c o n t e n t s

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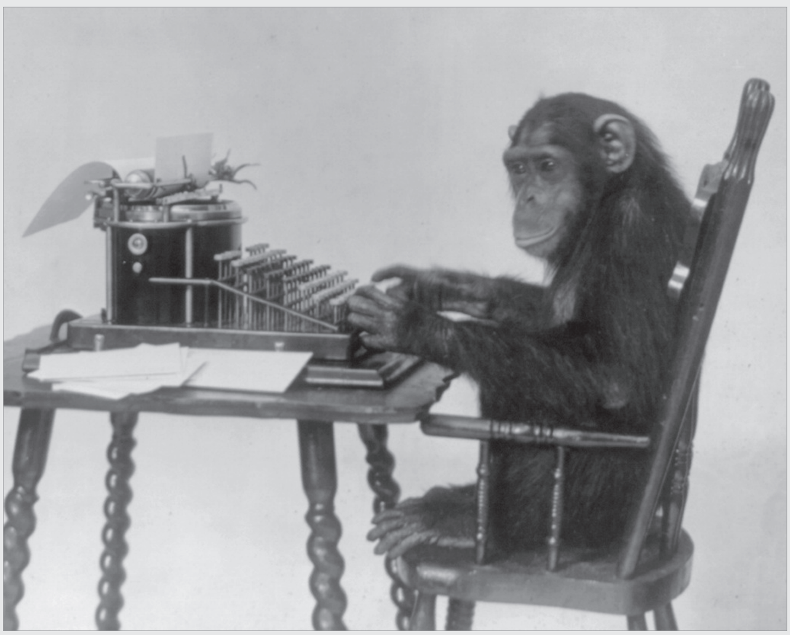

Your own continued fractions

R. Ramanujam,
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Continued Fractions (CFs) look forbidding (meaning, unfriendly or threatening in appearance). That is because continued fractions, as the name says, are infinitely continuing expressions! But they are easy once you realise what is happening.

For instance, let us consider Ramanujan's puzzle.

$$x = \sqrt{1+2\sqrt{1+3\sqrt{1+4\sqrt{1+\ldots}}}}$$

The answer is 3! Let us see how this comes about.

We know: $(x+1)^2 = x^2 + 2x + 1$.

We can rewrite the right hand side as: x (x+2) + 1, then further rearrange it to read: 1 + x (x+2).

Thus: $(x+1)^2 = 1 + x\,(x+2)$.

Therefore x+1 = sqrt(1 + x (x+2)).

where sqrt stands for the square root of the number.

Let x=2. Substituting for x, we get 3 = sqrt (1 + 2 (4)). Notice that there is the number 4 on the right hand side of the equation. Also, if we substitute x=3 in our original equation, we get 4 = sqrt (1 + 3 (5)). Substituting this expression for '4' in our equation, we get:

3 = sqrt (1 + 2 (sqrt (1 + 3 (5)).

And the next readily waiting equation (using x=5 in our original equation):

5 = sqrt (1 + 4 (6)),

tells us how to proceed.

Beware: such substitutions do not always work, there are some subtle points about 'convergence', which means that the generated values should approach a specific real number, however slowly.

But do you see how you can generate your own continued fractions?

Here is another pretty example. Consider the continued fraction in the picture.

$$\Phi = \frac{1+\sqrt{5}}{2} = \boxed{1 + \cfrac{1}{\boxed{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\ddots}}}}}}$$

Can you see that the expression in the inner box is exactly the same as the one in the outer box? If you call the inner one x, the outer one is also x and we get the equation:

$x = 1 + 1/x$

Multiply throughout by x and rewrite this to get:

$x^2-x-1 = 0$.

You know how to solve quadratic equations, we get two solutions:

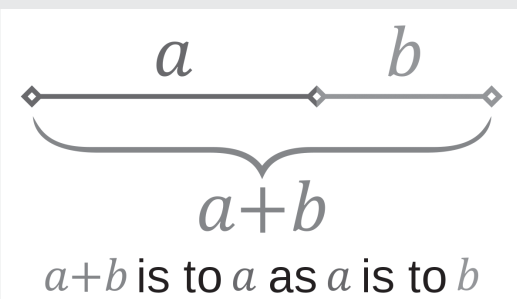
$x = (1+\mathrm{sqrt}(5))/2$ and $(1-\mathrm{sqrt}(5))/2$.

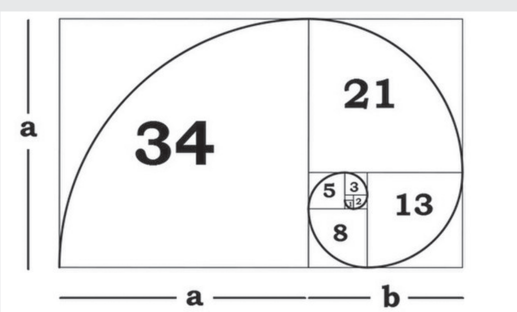
But x must be positive. (Can you see why?) So we discard the second solution.

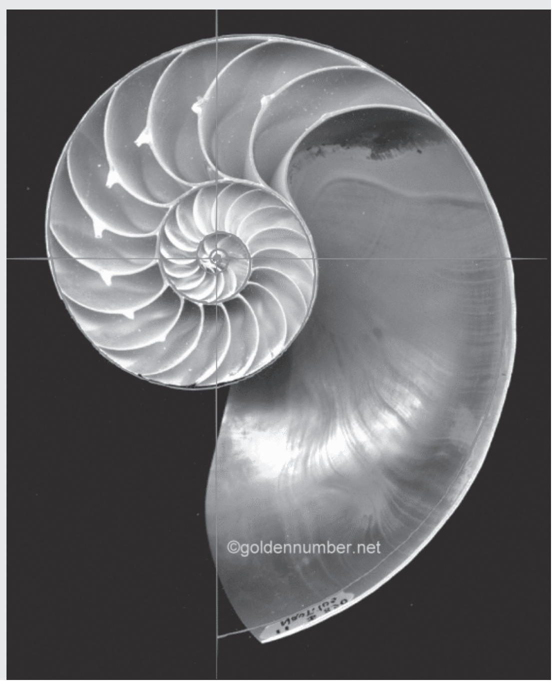
So we find that the continued fraction in the picture is equal to (1+sqrt(5))/2. This is a recurring decimal, which means if you try to find its value, the digits go on for ever, but the first few decimal places are 1.618. It has a special name: it is called the *golden ratio*and denoted by phi. This is another “fundamental constant” in mathematics, much loved by artists. We have written about it in JM earlier. For a reminder, see the Box. ●

Golden Ratio

The golden ratio is the ratio found by dividing a line into two parts (see figure) so that the ratio a/b is the same as the ratio (a+b)/a. This results in a special and pleasing set of proportions. For instance, the spiral shown in the figure is got by repeatedly drawing sections of circles through rectangles that are constructed in this ratio (that is, 1.618:1). Many shells, including snail shells are perfect examples of the golden ratio. Many leaves and petals in nature are placed on stems in this ratio. Even the proportions of the famous Pyramids of Giza in Egypt are constructed in this ratio.







The Ramanujan Machine

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Very recently, on July 23, 2019, a group of 7 researchers from Israel announced something very interesting. They have written an article titled "***The Ramanujan Machine: Automatically Generated Conjectures on Fundamental Constants***", and also built a website where you can go and generate your own mathematical conjectures. Everything about this is interesting and worth explaining, so listen! Or, rather, read on!

What is a conjecture?

The Cambridge dictionary defines the word conjecture as a guess about something based on how it seems and not on proof. That is, just as you would like to guess answers for problems in your exams (and hope to get them right!), the scientists are doing the same thing! See more on Conjectures in the Box.

Of the authors, **Gal Raayoni, George Pisha, Yahel Manor, Doron Haviv, Yaron Hadad** and **Ido Kaminer** are from Technion, the IIT of Israel. (In English it is called Israel Institute of Technology). **Uri Mendlovic** is from Google's Tel Aviv group. Indeed yes, there are people in companies like Google doing mathematical research.

Not a machine

Even though it is called a machine, what the authors offer is not like a machine you might imagine in a factory. Computer scientists call any automated method (algorithm) a machine. This is an algorithm implemented in a computer program. Normally programs take input from someone, do something and produce an output. This program asks you to input a “fundamental constant” *c* and will give you an expression *e*. The conjecture is then defined as “*c* = *e”* and it is upto you to prove this right or wrong.

For example, you can give the number π as input and the program gives an infinite summation. But you have to check that substituting values on the right gives the correct infinite expansion of π for more and more digits. Invariably, the program is able to assert the equation confidently, and it is hard to prove it wrong.

Fundamental constants

In school we learn that sqrt(2) is not rational (here sqrt stands for the square root of the number): it cannot be written in the form p/q where p and q are positive integers with no common factor. But it can be written as the solution to the equation $x^2 - 2 = 0$. In school we encounter π, which is the ratio of circumference to diameter of ANY circle, however large or small. As it turns out, π cannot even be written as the solution to equations like the one above, we need infinite expressions. For instance, π/4 = 1 - 1/3 + 1/5 - 1/7 + ... Such numbers are called *transcendental numbers*.

$$1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \cdots = \frac{\pi}{4}.$$

There are many famous transcendental numbers like π which are extensively used in mathematics and science. For instance, *e*, the Euler’s constant: e = 2.71828 .... For *e*, the Ramanujan machine gives the conjecture as shown.

$$\pi = 3 + \cfrac{1}{7 + \cfrac{1}{15 + \cfrac{1}{1 + \cfrac{1}{292 + \cfrac{1}{1 + \cfrac{1}{1 + \cfrac{1}{1 + \cfrac{1}{2 + \cfrac{1}{1 + \cfrac{1}{3 + \cfrac{1}{1 + \ddots}}}}}}}}}}}$$

Is this correct?! It is upto us to find out!!

Continued fractions

The expression on the right hand side of the equation for e is a continued fraction, where you start with a number on top as numerator, and the denominator has another fraction, whose denominator has another fraction, and so on, for ever. Showing that such equations are correct can be very hard, but it is possible and can be learnt (with great joy). See the article in this same issue for some fun with continued fractions.

Srinivasa Ramanujan

The great Indian mathematical genius Srinivasa Ramanujan was fascinated by continued fractions (CFs). It is known that he spent early years of his research exploring many CFs. Not only CFs, he loved all infinitely continuing expressions.

In 1911, Ramanujan posed *Question 289* in *Volume 3* of the **Journal of the Indian Mathematical Society**: does sqrt(1 + 2 sqrt(1 + 3 sqrt(1 + ...))) have a finite number as solution? If yes what is it? *(Six months went by*

Conjectures

Mathematicians celebrate not only theorems, statements that are proved to be true, but also conjectures, which are statements not proven either way so far. These are mere statements of belief by somebody, and as the community of mathematicians sharing that belief increases, the conjecture gains importance and more people start thinking about it.

