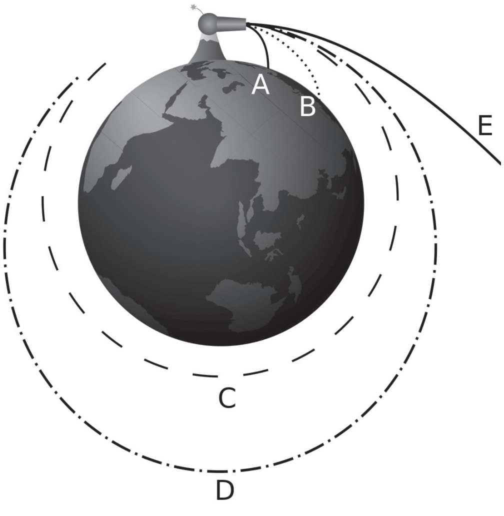
Newton's Cannon

This is shown in the picture of Newton's cannon. While bullets with lower velocities hit the Earth (trajectories A and B), the one with trajectory C just about has orbital velocity for it to go in a circular path. With a little more velocity, it goes in an elliptical path (D) and given even more velocity (greater than the escape velocity, it leaves Earth, as seen in trajectory E.

What about Moon's gravity?

Newton's third law states that action and reaction are equal and opposite and act on different bodies. This means that if Earth pulls the moon towards itself, the moon should do the same thing: it should pull the Earth towards itself with the exact same magnitude of force. Wouldn't this also make the Earth move in a circle? Essentially, it does. However, Earth's mass is 81 times greater than the mass of the moon, so it moves in a much smaller circle. The circle that the Earth moves around is so small that the center of this circle is inside the Earth. Cool, isn't it?

Sources: Wikipedia, NASA, Rhett Allain's article in The Wired, https://www.wired.com/2012/11/why-doesnt-the-moon-crash-into-the-earth/



The spreading of arithmetic

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How would you do calculation if you did not know how to use decimal notation and the arithmetic that you studied in school?

Of course you would know how to count three bananas, or ten plums, or three score and seven grapes (which is 67, since a score is twenty). You would know there are four score of fruit in all. How would you do the addition? Perhaps you can do that all in your mind?

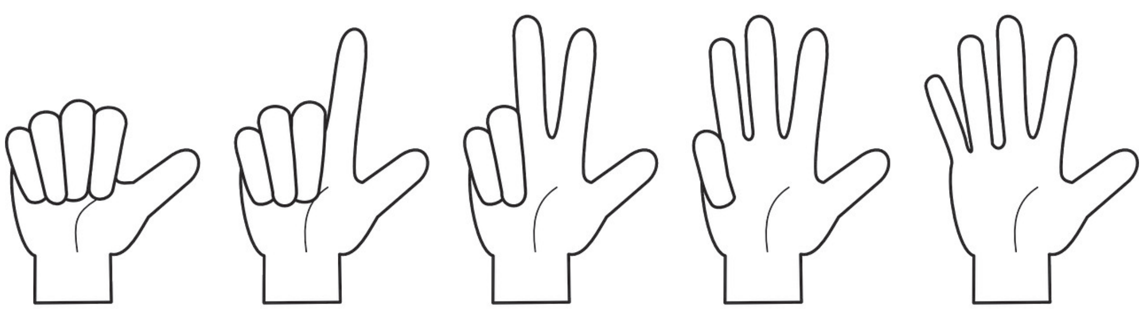
For somewhat larger numbers, say a month and three days of holiday, then four months, one week and one day of school, then two weeks and three days of examinations, how would you add up the days?

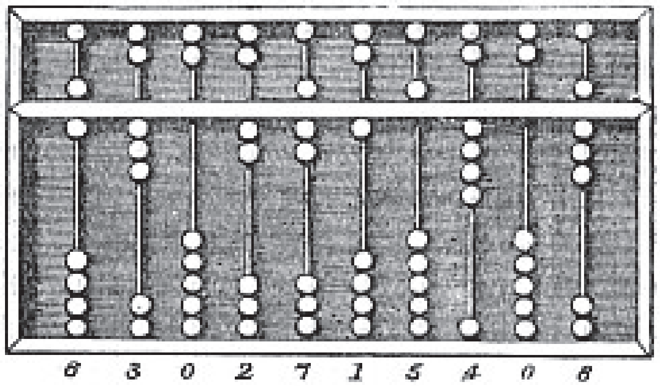
If you eat ten chapatis and three bananas at home every day of holiday, five chapatis and a score of grapes every day of school, and six chapatis and seven plums every day of the examinations, how many chapatis and how much fruit do you eat over all the days?

How to count

The most common method is counting on your fingers. (Actually the English word "digit" means finger or toe.) Very clever ways have been devised to represent large numbers using your fingers, and to add, subtract and multiply them. Before the decimal system became popular, the **Sumerians** and **Babylonians** in Iraq had a system with base 60 (we still use it for counting time) and they had expert scribes who were very good at calculation. Possibly they were able to represent numbers upto 60 using their fingers and then do the calculation on their hands.

Another method which developed later was the use of an abacus. This used pebbles on a wooden board. If you have seen an abacus today it probably uses beads on wires. Abacuses were common in China,





where they are called xuanpan. Again there are experts who are very good at representing numbers (usually a decimal base is used) and moving the pebbles around to do very fast calculations on the board. The picture shows a xuanpan with the number 6,302,715,408. Can you figure it out?

<pic of abacus>

Difficulties come about when people start trading. I am a merchant who wants to buy several things from you. Maybe bananas, plums and grapes, all at different prices. I come with my trusted accountant (my abacus expert) and you call your accountant and they both sit with their abacuses, calculate and find that the cost is the same. Then I pay you and take my fruit.