The following conjectures were discovered by a computer:

$$\underbrace{2.71828\cdots}_{e} = 3 - \cfrac{1}{4 - \cfrac{2}{5 - \cfrac{3}{6 - \cfrac{4}{7 - \cfrac{5}{8 - \dots}}}}}$$

$$\underbrace{3.50387\cdots}_{\frac{2}{\frac{\pi}{2} - 1}} = 3 + \cfrac{3}{5 + \cfrac{8}{7 + \cfrac{15}{9 + \cfrac{24}{11 + \cfrac{35}{13 + \cfrac{48}{\dots}}}}}}$$

RamanujanMachine.com

Thus good mathematicians often offer conjectures for others to work on. Some even claim to have results for which there is no understandable proof, and then other mathematicians refer to these statements as conjectures as well. This is merely being cautious, since however great this mathematician might be, there might turn out to be some mistake in it, until it is proven conclusively one way or the other.

For instance, we all learn in school that every positive integer greater than 1 can be written uniquely as a product of prime numbers. This is celebrated as the Fundamental Theorem of Arithmetic, and we not only learn to prove it, we also use it for learning long division. Instead of products, if we think of sums, there is a simple statement: every positive integer greater than 2 can be written as the sum of two prime numbers. This has been verified to be true for integers upto 4,000,000,000,000,000,000 (4×10^{18}), but it is still only a conjecture. It is the famous *Goldbach Conjecture*, named after the German mathematician **Christian Goldbach** who wrote this in a letter dated 7 June 1742 to the mathematical genius **Leonhard Euler**.

with nobody giving a solution, until Ramanujan provided one himself.)

In his famous letter to the mathematician **G H Hardy**, Ramanujan gave several CFs that Hardy said: “defeated me completely”. Ramanujan famously wrote a number of equations using CFs (which used numbers like *e* all over the place) without proof, and many were only proved several years later by other mathematicians. In fact, it was not until 1987 that all 17 of Ramanujan’s series for $1/\pi$ were proved (by the Canadian mathematicians, the **Borwein brothers**).

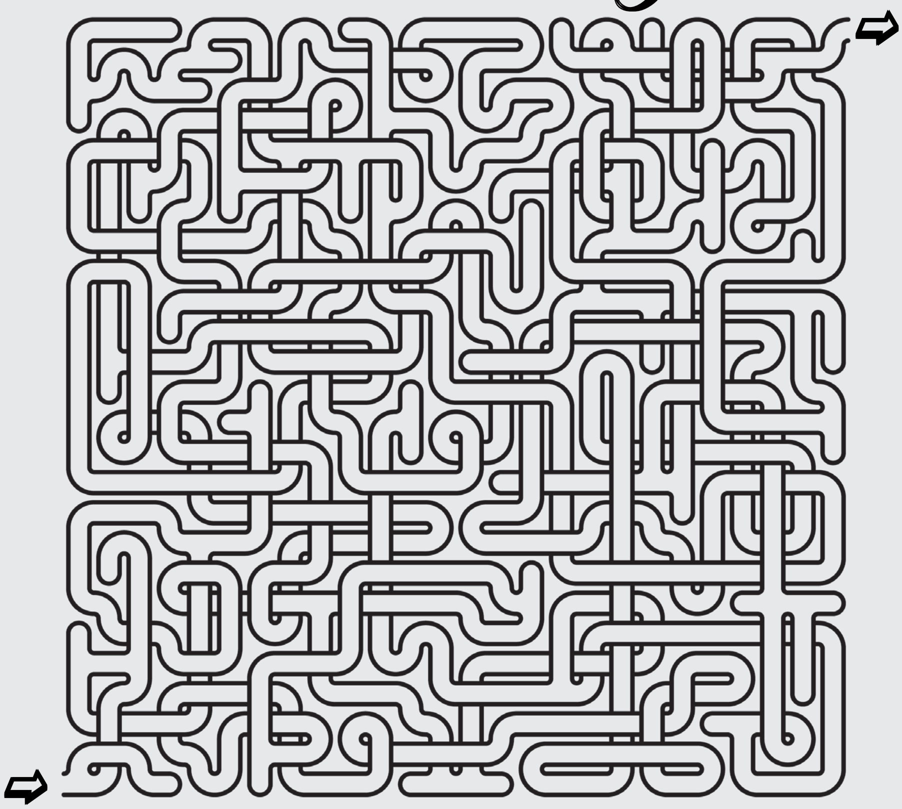
This is the reason the Israeli authors have called their algorithm “**the Ramanujan machine**”. They hope that it reflects the way Ramanujan worked, by deep analysis of patterns in formulas and “seeing” regularities. Their algorithm uses principles of “deep learning”, a method that perceives layer upon layer of patterns. It generates CFs based on patterns, then refines them over and over again, testing for how close the CFs get to the known values, making corrections and then looking for new patterns, this process eventually giving the conjecture.

The "paper"

The authors of the Ramanujan machine have written an account of their algorithm and posted it on the "archive". This is a repository (a place where resources can be stored and accessed by other scientists) of scientific articles, but whatever is written there is not considered a "publication" by the scientific community. Their article, called a "paper", has been submitted to a journal where some reviewers (whose names are unknown) are reading it. They will comment on the techniques and results, and if they are convinced, the paper will be published, and only then the "Ramanujan machine" will be accepted by the community and further developed. This process is itself like conjecturing and proving, isn't it?

Whether the conjectures generated by this algorithm are correct or not, it is a fascinating exercise, and may give new ideas to many mathematicians in future. •

Find the way



Space Diary

Chandrayaan-2

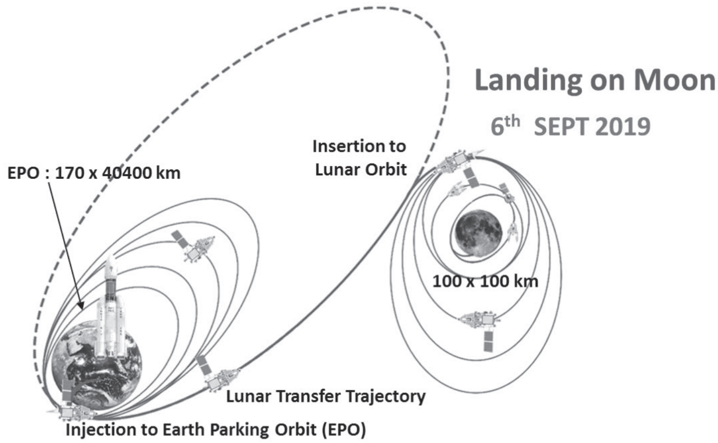
On July 22, 2019, India launched its second moon mission called **Chandrayaan-2**. The satellite was launched in space by a launch vehicle called GSLV Mk III that stands for *Geosynchronous Satellite Launch Vehicle Mark III*. The words "Mark III" means that it is the third improved version. For the meaning of "geosynchronous", see the Box.

First the satellite is put into an elliptical (egg shaped) orbit where the closest point of approach is as small as 230 km above the Earth but the farthest point of the orbit was 45,163 km. Slowly, this was raised by firing more rockets (called orbit-raising burn). Four such burns will bring the orbiter into an orbit from where it can escape Earth's gravity — this is called trans-lunar injection (TLI).

The TLI procedure was refined and perfected by the Soviet (old Russian) **Luna** space missions. The orbit burn is done at a time and place so that the satellite will go into a path that will arrive at the moon. Even then all is not yet complete: the satellite has to be slowed down and "captured" by the moon into an orbit around it, so that it becomes a moon to the moon! In fact, when the American Apollo 8 lunar mission was injected with such a TLI, the entire procedure could be seen from the islands of Hawaii.

In fact, Chandrayaan-2 was visible as a slow, bright, moving objectover Australia immediately after launch. The TLI for Chandrayaan-2 is expected to happen in the month of August.

It will take seven weeks for Chandrayaan-2 to reach the moon. It will spend 23 days orbiting the Earth, and 13 days orbiting the moon (decreased from the original 28 days due to delay in the launch). It is expected that the lander will land on 6th September, 2019. We have to wait and watch, literally!



The Chandrayaan-2 satellite has three parts: a lunar **orbiter**, a **lander**, and a **rover**. Its main objective is to map the location and amount of water on the moon, if any.

Geostationary Orbit

A geostationary or geosynchronous orbit is one that circles the Earth in a circular orbit with a time period equal to that of the Earth rotation, and moving in the same direction. This means that it will always be overhead at the same point on Earth. This is convenient if you want to send instructions and signals to the satellite in such an orbit from a fixed point in space (for instance, from the ISRO command station in Sriharikota to the satellite which will remain overhead). So it is “synchronous” with the movement of the Earth. The antennae on the Earth then can be permanently pointed at the satelite. The orbit turns out to be a fixed one, at a height of 35,786 km above Earth. It is difficult to place a satellite so high up in the sky. So it is done in stages.

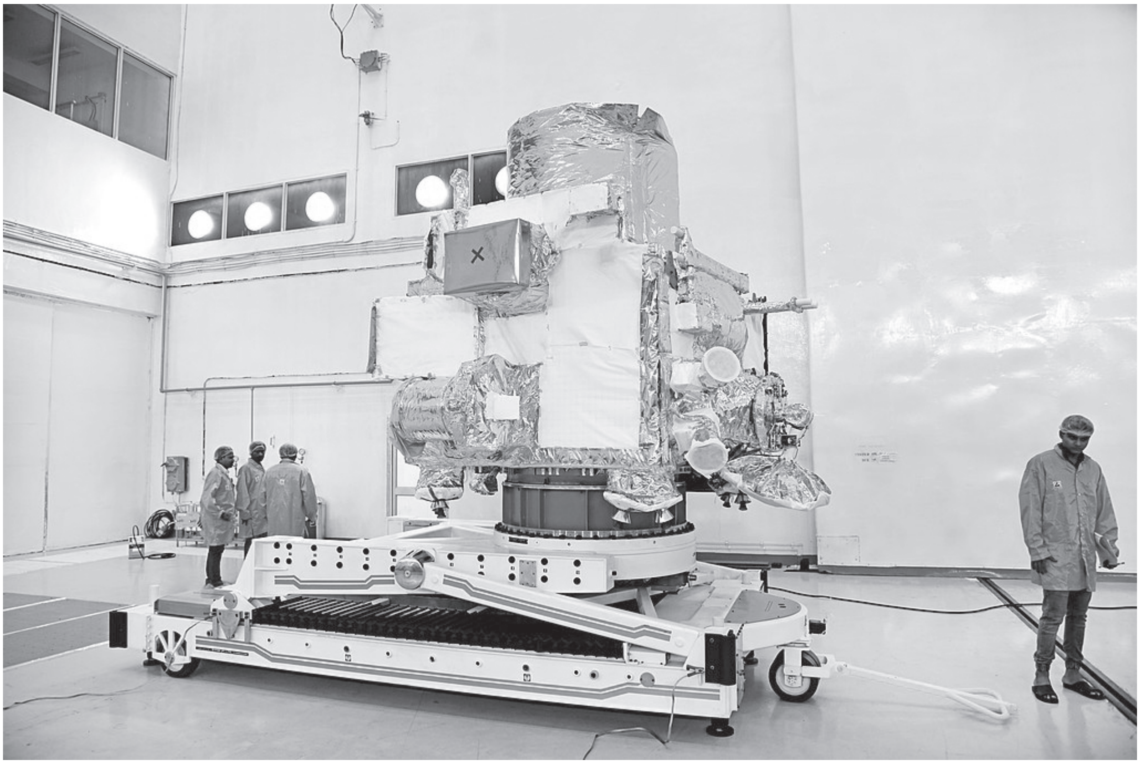
Lunar Orbiter

As the name suggests, the orbiter will orbit the moon at a height (altitude) of about 100 km. It carries five scientific instruments. Three are new, and two are improved versions of those launched in the earlier Chandrayaan-1 moon mission. The main goal of the orbiter is to observe the lunar surface and so it carries a high resolution camera. It was built so that its batteries would last about one year.