But I could be a trader who trades in many markets. Perhaps I send goods out on ships to several ports. It was the need to keep records of calculations that led to the arithmetic we learnt in school.

From Brahma to Arabia and Africa

The Indian mathematician **Brahmagupta** was born in 598 CE. He lived in Bhinmal (then in Gujarat, now in Rajasthan). In 628 CE he wrote the *Brahmasphutasiddhanta* ("Doctrines coming from Brahma"), a book which studies earlier *siddhantas* (texts), criticises them and rewrites them in his own way. Along the way, he introduces zero and negative numbers (this is the earliest book known which talks about them), and the techniques which you now use in school for addition, subtraction and multiplication.

Later Brahmagupta moved to Ujjain (now in Madhya Pradesh). In 665 CE he wrote the *Khandakhadyaka* ("Sweet food"), on practical astronomy. From the name it sounds as though it was meant to make a tough subject sweeter for students.

These methods were learnt by Arabian merchants about 700 CE. The Islamic caliph **al-Mansur** in Baghdad (ruled from 754 to 776 CE) invaded Sindh and Gujarat. **Kanaka**, an astronomer from there with knowledge of Brahmagupta's works, came to Baghdad as part of an embassy from Sindh. The Iraqi astronomer **Muhammad ibn Ibrahim** (son of Ibrahim) **al-Fazari** in the court of al-Mansur, translated the *Brahmasphutasiddhanta* into Arabic as the *Zij al-Sindhind al-kabir* (roughly, "Great tables from Sindhind") and the *Khandakhadyaka* as the *Arakhand*. With the spread of Islam all the way from Africa to India, Muslim merchants learnt how to do arithmetic using Indian numerals, so much so that they are often known as Arabic numerals.

Abu Abdallah Muhammad ibn Musa (son of Musa) **al-Khwarizmi** (from Khwarizm, Khiva, in Uzbekistan) lived around 800 to 850 CE. He wawas a Persian scholar who

Bases in Arithmetic

Base 10 refers to the numbering system in common use that uses decimal numbers. Base 10 is also called the **decimal system** or denary system. In base 10, each digit in a position of a number can have an integer value ranging from 0 to 9 (10 possibilities). The places or positions of the numbers are based on powers of ten (e.g., 1234.56 has entries 6,5,4,3,2,1 respectively in the hundredths, tenths, tens, hundreds, and thousands positions). Why is it called Base 10? Only ten numbers (from 0 to 9) can be entries in anyof the positions. The value of the number is given by the entry times the relevant power of 10. So, in this example, the number 1 actually represents $1x10^3$, which is 1000. The factor of 10^3 came in because it was the 4th (3 = 4-1) place to the left of the decimal point. So the number 1234.56 equals ($1x10^3+2x10^2+3x10^1+4x10^0+5x10^{-1}+6x10^{-2}$). Exceeding the number 9 in a position starts the counting in the next highest position. Similarly, if we allow only two numbers (0 and 1) in any position, we get the so-called **binary system**, which is popular in computers. Here 0 and 1 refer to 0 and 1, but to write 2, we must write 10, which can be read as ($1x2^1+0x2^0=2$). It is obvious that counting in Base 60 (also called **sexagesimal system**) involves multiplying the entries by the correct power of 60.

What is so special about 60? The number 60 is a highly composite number, which means that it has many factors. In fact, it has twelve factors namely 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60, of which 2, 3, and 5 are prime numbers. With so many factors, many fractions involving sexagesimal numbers are simplified. For example, one hour which is 60 minutes, can be divided evenly into sections of 30 minutes, 20 minutes, 15 minutes, 12 minutes, 10 minutes, 6 minutes, 5 minutes, 4 minutes, 3 minutes, 2 minutes, and 1 minute. 60 is the smallest number that is divisible by every number from 1 to 6; that is, it is the lowest common multiple of 1, 2, 3, 4, 5, and 6. To write fractions in Base 60, see the figure. Here the comma is to be read like a decimal point: for instance, the fraction 1/8 in sexagesimal is 7,30 so 1/8th of an hour refers to 7 minutes and 30 seconds, as you already know!

Fig: <fractions_60.jpg>

Fraction:	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{9}$	$\frac{1}{10}$
Sexagesimal:	30	20	15	12	10	7,30	6,40	6

produced works in mathematics, astronomy and geography under the patronage of the Caliph Al-Ma'mun of the Abbasid Caliphate (modern Iraq). He wrote his own version of the *Sindhind*, called the Kitab *al-Hisab al-Hindi* ("Book of Indian accounting"), which was translated into Latin in the 13th century CE using the name *Algorithmi de numero indorum* (or "Al-Khwarizmi's Indian numbers"), from where we get the English word "algorithm", named after the person who described the methods!

His *Kitab al jabr w'al-muqabala* ("Book of restoration and compensation") has methods for solving linear equations (as in a spreadsheet), and also solving simple quadratic equations. More colloquially, its

Statue of al Khwarizmi at Khiva

title describes "forcing" numbers from one side to another in the "contest" between the two sides of an equation. It was translated into Latin in 1145 by **Robert of Chester**, who used the name *Liber algebrae et almucabala*, from where we get the English word "algebra".

A towering figure from Pisa

Pisa in Tuscany (today in Italy) was a port in the middle ages. It is on the river Arno, a little inside from today's sea-port of Livorno. In the 12th century CE, the state was thriving with business. Its port would import grain from other Italian city states, salt from Sardinia, squirrel skins from Sicily, goatskin from North Africa, fur from Hungary, horses from Provence in France, spices from the East, and so on. Alum was imported and used in leather manufacture. Dyes and wool were imported and used for textiles. Timbers came by barge from upriver for shipbuilding, bars of crude iron came from the islands of Elba and Giglio. The city exported Tuscan wine, oil, hemp, flax, smelted iron and silver, tools, weapons, armour. In the port one could find Turks, Arabs, Libyans, selling silks, carpets, vases and other goods. Imagine the kinds of coins of different kinds that were used: *librae, solidi, denarii* (just like pounds, shillings, and pence)!