The Vikram Lander

Lander is the object that will detach from the orbiter and actually land on the moon. It will first descend into an elliptical (egg shaped) orbit of 30 km X 100 km so that it will fly closer to the moon. It has special liquid fuel engines for this task. After a series of check, it will attempt a soft landing on the moon.

Have you thought about this: Even on

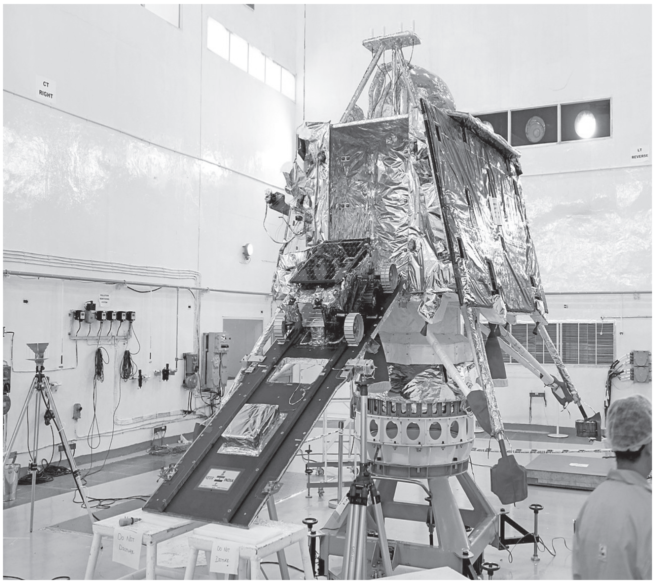


Lunar Orbiter

Earth, if you are falling, the friction from the air will slow down your fall. There is no atmosphere on the moon and so no braking effect. If you allow the lander to "fall" from the orbiter, it will crash-land, just as the "Moon Impact Probe" from Chandrayaan-1 did. This time, the scientists want the lander to survive the landing without getting damaged or destroyed. For this, the lander will have parachutes to slow the fall. Some landers even have rockets that go in "reverse" and slow the fall. Vikram will have 8 thrusters for attitude control and 5 main engines with liquid fuel.

It will have several cameras, mainly to check for obstacles in the path of its landing, such as rocky terrain, cliff, etc. It can land on surfaces with sloped up to 12 degrees.

Lunar lander seen with rover on the side ladder



What is the lunar temperature?

The moon is very cold or very hot, going to 125C in the "daytime" (which lasts 13.5 days on the moon!) and -170C at "night". Why is there so much variation, unlike on Earth? This is because the moon does not have an atmosphere. Why? The moon is very small, and has a small mass, just about 1% of the Earth's mass. So its gravity is very small, the value of g on the moon being $g=1.6\ m/s^2$. Contrast this with $g=9.8\ m/s^2$ on Earth. So the moon cannot hold down the gases that form an atmosphere. Years of being buffetted by the solar wind would have stripped off whatever little atmosphere was present. Another reason is that the moon also does not have a strong magnetic field unlike on Earth. Earth has a liquid core of iron that causes a strong magnetic field to be formed around it, which extends beyond the planet. Lots of charged particles and radiation (from the Sun and outer space) is blocked by this field. This prevents the Earth's atmosphere from being stripped off.

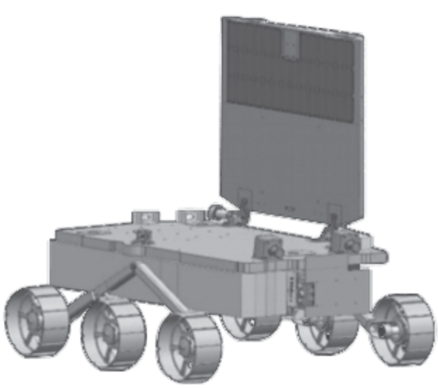
But in the case of the moon, there is no protection from this radiation. Unless you are in a place where sunlight cannot reach: that is, at the **lunar poles**. Why is this place special? Because if it remains cold all the time over here, it is possible that water (in the form of ice) may be found at these places.

This lander was named after the scientist **Vikram Sarabhai**, the father of the Indian space programme.

The Pragyan Rover

Once the lander has landed safely, it will release the 30 kg small rover that can "rove" or move about on the moon's surface. Operated on solar power, the rover will move on six wheels and is expected to cover about 1/2 km of the moon's surface. It will travel at the incredible speed of 1 cm/s, taking rock samples and doing a chemical analysis of the composition and sending the information back to earth. Since the moon's terrain at the exact spot of landing is unknown, each of the six wheels has an independent electric motor to turn it! So it can go over very bumpy terrain. It also has a "*rocker-bogie*" suspension system. This means that when the wheels are at different heights, going over different slopes, the main part of the rover (called the *chassis*) will be more or less kept horizontal and not shaken very much, so as to protect the instruments it carries.

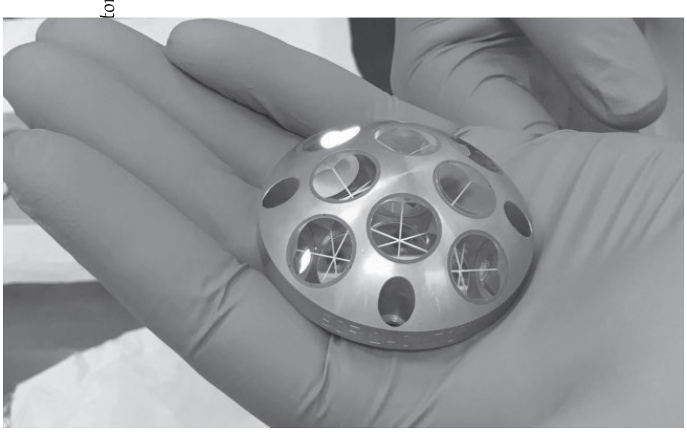
For the rover to move, there are two stereoscopic 3D vision cameras. These



cameras will take 3D images of the immediate surroundings so that an Earth-based team can decide which direction it can safely move without hitting a rock or toppling into a hole. The rover will operate for one lunar day (about 2 Earth weeks) since its electronics will not be able to operate in the intense cold of the lunar night. So for optimum operation, the rover should be brought out just when the day begins.

Not all eggs in one basket

As you can see, there are many tense moments about the operation, including at the lift-off itself, which happened successfully. In addition to positioning the orbiter in the correct lunar orbit around the moon, and landing the lander safely, the rover should also work well, and at the right time. Because of this, all these three carry different scientific instruments. These are called *payloads*. The orbiter carries 8, the lander 4, and the rover 2. Many will take detailed photographs and analyse the lunar rock. Some will measure if there are any “moonquakes”, that is, it will do seismology. Surface and air measurements will also be done. One of the quirkiest payloads is a NASA laser **retro-reflector** on the lander that will measure accurately the distance between the lunar surface and the satellites above. Many such reflectors are already there on the Moon, but this is so small that it fits on the palm of your hand! It is a testing arena for future Mars missions where such measurements will be critical.



However, one of the main missions of Chandrayaan-2 is to search for water on the moon. What is the interest in finding this out?

Is there water on the moon?

We know that liquid water cannot survive on the moon and water vapour is decomposed in the strong sunlight since the moon has no atmosphere. Why? See the Box. Since the 1960s, scientists have believed that water ice could survive in cold places on the Moon. At these places, the sunlight should never fall, so that it remains cold all the year around. Possible locations are deep craters at the Moon’s poles. Recently water molecules have been detected in the thin layer of gases above the moon’s surface. But it is more likely to find forms of water as in hydrates or hydroxides of lunar minerals.

In 1976 the Soviet *Luna 24* probe landed on the moon and showed evidence for water molecules 1-2 m deep under the lunar surface. But it was a small amount: just 0.1% by mass. On Sep 24, 2009, the NASA’s *Moon Mineralogy Mapper* (MMM) spectrometer on Chandrayaan-1 detected signatures of water on the moon surface. This was confirmed by NASA in 2018, whose MMM showed that water ice is indeed present at the Moon poles. If this water is indeed in considerable quantities, it will make long-term lunar habitation by humans possible.

This is why it is planned to land the lander of Chandrayaan-2 at the South pole: around 71 degrees south latitude, just north of the South Pole-Aitken basin rim. An alternate site at 68 degrees South also has been selected in case the first option does not work out. This basin is the largest, deepest and oldest basin that has been found on the moon. It is rich in minerals such as iron, titanium and silicate rocks.

Woman Power

Many women are part of the panel of instrumental scientists and engineers who were crucial to the development of Chandrayaan-2 project. Many women are in positions of authority as well. They are:

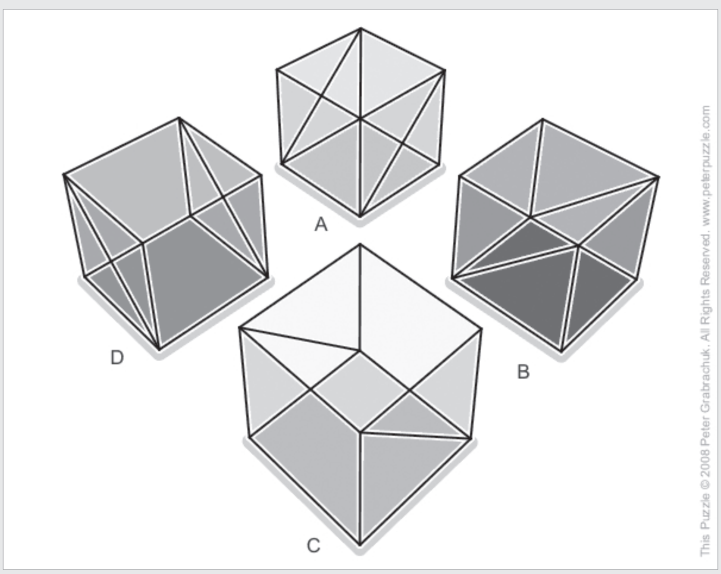
Muthaya Vanitha – Project Director, Chandrayaan-2

Ritu Karidhal – Mission Director, Chandrayaan-2

Chandrakanta Kumar – Deputy Project Director, Chandrayaan-2

We wish them all the best.