Leonardo Pisano (from Pisa) was born about 1170 CE. His father Guilielmo (William) Bonacci was a prosperous merchant. He was posted at Bugia (today Bejaia) in Algeria in north Africa as a trade and customs officer. He urged Leonardo to learn the methods of calculation of the Arabian merchants which were far superior to those used by his countrymen.

Leonardo did learn them, and it seems clear that he read the books by Al-Khwarizmi and perhaps also by other Arab mathematicians. But then he also wrote a "book of calculation" in Latin, *Liber abbaci,* explaining these methods. He later came to be called **Leonardo Fibonacci** (family of Bonacci), and he is mostly known today as Fibonacci. His book is similar in spirit to that of Al-Khwarizmi and is distinguished by having many more examples. One of his examples, involving rabbits, was immortalized as the Fibonacci sequence by American mathematician Edouard Lucas in the 1870s.

The first edition of *Liber abbaci* was in 1202. There was a second edition in 1228, of which 14 copies survive today. He also wrote many other books. The last reference we have to Leonardo is about 1240. Almost immediately many Italian writers wrote their own books of calculation, making copies of some of the material in Latin and in Italian.

Translation of these voluminous books took even longer than Al-Khwarizmi's. The first English translation of *Liber abbaci* was completed only in 2002.

The printing press was invented around 1450, and today we know about 400 Italian "books of calculation", published between the 13th and 16th century.

Popular writing on arithmetic

Why did Leonardo's books become so popular in Europe, much more so than Al-Khwarizmi's which were already available? Al-Khwarizmi's books were translated into Latin. Even the translations into modern languages remained in the hands of European scholars. Leonardo's books, although they were first written in Latin, were quickly translated into Italian, and spread fast among the Italian merchants. The printing press made them accessible to all Italians.

The Arabic arithmetic methods, and also the Indian ones, involve writing over and crossing out numbers. Thus although calculation can be done very fast and the final answer written out, the record of the calculation itself may get erased. In Leonardo's methods the whole calculation is displayed, and its record remains.

Al-Khwarizmi's books have many example problems, dealing with inheritance, legacies, dowries, and legal issues. Leonardo's examples were easily adapted to dividing capital among partners, finding value of merchandise in different quantities and currencies, minting and alloying of money. His examples would have immediately made sense to merchants.

American finance professor **William Goetzmann** wrote in 2004 that Leonardo's books gave the advantage to merchants who could calculate the relative value of commodities (like saffron or pepper) in the market, like today's stockbrokers do in a share market. The books explained how profit from a joint venture with unequal contributions from partners can be split in a fair way. They explain how to do accounting for a sequence of business trips where expense, withdrawal and profit occur at every stop. They explain how to work with quarterly and annual compound interest. This was the time when Italian trade and manufacture was growing and these practices became common to business. These teachings were widely adopted, and eventually entered schools.

Based on *Finding Fibonacci* by Keith Devlin

Answers to Do You Know?

1. Flies are difficult to swat because they are so much quicker than us. But can't we move so slowly that a fly can't detect the movement and actually get it?

Ans: Flies process motion information very fast, and so you are right. In principle, you can trick the fly by just moving very slowly. How fast the edges of your hand expand relative to the fly's vision is what triggers the fly to flee, so a slow hand could confuse the fly.

But then the fly motion vision is so sensitive that you would have to move so slowly that either you get bored and give up, or the fly just takes off for greener pastures. That is another characteristic of flies, they do not stay in one place for very long.

Apparently, confusing the fly with a clap of the hands makes the job easier. You approach the fly at normal speed and, instead of slapping it, clap your hand just above the fly to intercept it as it takes off. Some scientists have even worked out equations describing this!

You could also hold perfectly still and watch the fly until it starts washing itself, then strike quickly while it is distracted, just like jumping on someone in the shower.

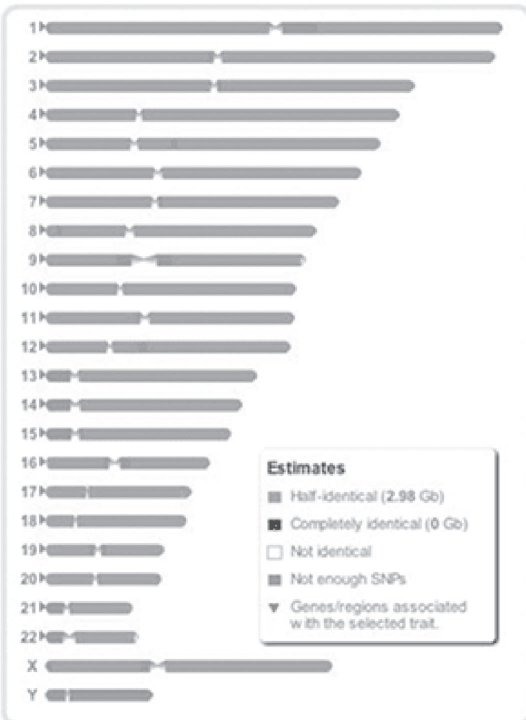
One other solution is to spread your fingers wide on the same surface as the fly and pull your middle finger back like a slingshot while you slowly slide your hand towards the fly and quickly release the cocked finger once the fly is in range. Since the fly is being approached from multiple directions it apparently gets confused enough to not take off as it normally would to an approaching hand, so you can effectively crush it when you release your middle finger.

Poor fly! If flies could know how much fun scientists are having plotting their capture ....

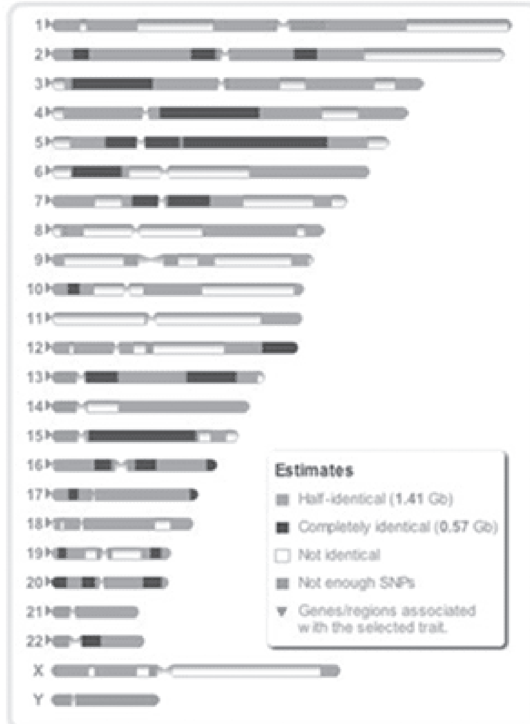
2. Genetically, who are we closest to — our parents, our chidren, or our siblings?

Ans: Now this is a really interesting question. When you ask children this question, they typically say parents, and when you ask adults, they think it is obviously their children.

Girl vs. Dad



Girl vs. Brother 1



The short answer is that it is a little bit complicated, as is usually the case in science. You are 50% related to your parents and you are 50% related to your children. When it comes to siblings you are 50% related to them ***on average***. In particular, we get half our DNA from our mother and half from our father, so we share our genetic material equally with our parents.

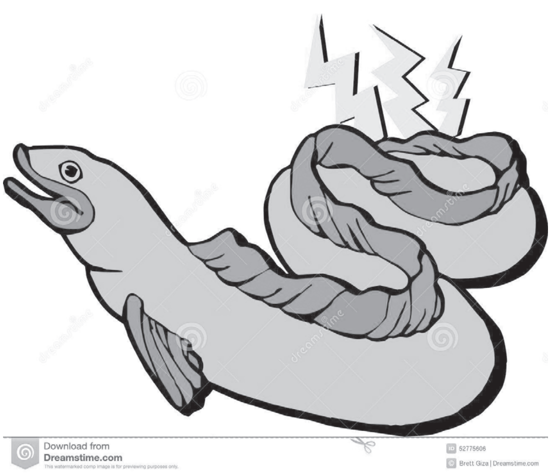
The reason is that when you inherit DNA from your parents, you get each of your 23 pairs of chromosomes from one parent. However, there is some mixing. If you comparing different siblings (brothers and sisters) they could take different parts of that chromosome and so it is possible for you to be taking the same parts or completely different parts. That is why it is 50% on average.

Of the 23 pairs, the last one is the sex chromosome. Females have XX sec chromosome pair while males have XY. All children inherit an X chromosome from their mother; girls inherit X from their father while boys inherit the Y chromosome (yes, it is the father who determines the sex of the child!). The sex chromosome (and the presence of mitochondrial DNA) complicates the issue. All daughters inherit the same X chromosome from their fathers, while they may inherit either of the X chromosomes of their mother. Hence on the average, sisters share 75% of this genetic material, while brother and sister share only 25%. There are always small differences because of a process called recombination in which some amount of genetic mixing happens, so we are all actually unique. This is what DNA fingerprinting is based on. Identical twins share their entire DNA exactly.

3. How do electric eels get their energy?

Ans: Perhaps they have built in generators? The answer is that electric eels use modified muscle cells. They are called electrocytes and they are strung together (like on a necklace) along the inside of the fish. If you connected a battery end to end, and you connected the plus of one battery to the minus of another the voltages add together. The same things happen to the fish too. These electrocyte cells slowly accumulate voltage and over a very big eel you maybe get 500 volts and they are discharged from just below the chin of the eel and its tail. (Note that eels live in water, which provides additional outlets for the current. So though generate a large voltage, the current generated is divided, and therefore small.)

So yes, the eel is basically a giant accumulator or battery. Tt is pumping ions of sodium and potassium in and out of



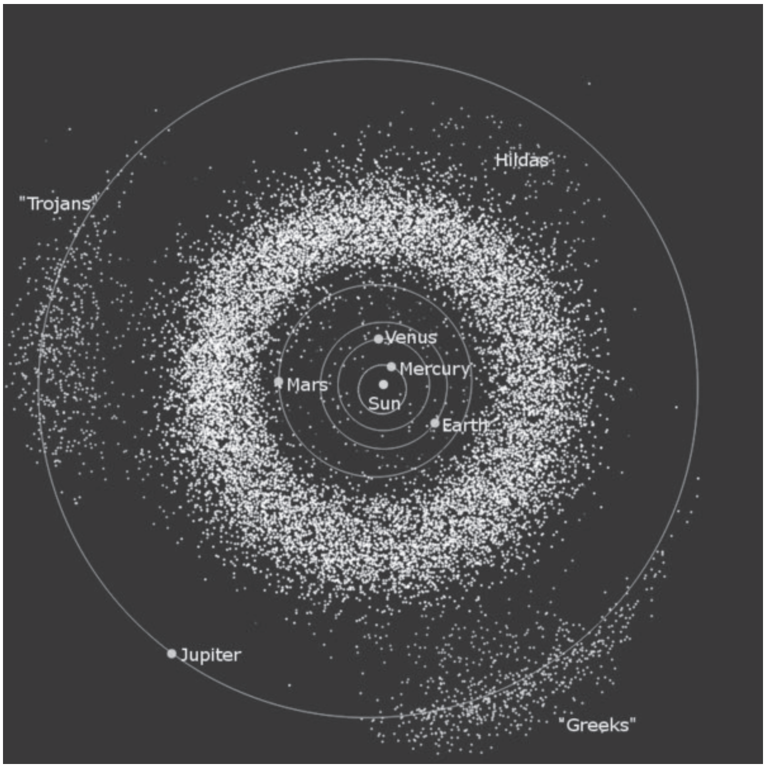
these cells to generate those tiny voltages which together, over the course of these thousands of cells, add up to make hundreds of volts.