—Compiled from several sources; images from ISRO website and Wikipedia.



Four Cubes Outlines Puzzle:

In the illustration four flat cube-like shapes are shown. Their patterns are drawn with bold black lines. Which of the outlines can you draw without taking your pencil off the paper or going along the same line twice? Which of them can't be drawn in this way?

Solution on back inside cover.

Source: https://www.mathsisfun.com/puzzles/

Thinking can be fun!

S.Narayani

Let us do an experiment.

What is the first thing that comes to your mind when I say "experiment"?

Are you inside a lab, wearing a lab coat and safety goggles?

Your next question would be "What are the materials required for this experiment?"

What if I told you that you do not have to physically conduct the experiment, but simply imagine it in your brain?

Welcome to the amazing world of Thought experiments.

Called "Gedanken experiments" in German, thought experiments are experiments that are conducted entirely in the realm of imagination. All you need is a question to begin with. Sit in a quiet place, close your eyes, and imagine an experiment that would answer the question.

Does this sound absurd?

What if I told you one of the most important scientific theories of our time has its origin in a thought experiment?

Einstein and Special Relativity

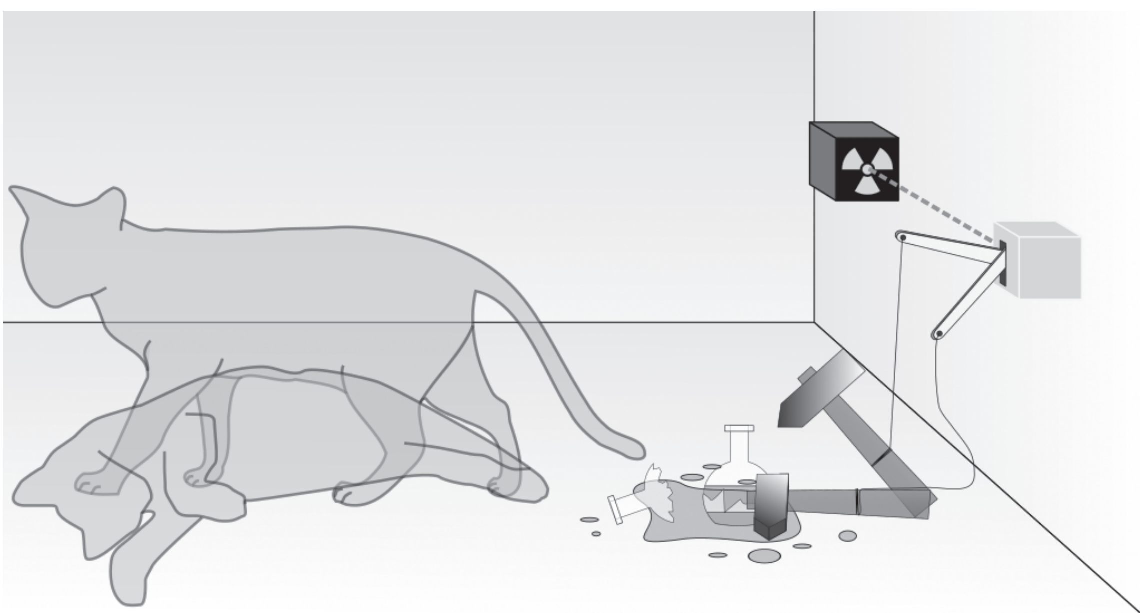
We have all heard of the special theory of relativity. This genius theory has its beginnings in a simple thought experiment. When Albert Einstein was just 16, he imagined himself chasing a beam of light. Assuming that he eventually reached the speed of light, he envisioned that he might see the beam of light at rest, though it is oscillating in space. This simple thought experiment led to a series of other tests, experiments and equations, ultimately giving us Einstein's special theory of relativity.

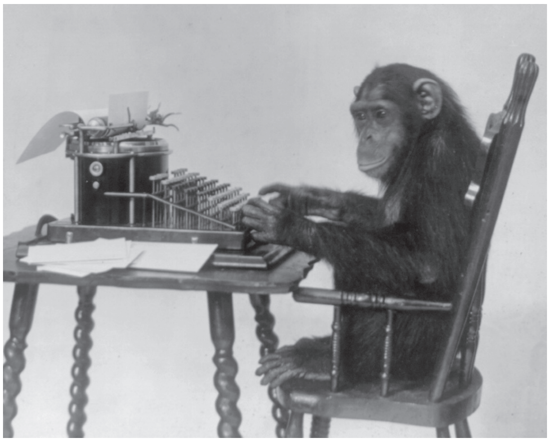
It can be understood why these experiments are never performed. We can only imagine ourselves travelling at the speed of light. In some cases, there is no intention to perform the thought experiment, because the questions it raises are good enough for further research.

Schrodinger's Cat

Let us consider the famous thought experiment: Schrodinger's cat. Austrian Physicist Erwin Schrodinger performed this experiment in 1935 in response to the so-called "Copenhagen interpretation". The Copenhagen interpretation is with respect to the quantum world, which assumes that a system is specified by a "wave function" that can be a *superposition* of several possible states. Superposition is exactly the behaviour that light waves show: they can add or subtract depending on whether the waves meeting and overlapping are in-phase or out-of-phase at that point. The Copenhagen interpretation states that unless the system interacts with the outside world or is observed by the observer, it remains in superposition. After the interaction, the system loses it superposition and collapses into a definite state, which is one of the unique states which are part of the superposition.

Schrodinger's experimental design has a cat in a box. The box also contains a radioactive substance with the potential to decay at a random time. When the substance decays, the attached Geiger counter releases a vial of Hydrocyanic acid, which would then kill





the cat. Until the cat dies for sure, the Copenhagen interpretation would say that the system is described by two superposed states, "Cat alive" and "Cat dead"! While it is very interesting to make the assumption that "the cat is both alive and dead" before opening the box, Schrodinger argued that such arguments cannot be made for a *macroscopic system*. He merely used this experiment to point out the obvious flaws in existing theories of quantum mechanics. Needless to say, this experiment is one of the most debated, most quoted and even most misinterpreted thought experiments till date.

Infinite Monkeys and Shakespeare

Consider this scenario, there are infinite number of monkeys. We give them an infinite number of typewriters and wait for an infinite amount of time. Eventually, one of the monkeys can type an epic poem! Perhaps even a Shakespearean epic! Called the "Infinite monkey theorem", this is a mathematical thought experiment that illustrates the nature of probability. It teaches us that any scenario can happen, given enough time and resources. This can also be correlated with the "Brute force algorithm" in Cryptography, which is based on the idea that a computer will eventually find the answer if it tries all the possible solutions. It pushes computers to try all the possibilities until a solution is found.

Thoughts about Evolution

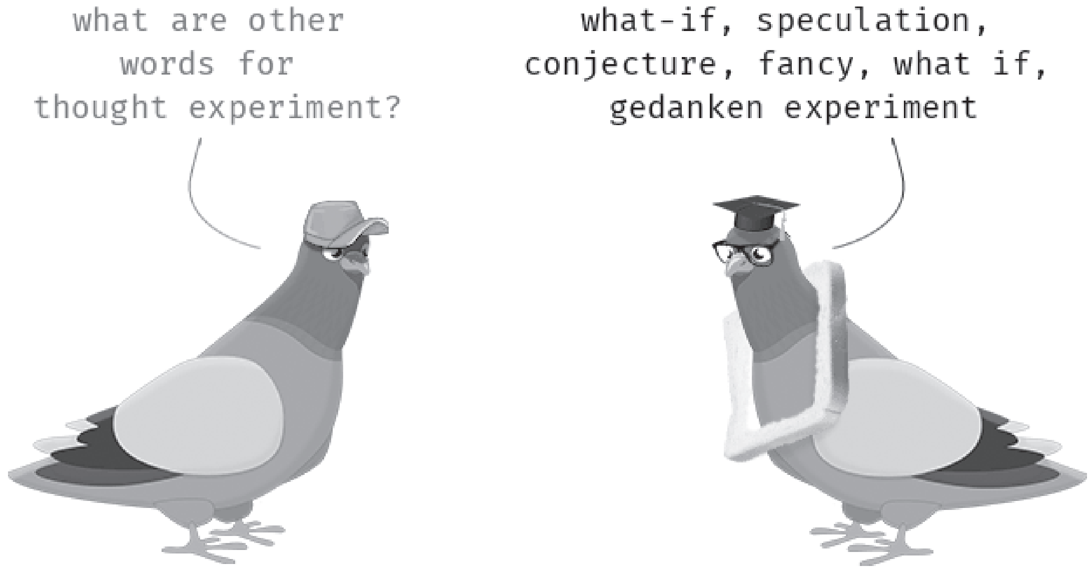
Let us consider an interesting thought process which is commonly used in debates of evolution. This thought process works more like an analogy to answer two most critical questions mankind has:

1. Where do we come from as humans?

2. Where are we going?/ What is our destiny?

Whenever debates about evolution arise, these two questions are raised. Harvard evolutionary biologist **Stephen Jay Gould** then proposed the **Infinite Hallway** thought process to answer these two questions:

"Imagine walking yourself down a long hallway—a corridor so long that it is impossible to see where you came from or where you're going. Then behind you in the distance you hear the sound of a bouncing ball. Sure enough, when you turn, you see the ball bouncing toward you. It is bouncing closer and closer, until it finally bounces past you, and just keeps going, bouncing into the distance and out of sight. The question is not:



Is the ball bouncing? Because clearly it is bouncing, and we observe it. The question is: Why is it bouncing? How did it start bouncing? Did someone kick it? Is it a special ball that simply enjoys bouncing? Are the laws of physics in this hallway such that the ball has no choice but to bounce forever? Where is the ball going?"

Stephen Jay Gould used this analogy to explain that while it is very easy to pose such questions to evolutionary biologists, our human lifetime and understanding is limited and we cannot answer these questions yet.