The eel has a highly specialized nervous system that has can synchronize the activity of these electrocytes. The nervous system does this through a command nucleus that decides when the electric organ will fire. When the command is given, a complex array of nerves makes sure that the thousands of cells activate at once, no matter how far they are from the command nucleus.

Why don't electric eels shock each other? Apparently scientists are not entirely clear why they can shock other animals without shocking themselves. One possible explanation is that the severity of an electric shock depends on the amount and duration of the current flowing through any given area of the body. For the purposes of comparison, an eel's body has roughly the same dimensions as an adult man's arm. To cause an arm to spasm, 200 milliamps of current must be flowing into it for 50 milliseconds. An eel generates much less energy than that because its current flows for only 2 milliseconds. Additionally, a large part of the current dissipates into the water through the skin. This probably reduces the current even more near the central nervous system or heart. A prey 10 times smaller in length than an eel is about 1,000 times smaller in volume. Therefore, the small animals close to the eel get shocked, rather than the discharging eel itself.

4. Why is there such a big 'gap' between Mars and Jupiter? There is an asteroid belt, but why did no planets form there?

Ans: Scientists seem to consider that it



was Jupiter that stopped any planet growing where the asteroids now are.

There clearly was planet-forming material all the way from near the Sun outwards to Jupiter and beyond. This should have clumped together into larger and larger bodies, eventually planet-sized bodies. But close to Jupiter, its gravity would stir up the orbits of such bodies just inside its orbit, which is where the asteroid belt is. This would cause collisions between such bodies to be too energetic to allow materials to clump together. So very large bodies cannot grew.

The largest bodies there today are less than about 1,000 kilometres across. So they are stirred up and most of the material has, in fact, been lost because of Jupiter. We could not make a planet now if we stuck all the asteroids together. They would make only about a hundredth of an Earth mass in total. This is a surprisingly small amount even though there are thousands of bodies in the belt.

Where has all that material gone, then? Have they become asteroids that rained down on us in the early phases of the solar system? Most of the material has been scattered out of the solar system. Some material scattered inwards and would have hit Mars and the Earth and Venus and Mercury, and doubtless, some has been gobbled up by Jupiter. Now Jupiter is 318 times the mass of the Earth, so this would scarcely be noticeable.

So yes, the verdict is clear: Jupiter is the culprit!

Source: Scientific American and Cambridge Science for Kids.

Rooting it out

José Dinneny studies how plants grow under stress. What he learns could help to feed Earth's growing population.

José Dinneny wants us to see plants as strange. They have no brain and no nervous system. Yet they take in different kinds of information and can make good decisions. Plants also find water without sight or touch.

They are everywhere in our lives: lawns, salads and pots on a sunny windowsill. They're so familiar it's easy to forget how odd they really are.

"We're out searching the solar system and the galaxy for extraterrestrial life," says Dinneny. Yet, he argues, "We have aliens on our own planet."

Dinneny is a plant biologist at the Carnegie Institution for Science in Stanford, California, USA. He says the thrill of discovering plants' alien ways drives him to explore how roots search for water. His research group "runs on curiosity," he says. He conducts projects just to discover how plants work. What he learns, though, could be useful in finding better ways to grow food. He started his career studying details of how plants develop their parts and shapes. With that background, he's now interested in how the roots of plants hunt for water.

The root of the matter

These questions are important in "this huge crisis we face as a species," says **Jonathan Lynch**. He is a root biologist at Pennsylvania State University, in University Park, and the University of Nottingham in

England. The human population is growing — and fast. Whether farmers will be able to boost their crops and keep up is huge question. And Earth's changing climate only makes this more complicated.

To study how plants grow those roots, biologists often start seedlings in petri dishes with a nutrient gel instead of soil. This lets researchers experiment with lots of plants in the lab. But this is very different from how plants grow in real life. For more realism, Dinneny and his colleagues created a system called **GLO-Roots**. It creates a special view of roots in soil. The technical name for the process is ***Fluorescence Activated Cell Sorting***. It shows how genes get expressed (turned on or activated) depending on the water availability.

In the GLO-roots system, plants grow their roots in slim sandwiches of soil held between two clear plates. The roots weave among air pockets, micro rivers and clots of dirt. It's like mini versions of the conditions that roots find in the ground. But these roots are special: They glow when various

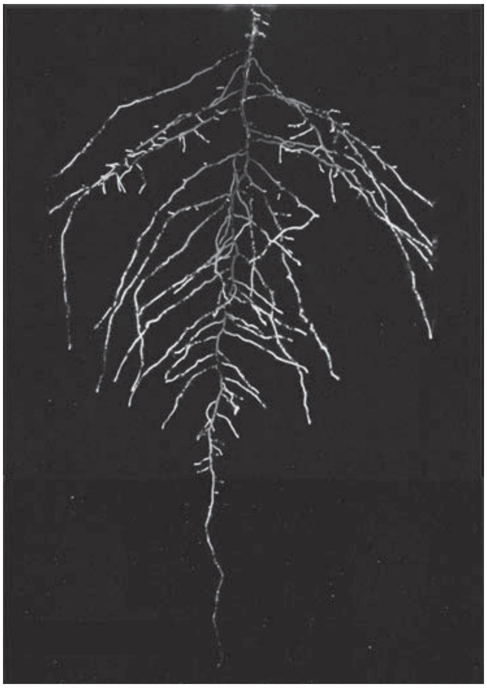
About Prof José Dinneny

Dinneny spent much of his childhood in California's San Fernando Valley. "I was placed in classes that weren't particularly challenging." The school he went to had a high dropout rate. In 10th grade, though, he took an Advanced Placement biology class. Suddenly, things changed. He still remembers a pivotal moment when his teacher asked about a *chemical bond* in DNA. "I was the only person who raised his hand." The answer: a phospho-diester bond. "Everyone looked around the room sort of wondering who could possibly have known that factoid," he remembers.

He even surprised himself. Dinneny began to realize he had a talent for understanding biology. He lobbied hard to transfer to advanced classes. He began to apply himself to studying. Dinneny didn't come from an academic family, but he had fine examples of working hard. That included his mother. She raised him as a single mom working as a government accountant.

"Often we kind of cubbyhole ourselves into, 'OK, I'm good at this,' or 'I'm not good at that.' Or they're doing well because they're just *inherently* better at doing this than I am,'" he says. "There is a magical relationship between effort and success." Not every goal gets met, but "you're going to do better than you ever thought."

By his final year of high school, Dinneny was a straight-A student, and he went to University of California, Berkeley. There, plant science captivated him. For his PhD, he went to the University of California, San Diego. He studied the genetics of plant development. Later, he studied plants trying to grow in difficult places. Now he's focusing on ways to figure out what's happening in roots.

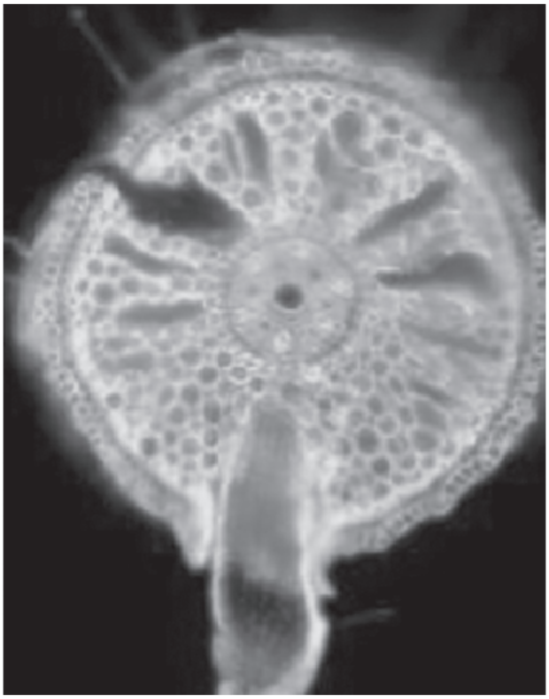


genes turn on in this twinkling underground observatory. Computers analyze where that glow shows up. And that gives researchers clues to how roots are responding to their environment.

The GLO-roots set-up allows researchers to visualize how the roots of a seedling explore the soil. The photo shows this by combining daily images of a growing root starting 11 days after sowing a seed. The closer the colouration gets to white, the more recently the little rootlets formed.

We know that roots grow out side branches in their search for water. How do they decide in which direction to grow? How do they know that there is more water in a certain direction? In order to be able to sense this, root's tissues should be able to sense

differences in the wetness of the surrounding soil. It turns out that the root tissues can sense differences at points that are only about 100 microns apart (0.1 mm apart). Dinneny and his colleagues learned this by analyzing /hormones/ in the root tissues. Dinneny calls this "hydropatterning."



Hydropatterning

Hydropatterning may regulate nearly every aspect of root development. The contact of a root tip with water (or any liquid) or air determines the tissue growth. Changes in the liquid availability at the root tip can drastically change the way the root tissue develops.

On one hand we may not find this strange. After all, we have learned from early classes that roots grow this way. But for the first time Dinneny asked the question, How do they do this? And he found the answer at the very fundamental genetic level. It allows the plant to grow its roots to optimise soil exploration. It automatically ensures that roots do not grow out into dry or hostile soil.

The photo shows a cross section of a rice root. The root has formed a branch poking out to search for water. This is just one of the many tiny directional choices that will determine whether a plant can find what it needs to survive.

Adapted from Science News for Students, ***https://www.sciencenewsforstudents.org/***

Sunflowers follow the Sun!