While the Infinite hallway model is not a thought experiment and it is more of a thought process to explain certain concepts, there are a wide variety of thought experiment types for us to choose from. Real life experiments have their own merit, but thought experiments push our brains into questioning our own beliefs and challenging our biases. Thought experiments are an interesting way to unlearn. Thought experiments are commonly used in philosophy to either answer pressing questions, or even create more pressing questions!

Next time when you are presented with a scientific problem, instead of running to the lab immediately, try and find out if you can work out a though experiment for the issue at hand. May be you will suceed, may be you will not. But I can guarantee you, it will be fun!!

To put it in the words of **Goethe**,

"All truly wise thoughts have been thought already thousands of times; but to make them truly ours, we must think them over again honestly, until they take root in our personal experience."

Do You Know?

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

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

3. How many atoms are there in the world?

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

Answers to Last Issue's Do You Know?

1. What is the difference between a jet and a plane?

Answer: First thing, every jet is an aeroplane, but there are planes which are not jets. So it is like the difference between a square and a rectangle.

The word jet refers to the "jet engines" inside these particular type of planes. Non-jet planes may be driven by propellers at the front of the plane, and some are not powered at all, they just glide!

Mostly, jet engines are found at the bottom of the jet planes, and they use *propulsion*: they suck in air, then mix the air with a special type of fuel that makes the air explode in such a way that the exploding air can only exit from the back of the jet engine. This exerts a really strong force pushes the plane forward. The turbochargers used in jet engines can use even the very thin air

present in the upper atmosphere for combustion.

Why should one want jet engines? One reason is that jets can travel much faster than propeller planes, up to and beyond the speed of sound. Another reason is that they can travel at higher altitudes. Propellers require dense air to engage their spinning blades, whereas jets can work with thin air. Flying higher allows planes to avoid turbulence and also increases the number of aircraft in the skies since they can operate at different altitudes.

2. What kind of chemical reaction is photosynthesis ?

Answer: Photosynthesis is a chemical change process, that can be summarized in a single chemical equation, but that equation is actually the sum total of a collection of chemical reactions. In words:

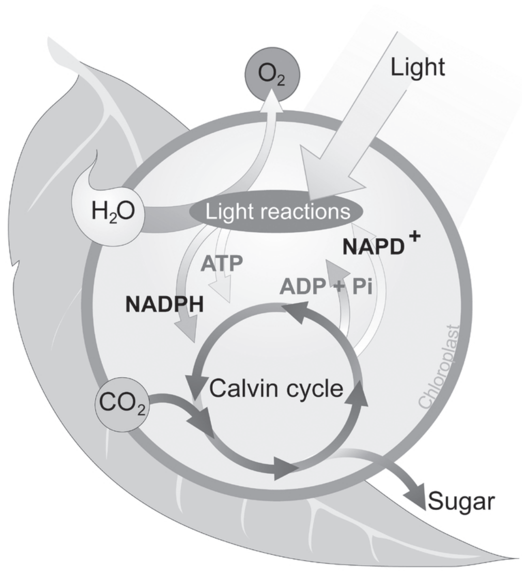
carbon dioxide + water + light -> glucose + oxygen

More quantitatively:

$6CO_2 + 6H_2O$ (+ Light) —> $C_6H_{12}O_6 + 6O_2$

Although the chemical equation appears straight-forward, the process actually involves several "steps" occurring in two major groups of reactions: the **light reactions** and the **dark reactions (or Calvin cycle)**.

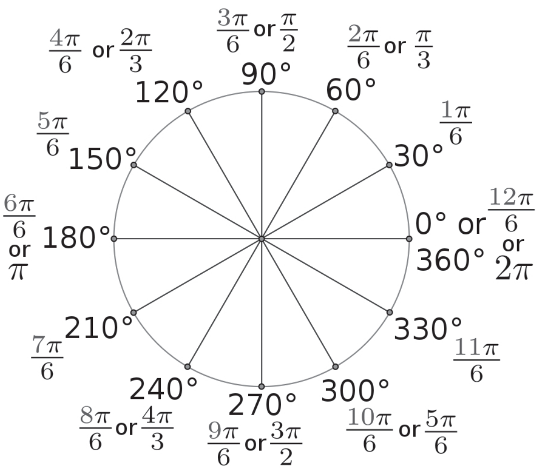
As light energy from the Sun (in the form of photons) reaches a plant, chlorophyll molecules forming a light harvesting complex absorb that energy, exciting electrons. These electrons move along an electron transport chain, eventually transferring their energy into the bonds of special molecules called ATP



and NADPH. These act as highly charged energy carriers ready to provide energy to continue photosynthesis in the dark reactions. These also happen in the daytime; they are called "dark reactions" only because they do not need sunlight to occur.

Using the energy of these molecules and others (including water and carbon dioxide), a carbohydrate called glucose is formed. Each chlorophyll molecule replaces its lost electron with an electron from water; this process essentially splits water molecules to produce oxygen.

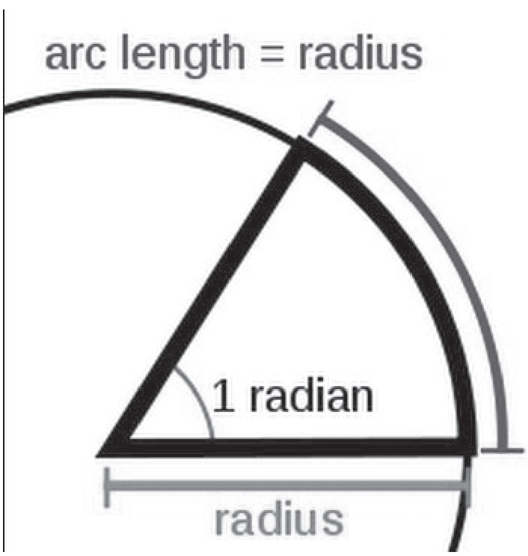
Thus photosynthesis not only drives the **carbon cycle**, it also creates the oxygen necessary for respiring organisms. Interestingly, although green plants contribute much of the oxygen in the air we breathe, phytoplankton and cyanobacteria in the world's oceans are thought to produce between one-third and one-half of atmospheric oxygen on Earth.



3. Angles are so easy to understand in degrees. What are radians and why do we need to understand angles in radians ?

Answer: This is such a reasonable question that it is rather surprising that it is never clearly answered in school. The message always is: "Learn radians because they make math easier."' But why?

We all seem to find *degrees* natural: at least 30 degrees, 45 degrees and 90 degrees. But where do degrees come from?



Like most things in mathematics and science, the answer lies in **astronomy**. Ancient civilizations used astronomy to mark the seasons, predict the future, and appease the gods. They looked up at the sky, and realised that constellations make a circle every day. If you look at the same time every day (midnight), you realise that the constellations also make a circle throughout the year. Thus, every day, the constellations they were off by a tiny bit ("a degree"). Since a year has about 360 days, they decided that a circle had 360 degrees.

Please do not complain that it should really have been 365.242199 degrees! 360 is a nice number, with many factors: 2, 3, 4, 6, 10, 12, 15, 30, 45, 60, 90, 120, 180. It fits nicely into the **Babylonian** base-60 number system. Basing mathematics on the (apparent) movement of the sun is quite reasonable.

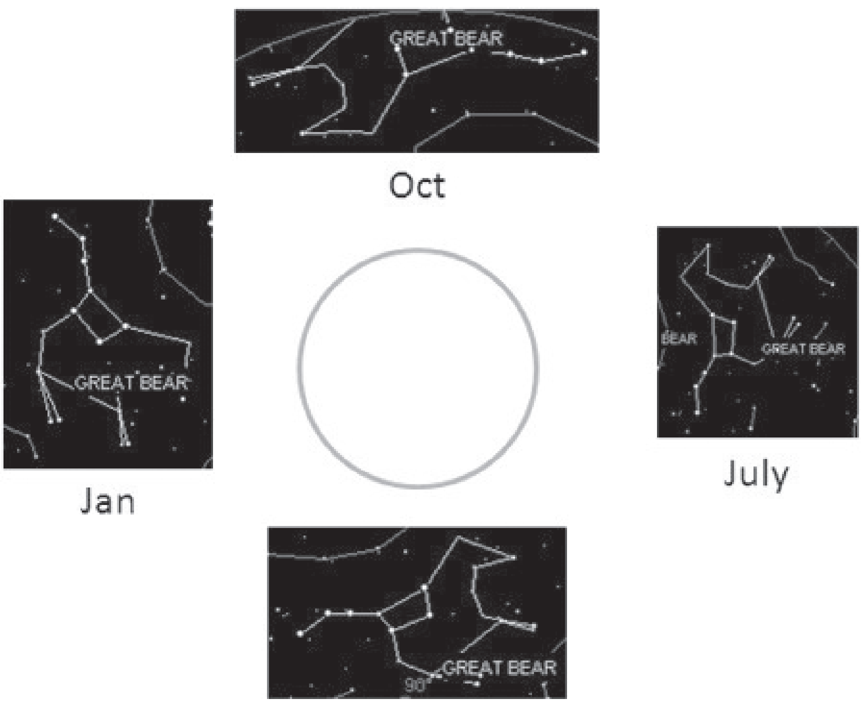
Thus, a degree is the amount you, as an observer, need to tilt your head to observe movement in a circle.

Instead we could be looking at the distance travelled by the mover within that time; this would give us *radians*. Degrees measure angles by how far we tilted our heads. Radians measure angles by distance traveled.

But then absolute distance is not very useful, since it depends on how large the circle is. So we divide by the radius to get a "normalized angle".

Thus angle in radians (θ) is arc length (s) divided by radius (*r*). If we go all around the circle, that is 360 degrees, we are travelling a

Constellation Rotation



distance of 2 X π X r (the circumference!) and thus we get: 360 degrees in radians = (2 X π X r) / r, which is 2 X π radians. Therefore 180 degrees = π radians.

Why are radians better for doing math? Consider a giant truck with each wheel having a radius of 2 metres and you want to see how fast the wheel is turning and learn how fast the truck is moving. If it is turning 2000 degrees per second, it means 2000/360=5/9 rotations per second, which means a distance of 2 X pi X (5/9). It is a little messy. On the other hand, if we say it is turning 6 radians a second, we simply scale by the "real radius" to get 5 X 2 = 12 metres per second. This is so much better!

When you get to calculus, radians make life enormously easier, and expressions like (sin x / x) make sense. I suppose by now you have figured out that (sin x/ x) = 1 for small x when x is measured in radians!