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

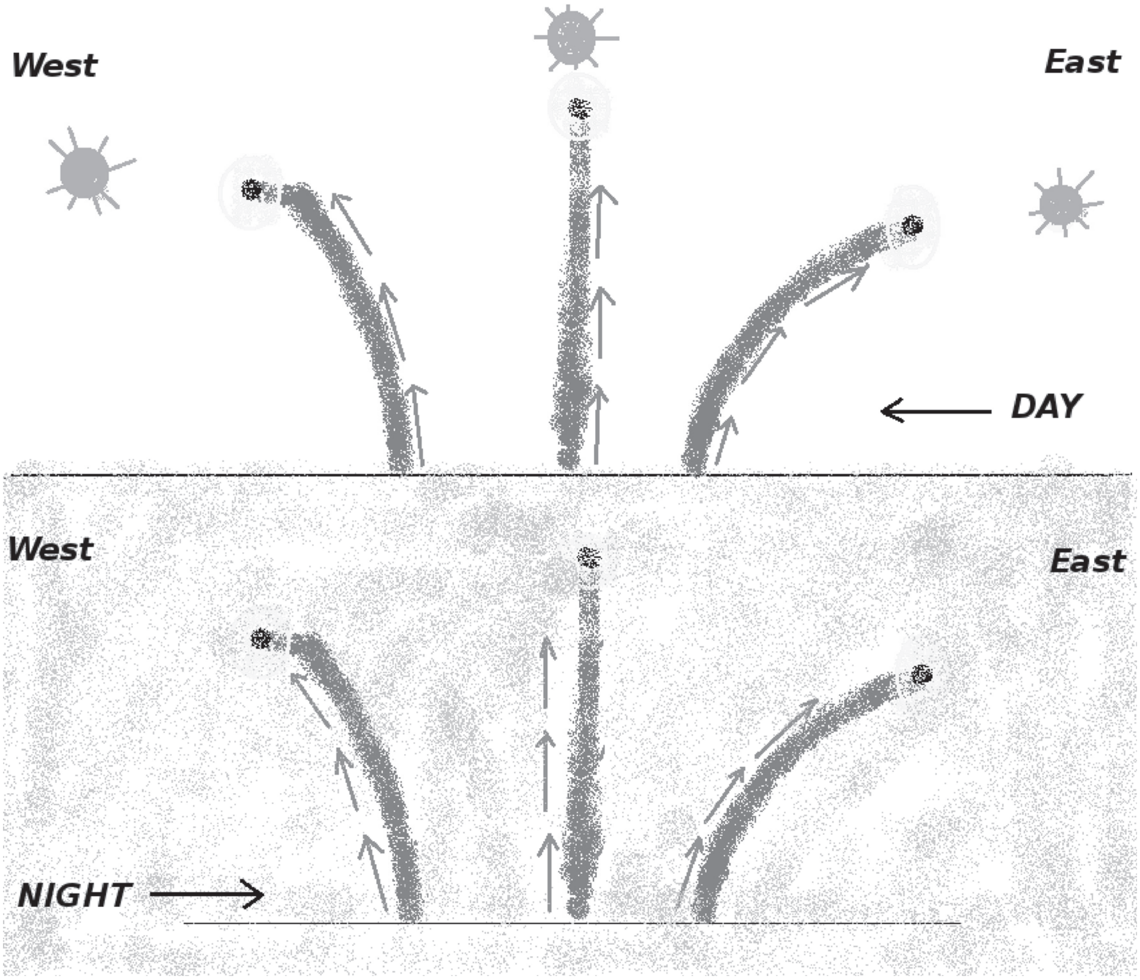
It is easy to spot a sunflower—it is big and bright in colour compared to many other flowers. Sunflower has got its name because the flowers turn toward the Sun. Even though it is native to North-America, now sunflowers are grown almost everywhere for food, seeds and oil. The sunflower plant (***Helianthus annuus***) has a large flower at the end of of the stem. The stem of the flower can grow up to 3 meters tall, with a flower head that can grow up to 30 cm in width. The flower head is made of hundreds of tiny flowers called *florets*. Together they make up a "false flower" also called *pseudanthium*. It is very easily visible to insects and

birds which help pollinate it. A typical sunflower can produce up to 1,000 seeds.\

Is there an internal clock?

It has been known for a long time that sunflowers, as the name indicates, greet the Sun in the east each morning and follow the movement of the Sun throughout the day until it sets in the west- well almost. But then what happens after the Sun sets? How does the sunflower greet the Sun in the east again next morning? Does it have an internal clock? Scientists are slowly but surely beginning to understand the mystery of the movement helped by some recent research findings from University of California at Davis in the USA.

Some observations first: It is not that all sunflowers follow the movement of the Sun. This is common misconception,

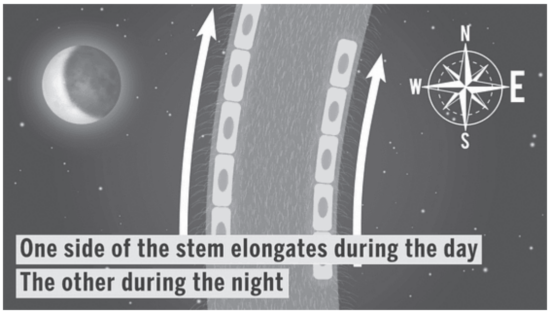


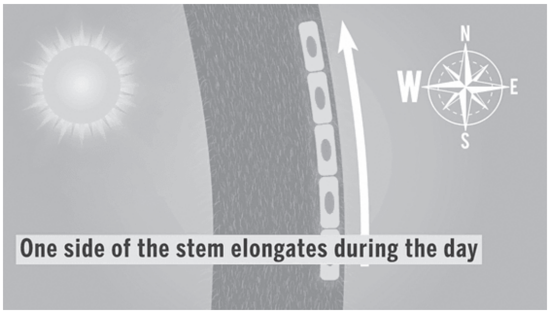
actually a fully grown sunflower does not follow the daily rhythm but faces east all day. It is the young, not fully mature, sunflowers that follow the movement of the Sun. This movement slows down and comes to a stop as as the flower matures to it full size and faces the same direction.

Circadian rythms

The scientists were interested in the day-night rhythm followed by young sunflowers during their growing phase. Any biological process that follows this rhythm of day-night 24 hour cycle is said display what is known as "*Circadian Rhythm*". It is a rhythm that your body also follows and it influences important bodily functions. Sunflower appears to follow this circadian rhythm like humans and many other living beings.

The next question is then how do they do it: The stem of the sunflower plant has a single sunflower at the top. Scientists have found that during the day the young sunflower follows the Sun's progress and return to the original position in the morning. In fact they have observed that the plant rearranges itself at night to begin the same process the next day. It does not





matter if the day is longer or shorter than the night. They do this by growing the stem in a peculiar way. During the day the western edge of the stem grows more than the eastern edge so that the flower can follow the Sun. And during the night the eastern edge grows longer than the western edge, bringing back the flower to the original position to greet the Sun again in the morning. It is some thing like a car wheel close to the curb covers lesser distance than the outer wheel to turn left and the opposite while turning right. The differential growth of the stem on the eastern edge and western edge allows the sunflower to rhythmically move along with the day night cycle. How did they measure this? They put ink dots on the stems and filmed them with a video camera. On a time-lapse video, they could measure the changing distance between the dots.

Is the clock internal or external?