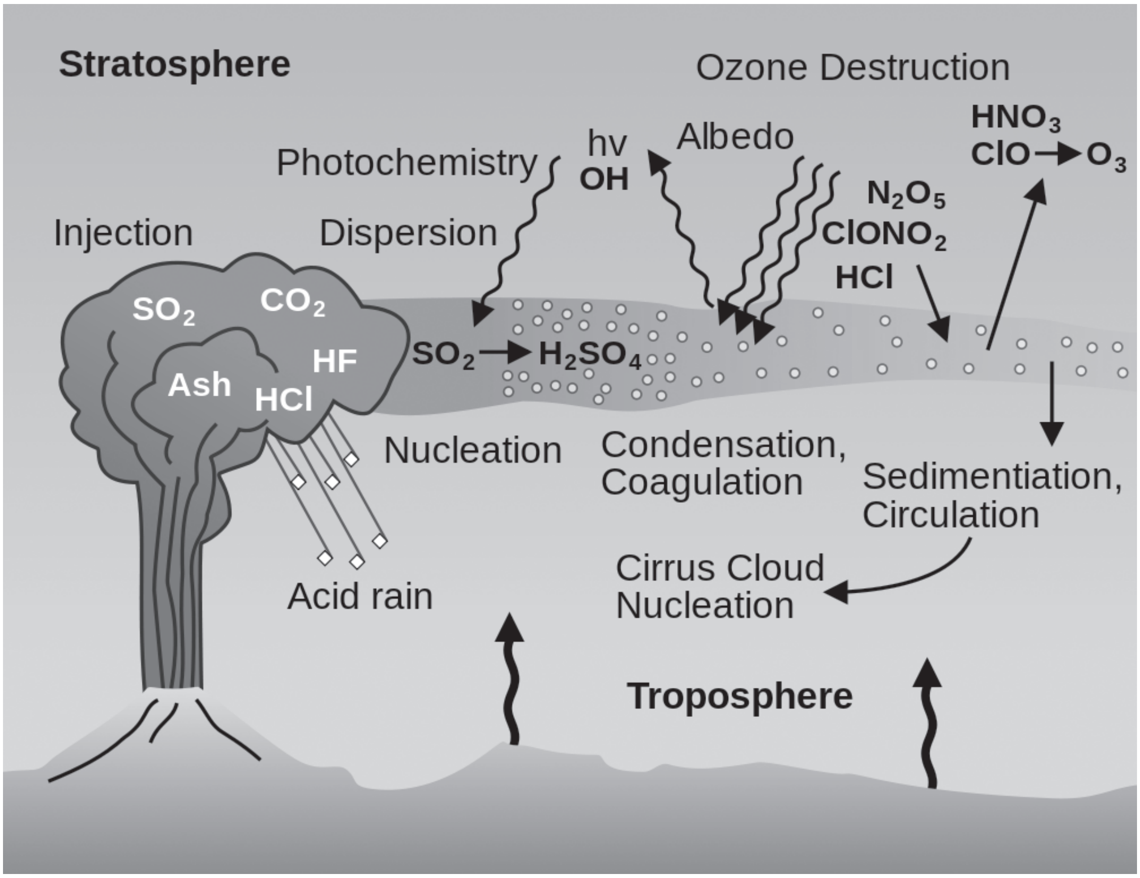
4. What causes a volcano to erupt ? Can we predict this accurately ?

Answer: We think of the earth as solid rock, but you know that there is an upper mantle and a lower crust. Interestingly a part of these can melt, and when that happens, something called magma forms. A volcano is essentially an opening or a vent through which this magma erupts. Along with it the dissolved gases it contains also escape.

What triggers a volcanic eruption? There are many factors, but three are important: the buoyancy of the magma, the pressure from the dissolved gases in the magma and the injection of a new batch of magma into an already filled magma chamber.

Buoyancy: As rock inside the earth melts, its mass remains the same while its volume increases. This produces a "melt" that is less dense than the surrounding rock. This lighter magma then rises towards the surface by virtue of its buoyancy. If the density of the magma between the place where it is generated and the surface is less than that of the surrounding and overlying rocks, the magma reaches the surface and erupts.

Gases: Magmas contains many dissolved volatile elements such as water, sulfur dioxide and carbon dioxide. Experiments have shown that the amount of a dissolved gas in magma (its solubility) at atmospheric pressure is zero, but rises with increasing pressure. For example, in magma saturated with water and six kilometers below the



surface, about 5 percent of its weight is dissolved water. As this magma moves toward the surface, the solubility of the water in the magma decreases, and so the excess water separates from the magma in the form of bubbles. As the magma moves closer to the surface, more and more water escapes from the magma, thereby increasing the gas/magma ratio in the path. When the volume of bubbles reaches about 75 percent, the magma disintegrates into partially molten and solid fragments and erupts explosively.

Injection: When a 'chamber' already filled with magma and some more magma comes in, it pushes some of the magma in the chamber to move up through the pathway and erupt at the surface.

Determining the timing of an eruption in a monitored volcano is very difficult, and scientists cannot also tell how large the eruption can be. They keep watching for earthquakes, changes in ground formation nearby and gas emissions. Moving magma shakes the ground and hence measuring seismic activity helps. Gas and magma can push the slope of the volcano upwards, and this can be measured by "tilt-meters". Measuring gas emissions can be done at site, but these days, remote sensing satellites are used.

Sources: *Scientific American, Jefferson Lab*

Evolutionary tales: Ant eating toads?

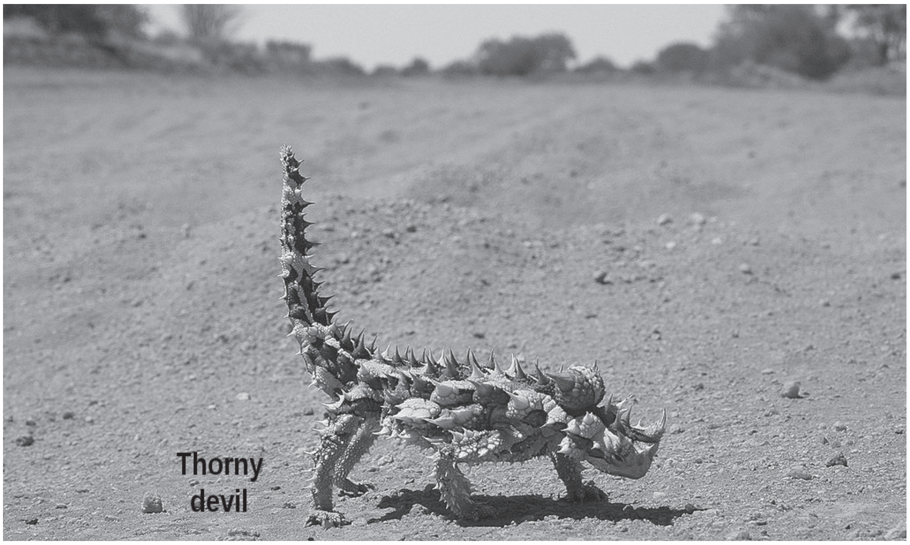
Zareena, Mookayi and Mari

In the beginning:

Zareena came in all excited. "Do you know of a toad that eats thousands of ants in a day?" she asked Mari. Mookayi who was reading a book on reptiles with Mari said "Yes. Thorny toads. But they are not toads". Zareena was surprised "How did you know that!"

Mari's mother Usha came in and said "Glad you are here, Zareena. These two have been chattering and reading this book I got from Australia. It talks of the thorny toad also known as thorny lizard". Mookayi piped in "Yes. But we also found out from Google Aunty that there are horned toads in the North American continent. These are distantly related to the Australian thorny lizard but look similar and eat ants". "How can it be so – Australia and North America are kilometers apart" exclaimed Zar.

Usha said "It is called ***convergent evolution*** – they are similar but different! Come sit. Let's eat the biscuits I made and have some coffee. I will tell you tales of these animals". And so the stories unfolded even as the snacks and coffee got over. With their usual enthusiasm, the three science lovers decided to read more and write about all that they learnt and send it to their favourite magazine ***Jantar Mantar***.



And that is how you, dear reader, are able to read about these fascinating animals here.

Thorny devil

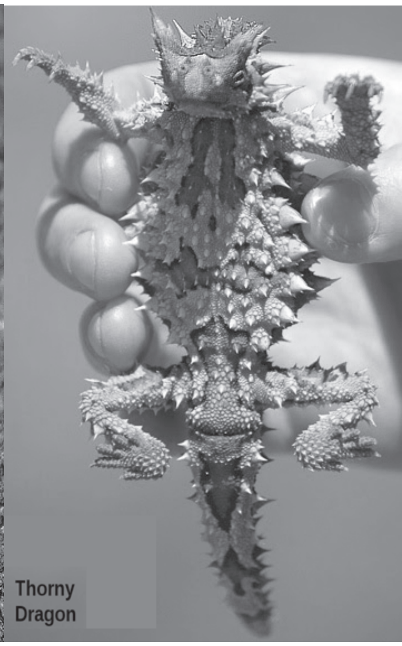
A popular anecdote goes that a US servicemen stationed in South West Australia during World War II were sold "thorny devil eggs". It turned out to be a scam as they were nothing but the thorny fruits of a type of weed called there popularly as “double-gee” (or more formally as *Emex australis*). The story made the thorny devil popular. The actual lizard known as the thorny devil was first described in 1841 by **John Edward Gray**. It is also popularly called as *mountain devil*, *thorny lizard*, *thorny toad*, *horned lizard* or devil lizard. Formally it is called *Moloch horridus* and is the only species of the genus *Moloch*. The scientific name was inspired by the reference to a horrible god smeared with blood called *Moloch* in the poem “Paradise Lost” by John Milton. The lizard lives up to the name and looks terrible; it is covered densely with thorny spikes – about the size of rose thorns - all over the body and is capable of shooting blood from its eyes to ward off those predators that attempt to eat the thorny devil (How does it squirt blood? – read on).

The thorny devil lives in the sandy desert of Central and Western Australia. The lizard can change colour depending on the soil and temperature from yellow to reddish brown to black. It has an unusual walking pattern of freezing and rocking to and fro. This helps it to evade its predators — mostly wild birds and goannas (a type of monitor lizard found in Australia). From a distance it looks like a toad. The false head on its back made of soft tissue seems like a horn and so it got the name horned toad. The false head is used to fool predators by dipping its real head and presenting the false head. It can also puff up its body to make it more difficult for the predator to swallow.

The lizard can eat up to 45 ants a minute and about 600 to 3000 ants in one meal. Thorny devils are “sit-and-wait” predators. They find a feeding site near ant trails and wait for their prey to pass right in front of them, using their sticky tongues to capture the ants. The females are bigger than the male reaching up to 20 cm in length. They lay about 3-10 eggs about 30 cms underground in a tunnel. The eggs are usually laid between September to December and hatch after about 3 to 4 months. They can live up to 20 years.

But what makes the thorny devil more interesting is the way it collects and drinks water. **Buxton** in the book *Animal life in deserts* published in 1923 described the lizard as “a repulsive animal with tubercles and spines, it has the power of absorbing water through its skin after the rains”. Then **Bentley** and **Blumer** in 1962 from the *Dept of Physiology and Anatomy* of the University of Western Australia showed (using a series of hydration/dehydration experiments and using staining dyes) that the movement of water along the skin is due to *capillary action* along fine open channels about 20 micron in size (one micron is 10^{-6}m or 1/1000th of 1/1000th of a meter) formed by *keratin* (a fibrous protein found in all animal nails and hair) *ridges*. Using adhesive tape to close its mouth they showed that the lizard has to move its jaw to take in the water which flows to the lip edges. Subsequently, several groups worked on this lizard and related horned lizards from North America to probe into more details of this mechanism.

In 2016 a group from Aachen University, Germany, University of Western Australia and Johannes Kepler University Austria used six lizards in the laboratory to show that special skin structures in between overlapping scales allows the lizard to collect water by capillarity and transport it against gravity into its mouth. They found that the water volume to fill the skin capillary system is 3.19% of the body mass of a lizard. Also they showed that thorny devils standing in water puddles can fill their capillary system and then drink from that water at 0.7 microlitres per jaw movement. The lizard when on moist sand puts sand over itself. This they showed is a way for it to take water from the moist sand for drinking! This is most important for lizards that live in such dry desert climates, for survival.



North American desert dwelling lizard

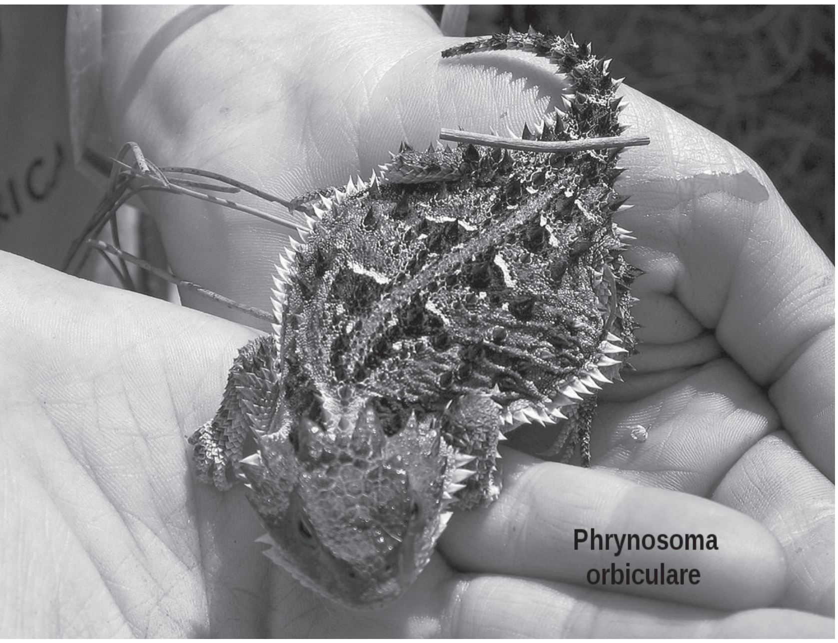
The North American horned lizard is similar in appearance and most behavior pattern to the Australian thorny lizard suggesting an instance of ***convergent evolution***. It belongs to a different genus Phrynosoma meaning "toad-bodied" (for example humans belong to the genus Homo while orangutan belongs to the genus Pongo). Of the 22 species in this genus, 15 are native to the United States. The largest-bodied and most widely distributed of the US species is the Texas horned lizard.

Mechanism of squirting blood

Eight of the species are capable of squirting blood from its eyes when attacked by predators. This mechanism has been studied by many groups. The lizard uses a set of thin-walled, blood-filled spaces called *sinuses* found within its eye sockets. The muscles around these vessels cut off supply to the heart so the blood builds up in the sinuses. The blood pressure increases rapidly within these sinuses, causing the sinus walls to break suddenly. The blood is then squirted out like a jet at times even to distances of 4 feet (or 1.2 meters). The blood also contains a chemical that smells foul to canine and feline predators but not to birds. How the lizard recovers from this is not known.

Another use of this ability is as follows: if there is any dust or particles that gets into the eye, the lizard first uses a third transparent eyelid to move across the eye and push the dust to a corner of the eye. Then by controlled muscle movement (so that the sinus wall does not break), the lizard can use the filling of blood under the socket to dislodge the dust.

Pygmy short horned lizard (Phrynosoma douglasii)


Phrynosoma orbiculare

The short horned lizard (also commonly called Horny toad) was named after the Scottish Botanist **David Douglas**. In 1997 **Karen Dvornich** was trying to understand why the numbers of these short horned lizards were dropping. On a visit to the Waterville Elementary School in Washington State she met 4th and 5th standard students saying they have seen a lot of Horny toads in that area. In 1999 the Adopt-a-farmer idea sprang up and Karen sent the students a list of questions. The students made forms that farmers could carry on their tractors. The farmers gathered data through the summer, and when school started they brought it in to the students. Karen helped the students and farmers make graphs using the data that the farmers collected through the summer. There was a location graph, a size graph, a time of day graph, a habitat graph and a "Did it bury itself?" graph. The graphs had lines to put colored stickers on it. The farmers and students counted how many horny toads they found. If a farmer did not come, the student was teamed with another farmer and would later contact his/her adopted farmer.

Washington Department of Fish and Wildlife provided disposable cameras and rulers, so the students could document their work and take precise measurements of the lizards. The 2nd standard students collected different insects to see what the short horned lizards would eat.

The Adopt-a-Farmer Project not only created a task-force of young herpetologists (those who study reptiles and amphibians), but young scientists who learned to ask a question, gather and analyze their data using the latest technology, and involve their community in the process.

Sources:

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Apollo 11 and the quest to land humans on the Moon

50th Anniversary of the First Moon Landing

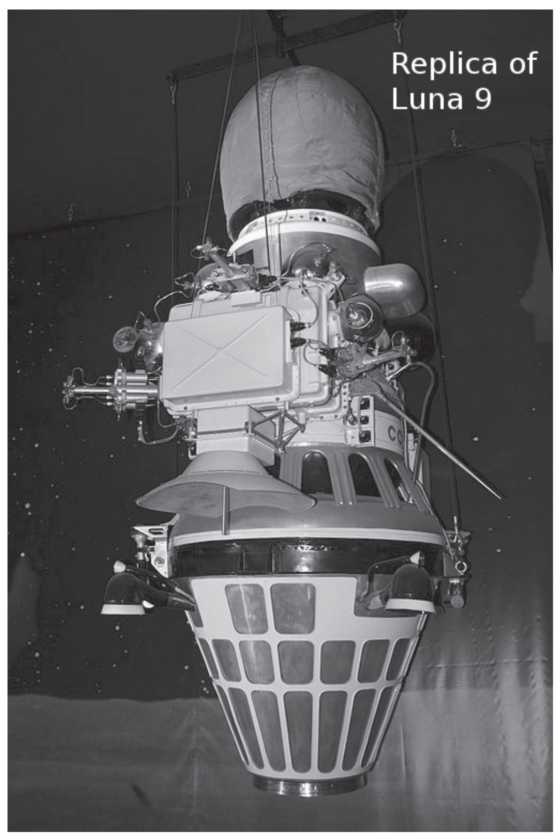
D. Indumathi

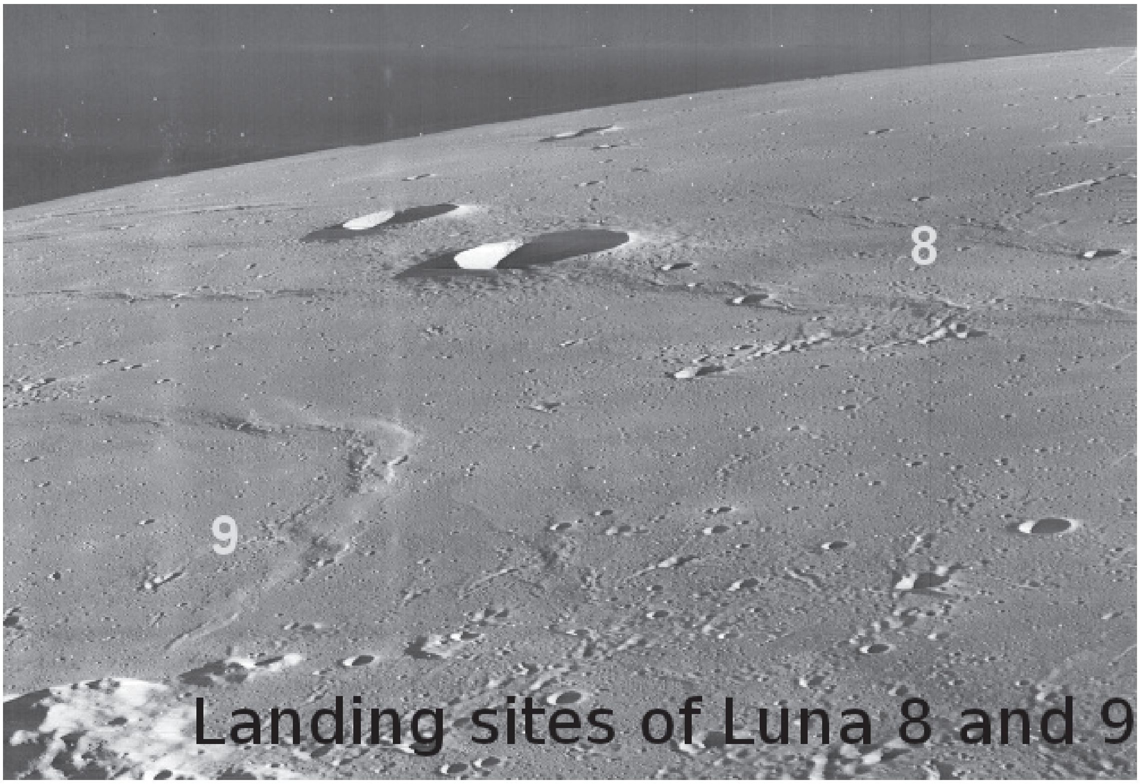
The Institute of Mathematical Sciences, Chennai

The journey to space

On April 12, 1961, Soviet cosmonaut **Yuri Gagarin** became the first person to fly in space. His capsule, called *Vostok 1*, completed one full orbit around the Earth on 12 April 1961. This was a great achievement for the Soviet Union after the failure of the *Luna 1* unmanned moon mission in 1959. later, both *Luna 2* and the American R*anger 4* managed a crash-landing (or hard **landing**) on the moon. After this several Soviet and American moon missions attempted a soft **landing** on the moon by using rockets to brake the speed of the probe as it descends.