Is the growth pattern then determined by an internal circadian clock? In order to find out, scientists grew the sunflower plants inside with artificial light with different light and dark cycles going up to 30 hours instead of 24 hours. However, the sunflower seemed to follow an imaginary path of the Sun maintaining the circadian rhythm showing that indeed they have this incredible internal clock mechanism.

Why do these plants behave in this way? Apparently facing the Sun helps the plants to grow larger maximising the photosynthesis. Furthermore, the early warming of the flower that faced east helps in attracting the bees which help in pollination.

Is this peculiar to sunflower plant alone among plants? Actually the circadian rhythm is widely observed in many variety of plants as in the case of animals. It may not be as dramatic as in the case of sunflower; in fact the research on circadian rhythms began in 1729 when the French astronomer de Mairan noticed the daily leaf movements of a plant. After nearly a century it was accurately measured that these rhythms had a period of 24 hours and are not due to environmental factors, but internal in origin.

The importance of the study on sunflower is because it seems to be the "first example of a plant's internal clock modulating the growth in a natural environment," as the scientists say. As molecular biologists, they had earlier shown the connection between genes responsible for *rhythm* and the plant hormone responsible for *growth*. Sunflower plant provides a nice example to understand the relationship between the 'clock' and 'growth' at the molecular level where the growth is driven by genes that respond to light and the circadian rhythm.

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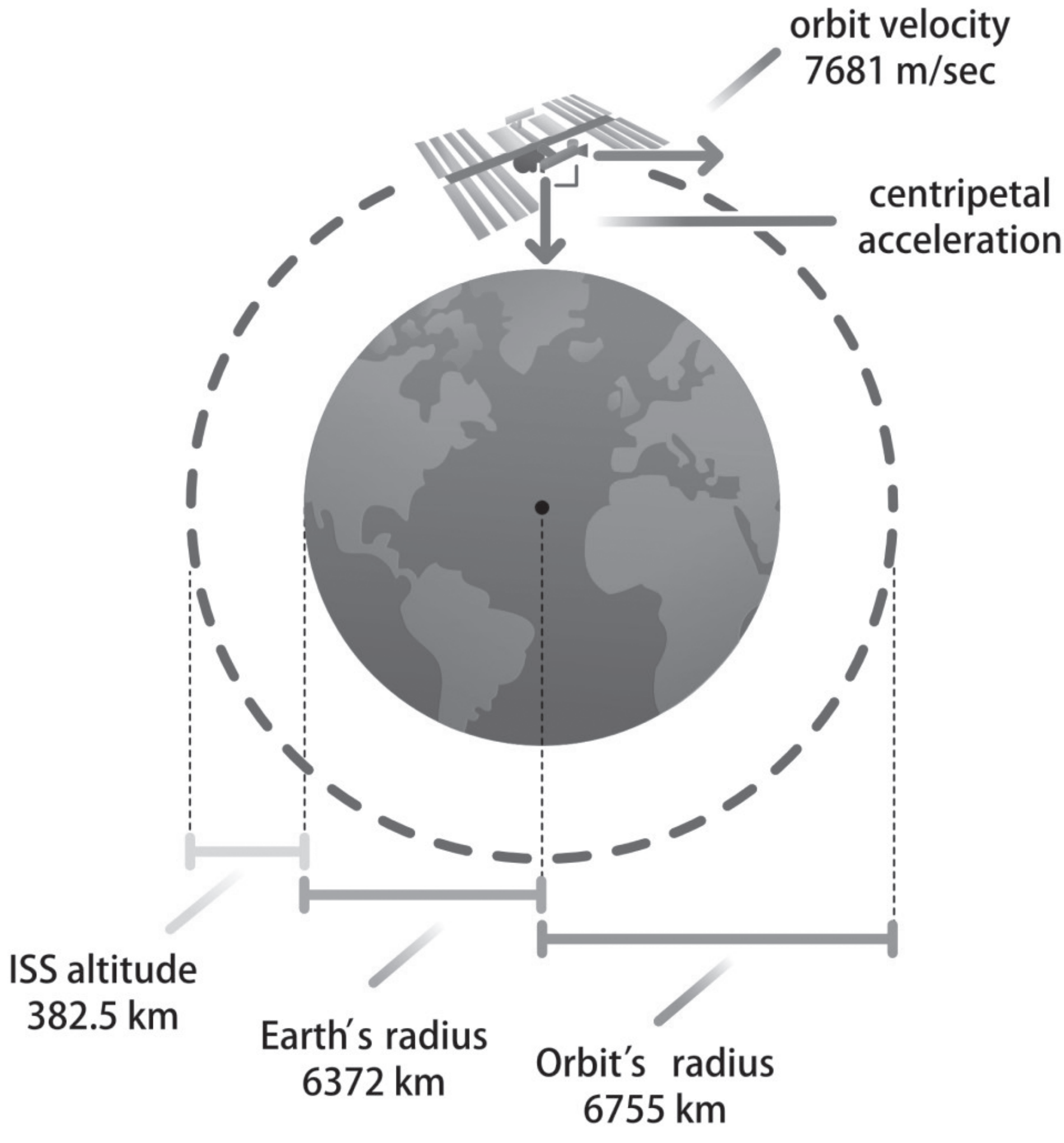
Cover

A rainbow rose. Photo by Ryan Amos. Technique developed by Peter van de Werken; based on fact that rose petals are arranged in a Fibonacci spiral.

Back Cover:

Pansies are the most cross-bred flowers that are available in hundreds of colours.

"The environment people know we're an endangered species, the hunters know we're an endangered species... If only the lions knew we're an endangered species."



Schematic showing the orbit of the International Space Station which is a satellite in low Earth orbit (about 400 km above Earth). It completes about 15.5 orbits per day and can often be seen with the naked eye. Its first component was launched in 1998, the last module was fitted in 2011, and it is expected to be in use till 2028!