In 1966 the USSR achieved the first soft landings and took the first pictures from the lunar surface during the *Luna 9* and *Luna 13* missions. The photo shows the landing sites of both the Luna 8 crash landing and the *Luna 9* soft landing. A replica of the Luna 9, pictured here, is exhibited in the Air and Space Museum in Paris, France. It was only in 1970 that the Soviets managed to successfully land a probe andd bring it back to the Earth. The *Luna 16* probe had no humans on it, but used robotic devices to





Landing sites of Luna 8 and 9

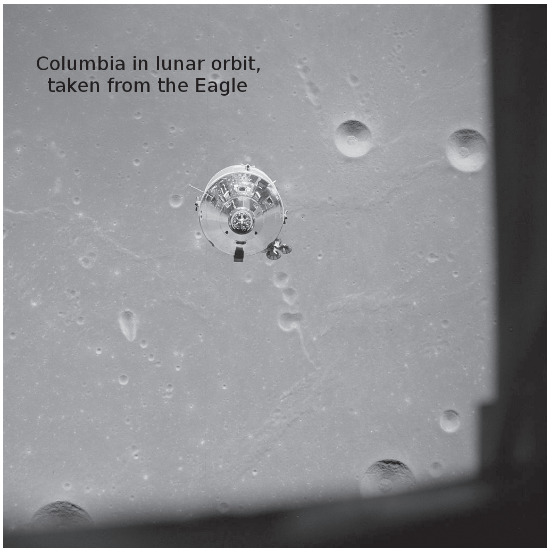
bring a soil sample back. Many more unmanned missions followed, both successful and unsuccessful. The rivalry between the Soviets and the Americans spilled over, and both considered conquering of space as the final frontier.

Human moon missions

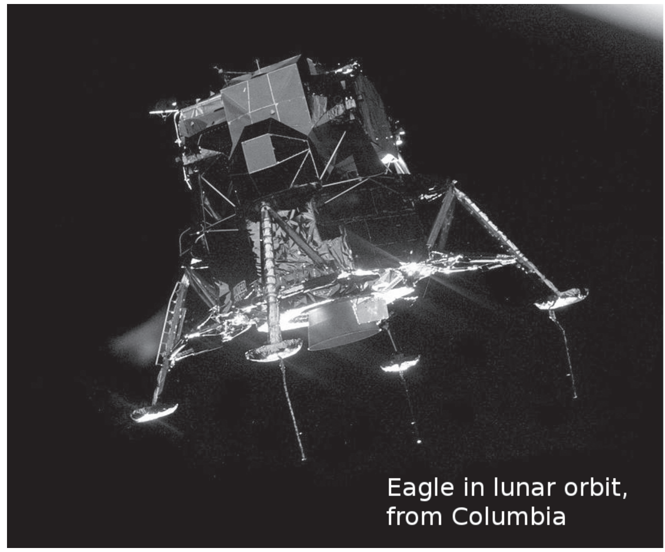
It was with the beginning of the **Apollo** missions by the Americans that moon missions included human cargo. The first was that of ***Apollo 11***, whose successful journey allowed two humans to set foot on the moon on 20 July, 1969, almost exactly 50 years ago. The Apollo programme allowed twelve humans (all men) to land on the moon. The first men to land on the moon were **Neil Armstrong** and **Buzz Aldrin**. After being launched into orbit by a *Saturn V* rocket four days earlier, the astronauts separated the spacecraft from the rocket and travelled for three days to enter the lunar orbit around the moon. Armstrong and Aldrin then moved into the *Apollo Lunar Module* called **Eagle.**

Apollo 11

Apollo 11 had three parts: a **command** module called **Columbia** with a cabin for the three astronauts, a **service** module which supported the command module with



Columbia in lunar orbit, taken from the Eagle



Eagle in lunar orbit, from Columbia

propulsion, electricity, oxygen, and water, and a **lunar** module called the **Eagle** which would actually land on the moon.

The picture shows Columbia in lunar orbit, photographed from the Eagle, with the moon's surface as background. The second picture shows the Eagle in lunar orbit photographed from the Columbia. Perhaps selfies were not common then, but certainly photography was as popular then as it is now!

The lunar module had two parts, one for descent for landing the two astronauts on the moon and one for ascent which would take them back into the lunar orbit.

First men on the Moon

Armstrong became the first person to step onto the lunar surface six hours 39 minutes after landing on the moon, on July 21 at 02:56 UTC. Aldrin joined him 19 minutes later. The long time was because of the many check lists that they had to go through, including food packets and tools. Remember that there is no atmosphere on the moon and gravity is very small, about 1/10th of that on Earth.

Eagle's hatch was opened at 02:39:33. Armstrong initially had some difficulties squeezing through the hatch with his portable life support system. He then descended a nine-rung ladder, activating his camera to show his descent.

At all times, all the vitals of the astronauts were being recorded. It turned out, expectedly, that some of the highest heart rates recorded from Apollo astronauts occurred during exiting and entering the module. You can imagine the feelings of the men, the first to set foot on the moon, and not knowing whether they would ever return home again.

They spent about two and a quarter hours together outside the spacecraft, and they collected 21.5 kg of lunar material to bring back to Earth. In order to bring back so much material, they had to leave behind a lot of waste matter which is still lying on the moon.

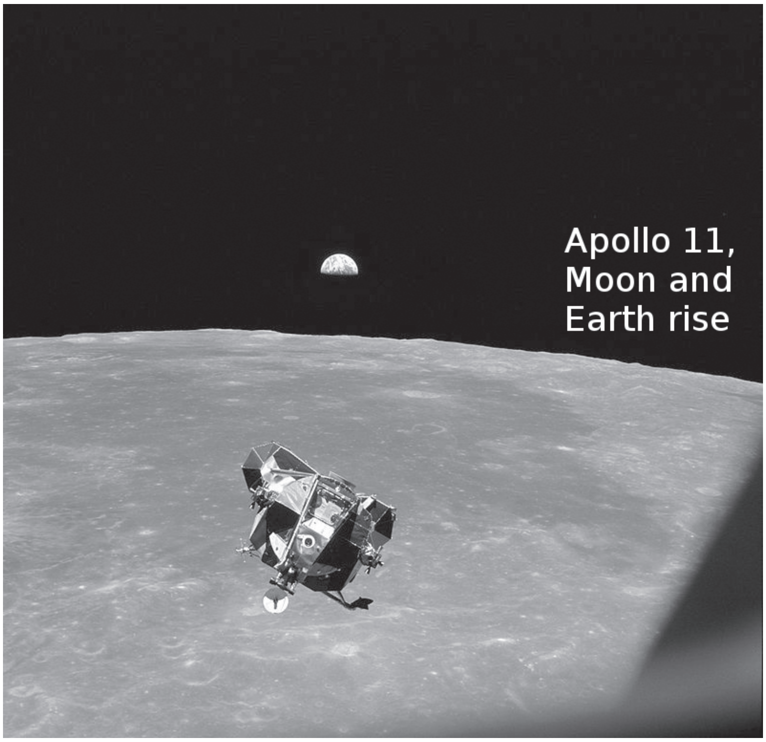
One small step ...

Armstrong's first step onto the lunar surface was broadcast on live TV to a worldwide audience. He described the event as "one small step for [a] man, one giant leap for mankind."

While still on the ladder, Armstrong uncovered a plaque mounted on the lunar module's descent stage bearing two drawings of Earth (of the Western and Eastern Hemispheres), an inscription, and signatures of the astronauts and President Nixon. The inscription read:

"Here men from the planet Earth first set foot upon the Moon July 1969, A.D.

We came in peace for all mankind."



Aldrin joined Armstrong on the surface. He described the view with the simple phrase: "Magnificent desolation."

Returning home

Command module pilot Michael Collins flew the command module Columbia alone in lunar orbit while they were on the Moon's surface. Armstrong and Aldrin spent 21 hours 31 minutes on the lunar surface at a site they named *Tranquility Base* before lifting off to rejoin Columbia in lunar orbit.

The picture shows a view of the Apollo 11 lunar module Eagle as it returned from the surface of the moon to dock with the command module Columbia. A smooth mare area is visible on the Moon below and a half-illuminated Earth hangs over the horizon. The lunar module ascent stage was about 4 meters across. Command module pilot Michael Collins took this picture just before docking at 21:34:00 UT, 21 July 1969.

Memorials

After more than two and a half hours on the lunar surface, the scientists left behind, in addition to the scientific instruments: an Apollo 1 mission patch in memory of astronauts **Roger Chaffee, Gus Grissom**, and **Edward White**, who died when their command module caught fire during a test in January 1967; two memorial medals of Soviet cosmonauts **Vladimir Komarov** and **Yuri Gagarin**, who died in 1967 and 1968 respectively; a memorial bag containing a gold replica of an olive branch as a traditional

symbol of peace; and a silicon message disk carrying the goodwill statements by Presidents Eisenhower, Kennedy, Johnson, and Nixon along with messages from leaders of 73 countries around the world.

Before returning in the Columbia, they discarded the lunar module, Eagle, and propelled Columbia back to Earth, and like most air travellers, slept most of the time during the return journey. They splashed down in the Pacific Ocean (as the safest way to re-enter) on July 24, after more than 8 days in space, packed into a small space leaving no room to walk or manouvre. But they had made history.

Other manned missions

Apollo 12 was the second to land on the moon, four months after Apollo 11. Commander **Charles "Pete" Conrad** and Lunar Module Pilot **Alan L. Bean** performed just over one day and seven hours of lunar surface activity while Command Module Pilot **Richard F. Gordon** remained in lunar orbit.

However, **Apollo 13** reached the moon but could not landd. The crew managed to return to Earth, but without completing their mission. **Apollo 14** landed successfully, as also **Apollo 15, 16, and 17**. Apollo 17 was the last moon landing by humans, in Dec 1972. All the rocks collected over these missions were analysed for their age, mineral content, presence of water, and evidence of formation age of the moon. Not only that, the Apollo programme has been called the greatest technological achievement in human history, achieving many advances in technology, leading to over 1,800 spinoff products as of 2015.

International Cooperation

But in spite of all that was learned about the Moon, the Americans could not sustain the cost of these missions. Instead, they truend to developing the Space Shuttle (a reusable spacecraft) and then the International Space Station (ISS). The ISS is a space station or habitable artificial satellite in low Earth orbit. The ISS programme is a joint project between five participating space agencies: NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), and CSA (Canada). The ownership and use of the space station is established by intergovernmental treaties and agreements. Here the crew members conduct experiments in biology, human biology, physics, astronomy, meteorology, and other fields. It has been visited by astronauts from several countries and marks another area like the Earth's South Pole where international cooperation has resulted in turly global scientific understanding.

—Compiled from several sources; pictures from Wikipedia and NASA